Copyright Warning & Restrictions

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted material.

Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a, user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use" that user may be liable for copyright infringement,

This institution reserves the right to refuse to accept a copying order if, in its judgment, fulfillment of the order would involve violation of copyright law.

Please Note: The author retains the copyright while the New Jersey Institute of Technology reserves the right to distribute this thesis or dissertation

Printing note: If you do not wish to print this page, then select "Pages from: first page # to: last page #" on the print dialog screen

The Van Houten library has removed some of the personal information and all signatures from the approval page and biographical sketches of theses and dissertations in order to protect the identity of NJIT graduates and faculty.

ABSTRACT

Reducing Health and Safety Risks by Replacing Compressed Air with an Electromechanical System

by Joseph Michael Schwed

The continuous use of compressed air in many applications can often be expensive and very noisy. When compressed air is blowing freely from a nozzle, it can be used in a variety of processes. One of these is checking for the presence of a product inside a box.

In the manufacturing field, a facility has been using compressed air as a quality assurance inspector, to make certain that products are shipped properly. As the products go by on a conveyor, two employees must insert them into a carton as it is transferred to another conveyor. If an employee does not insert the product into a carton, it will be closed and processed the same way as if it were full. The carton will then pass over a compressed air jet; if it is too light it will be blown out of the way, if not, it will continue down the conveyor for shipping.

The purpose of this thesis is to analyze the problems associated with the current setup and to correct them by installing a quieter and more economical system. It will examine the amplitude of noise for compressed air, the costs involved, the safety and health risks for employees, and the pro's and con's of various experimental ideas that can mitigate these problems.

REDUCING HEALTH AND SAFETY RISKS BY REPLACING COMPRESSED AIR WITH AN ELECTROMECHANICAL SYSTEM

by
Joseph Michael Schwed

A Thesis
Submitted to the Faculty of
New Jersey Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Occupational Safety and Health Engineering

Department of Mechanical and Industrial Engineering

May 1993

Blank Page

Copyright © 1993 by Joseph Michael Schwed

ALL RIGHTS RESERVED

APPROVAL PAGE

Reducing Health and Safety Risks by Replacing Compressed Air with an Electromechanical System

Joseph Michael Schwed

Dr. Howard Gage, Thesis Advisor
Associate Professor of Industrial Engineering and Director of the Occupational Safety and Health Program, NJIT

Dr. Min-Yong Park, Committee Member
Assistant Professor of Industrial Engineering, NJIT

Dr. Layek Abdel-Malek, Committee Member
Professor of Industrial and Management Engineering and Associate Chairperson of Industrial Engineering, NJIT

BIOGRAPHICAL SKETCH

Author: Joseph Michael Schwed

Degree: Master of Science in Occupational Safety and Health Engineering

Date: May 1993

Undergraduate and Graduate Education:

- Master of Science in Occupational Safety and Health Engineering,
  New Jersey Institute of Technology, Newark, NJ, 1993

- Bachelor of Science in Mechanical Engineering,
  New Jersey Institute of Technology, Newark, NJ 1990

Major: Occupational Safety and Health Engineering

This thesis is dedicated to my mother and father

ACKNOWLEDGMENT

The author wishes to express his sincere gratitude to his advisor, Professor Howard Gage, for his guidance, friendship, and moral support throughout this research.

Special thanks to Professors Min-Yong Park and Layek Abdel-Malek for serving as members of the committee.

The author is grateful to Peter Braddock for helping with the electrical setup of the system and various ideas that lead to a final decision on the proper system.

The author appreciates the suggestions that were made by Richard Bowden, Sydney Hartley, Martin Bailey, and Pete De Rose in finding a workable model to solve this problem.

And finally, a thank you to Glen Giles and Chuck Raba for allowing the author to use their facility.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure **Page**

CHAPTER 1

INTRODUCTION

The manufacturing of any product to be sold on the market should include a production line which is free from health and safety risks to all employees, while keeping the cost of producing these products as low as possible. This thesis is based on an actual problem observed in a manufacturing facility.

The use of compressed air was thought to be unavoidable when dealing with this type of environment. Compressed air is needed to operate all types of pneumatic equipment varying from tools to rebuild or changeover production lines, to the mechanical equipment needed to run these lines. Compressed air, when blown continuously out of a nozzle can be very costly. A breakdown of the cost is noted in a cost-benefit analysis done for the actual system involved here.

There are various applications that are necessary to recommend the use of compressed air. It is used in some cases to dry products, move products into a precise location, or even to blow products off a conveyor. It will be shown that compressed air is very loud. Recorded Sound Pressure Levels (SPL) vary with the number of pounds per square inch (psi) exiting the nozzle. In almost all situations the SPL is above 85 dBA which may create a problem with the standard published by the Occupational Safety and Health Administration (OSHA). OSHA has set a specific level at which hearing protection must be worn to avoid hearing loss. The investigation into this problem will cover the rule making OSHA has established for SPL in a working environment.

There are a number of ways to solve this problem which will be identified and discussed later. Various experimental ideas have been formulated which will be explained, but cost considerations are paramount in choosing the best setup possible. There are a number of constraining factors involved that would not allow these ideas to be implemented. The production line at present runs at a certain speed which could not be altered in any way. In addition, the length of the line could not be increased due to the limited availability of space and the relatively high cost of moving machinery. These experimental setups are reviewed on a case by case basis using a feasibility analysis relative to their implementation.

The result of this investigation is a system fully capable of recognizing the presence of a product inside a carton. An electromechanical device is being developed which prevents defective products from ever being packaged for shipment. Health and safety risks to employees are significantly reduced if this system is utilized. Also a potential savings of 400% for the first year and 500% thereafter is envisioned.

CHAPTER 2

PRESENT TECHNOLOGY

The production line that creates an end product ready for shipment is composed of fourteen employees who must collectively work together to ensure that acceptable levels of quality and quantity are simultaneously achieved. It is crucial for good business that these products be shipped with the entire contents enclosed in the package. The technology used in checking a package to determine if the contents have been inserted properly is primitive. It lacks sensitivity to the well being of the individuals who must work with and around the system on a daily basis; it must not disrupt production and it should not be too costly.

The present system that was investigated directly involves three workers. In Figure 1, the positions of the operators can be identified as A, B, and C. Operators A and B are positioned in front of a conveyor which carries the product to them. These operators pick up the product from the conveyor and manually drop them into pre-opened cartons. Once these cartons pass the operators, they enter a carton machine which closes the boxes and sends them to operator C, the carton inspector. Operator C sits in a chair facing the conveyor where the cartons are being discharged from the carton machine. These discharged cartons fall on their sides on a conveyor and are led past the inspection operator's position to another machine which groups twelve cartons to be placed into a cardboard box. The inspection operator must make sure that all the cartons are facing a particular way on the conveyor and monitor them for damage, cleanliness, or sudden jam-ups. It is at this position that the compressed air is used to blow off any cartons from the conveyor into which operators A and B have neglected placing the products.

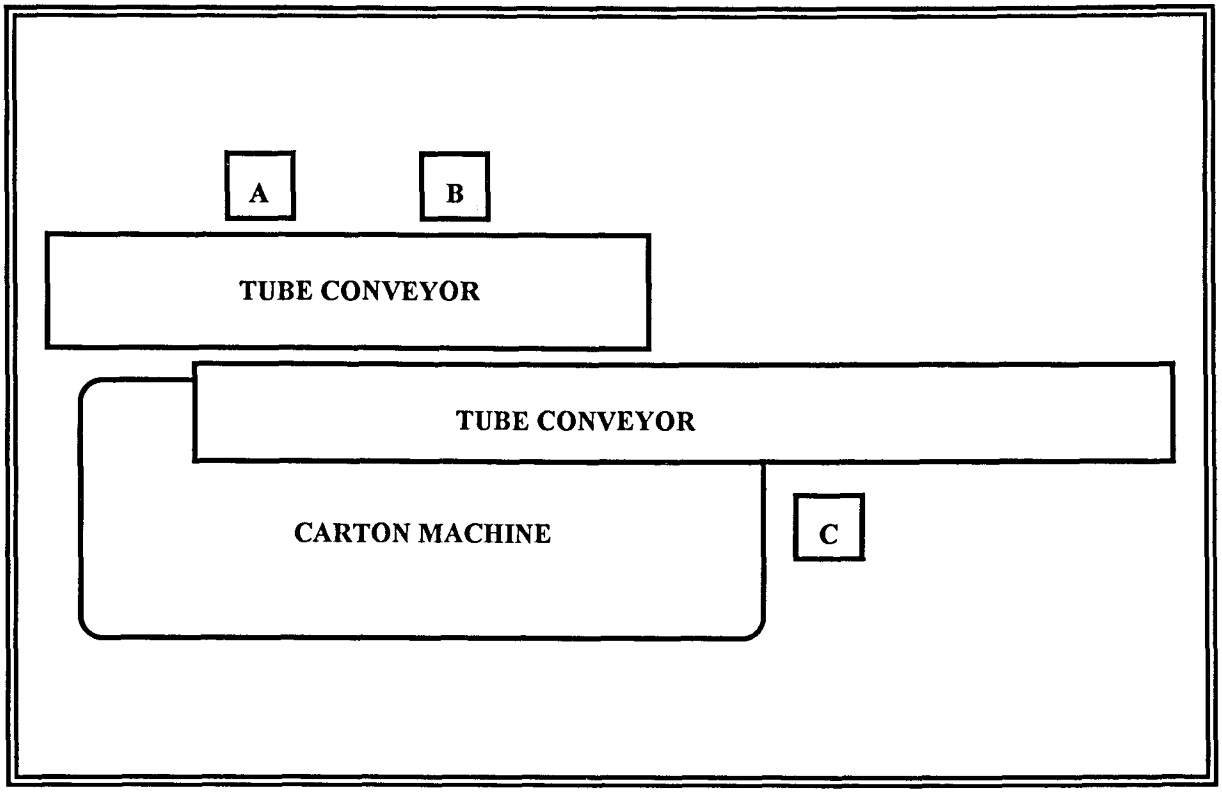


Figure 1. Operator Positions - A, B, and C

In Figure 2, the location of operator C is enlarged with respect to the compressed air jet. The operator's position is approximately twenty inches from where the compressed air is blowing constantly at 90 psi. This pressure level is necessary in order to completely remove the carton from the conveyor and allow the other full cartons to continue to the next station without disrupting production. There are two problems that must be discussed concerning the compressed air.

The Occupational Safety and Health Administration has established the standard, 29 CFR 1910.95, Occupational Noise Exposure. This standard establishes the need for feasible administrative or engineering controls when sound levels exceed those shown in Table 1. If controls fail to reduce these sound levels, personal protective equipment must be provided and used to reduce them to less than 90 decibels as measured on the A-scale (slow response). If an employee's eight-hour time-weighted average equals or exceeds 85 dBA, then they must be participate in the company's hearing conservation program.

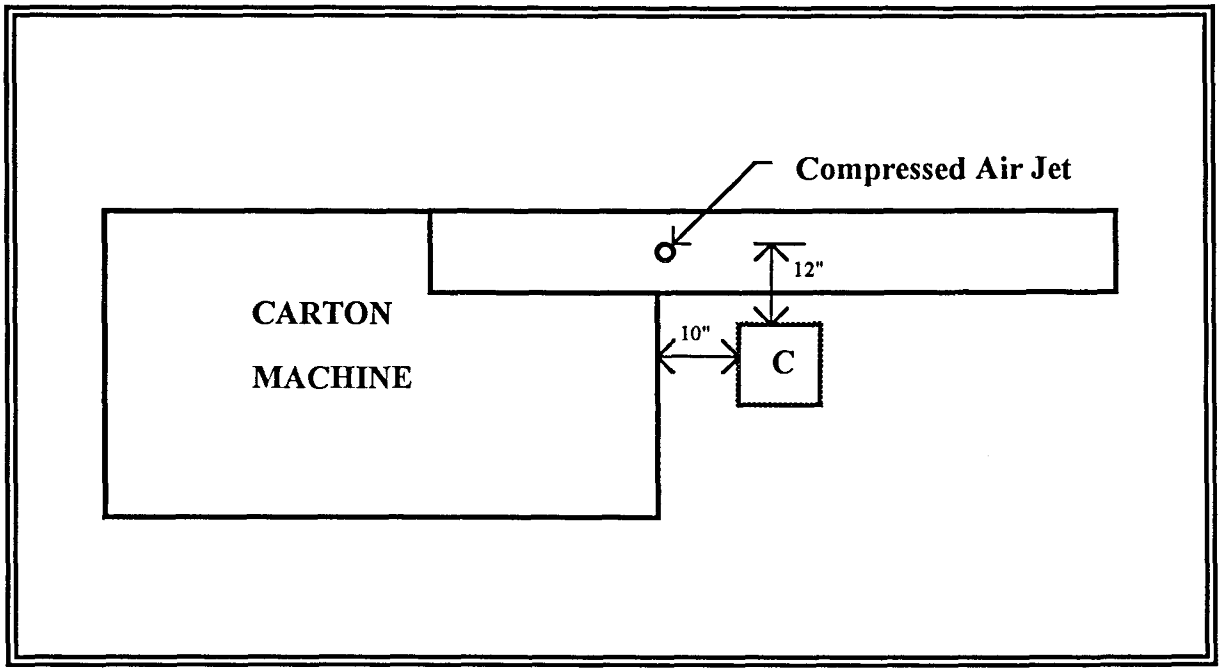


Figure 2. Position of Operator C with Respect to Compressed Air Jet

A noise monitoring study was performed on the compressed air jet (area monitoring) and the employees (personal monitoring) working around that system. Figure 3, a diagram for the locations of the area sampling and personal sampling sites, may be used to review the situation. Seven area samples and three personal samples were recorded for this study. The sound pressure level at the compressed air jet (1) was measured at 96 dB, which is also the 8-hour TWA. Also, it should be noted that this jet blows constantly at 90 psi for sixteen hours a day, five days a week. At location two, which is approximately twenty inches from the point source, a level of 94 decibels was recorded. At locations three, four, and five, which were approximately two feet away, sound pressure levels were recorded at 90 dB. Recorded measurements for locations six and seven, which were eight and ten feet from the source, were 87 and 88 dB, respectively. The personal sampling study returned eight hour time weighted averages of 86.8, 87.2, and 90.1 dBA for operators A, B, and C, respectively. A summary of this study is found in Table 2.

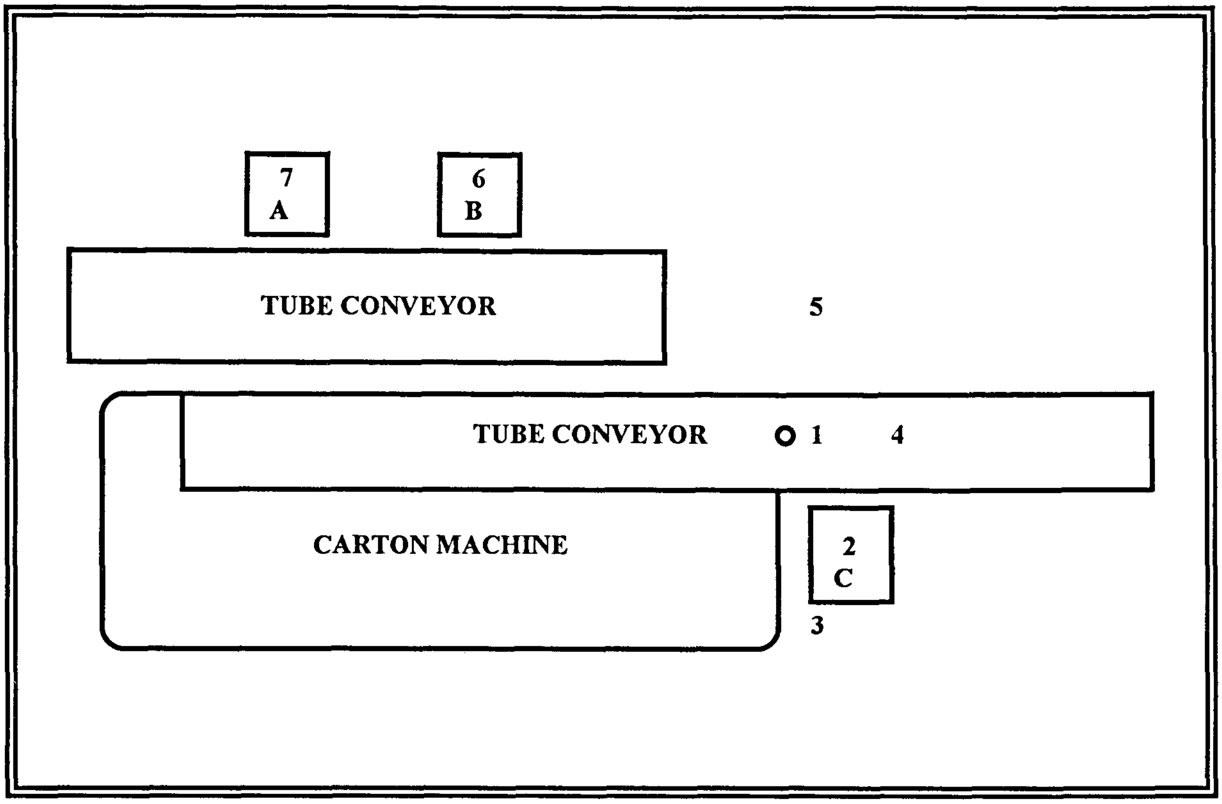


Figure 3. Locations for Area and Personal Sampling of Noise Measurements

The values for the study reveal that the operators must be involved in a hearing conservation program since personal monitoring data recorded was above the OSHA established action limit of 85 dBA. In addition, because operator C exceeded 90 dBA over an eight hour period, engineering or administrative controls must be investigated in order to lower that exposure level.

At present, administrative controls are being used but the exposure levels still exceed the maximum allowable dose as defined by OSHA. The next step that must be taken is to develop engineering controls to reduce the sound pressure levels that are being emitted from the system. According to OSHA, if engineering controls and administrative controls are not feasible, proper personal protective equipment must be worn, in this case hearing protection devices.

The second concern with the compressed air jet being used as a method to detect empty cartons is the constant disruption to production it can cause. At high pressures, the compressed air can move or rotate a full carton into a position which

Table 1. Permissible Noise Exposures

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1 ½	102
1	105
.5	110
¼ or less	115

Source: Occupational Safety and Health Administration, 1992 Code of Federal Regulations, Title 29 Occupational Safety and Health Act, 204-205.

may cause a jam-up. When this happens, the machine has to be stopped and the problem corrected. It is possible for this disruption to effect the entire production line. Operators A and B must stockpile products on an adjacent bench if the jam-up cannot be quickly resolved.

These two problems have prompted an investigation to do away with the use of compressed air as a detection system. The next chapter describes various ideas for replacing the present system.

Table 2. Noise Monitoring Study

Position	Sample Time	Average Decibel Level	*Noise Dose Percent	Maximum Allowable Dose	Maximum Allowable Decibel Level
1	480	96	230	-	-
2	480	94	175	-	-
3	480	89	87	-	-
4	480	89	87	-	-
5	480	89	87	-	-
6	480	87	66	-	-
7	480	86	58	-	-
A	480	86.8	65	100	90
B	461	87.2	70	100	90
C	477	90.1	102	100	90

Table Notes :

*** A dose of 100% is equivalent to 8 hours of exposure at 90 dBA.**

Exposures were monitored using a Mark series MK-3 audio dosimeter. The audio dosimeters were worn for the entire workshift. The audio dosimeters were calibrated before and after the study.

CHAPTER 3

FUTURE TECHNOLOGY

The best solution to the problems created by this compressed air system would be to remove the jet and still be able to detect an empty carton. A number of solutions are discussed in this chapter, but the most practical and feasible method must be selected.

The system at present relies solely on compressed air. In a later discussion, the cost of compressed air will be calculated and a cost-benefit analysis presented. The analysis will compare the present system with the final system chosen. The solutions that were investigated could work, provided that the application and the necessary adjustments were capable of being performed. In some cases, the limited availability of space and feasibility would not allow the application to be implemented. All are still mentioned, however, in order to give the reader possible solutions to problems similar to the one being discussed here.

The possible solutions have been limited to a brief overview of the idea and the type of equipment that would be needed to apply it in an actual situation.

The first method that could be used to detect whether or not a product is present in a carton or box would be a conveyor with a built-in scale. The known weight of the full box would be necessary to enable the scale to send a signal to a gate device. If the carton was too light, a gate could open and force the carton off the conveyor and into a box for collection. The carton would not be damaged and could be reused when needed. A diagram of such a setup is shown in Figure 4. Two conveyors are needed, one operating at a faster speed so that when the gate opens, it could force the carton to be quickly moved aside so as not to disrupt the other cartons.

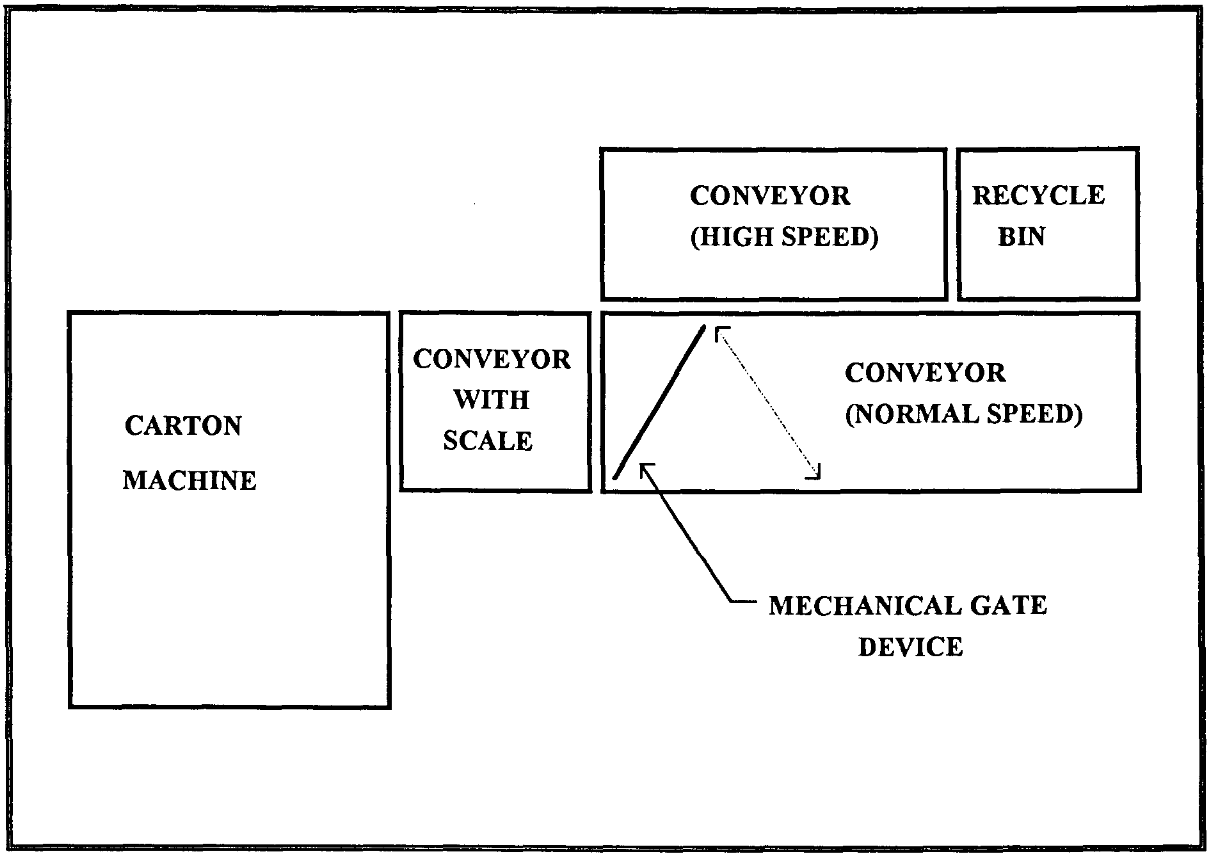


Figure 4. Conveyor with Scale and Mechanical Gate Device

The conveyor scale could also be connected to a solenoid switch that operates a pneumatic piston. When a carton or box passes over the conveyor and the scale detects that it is empty, a pulse is sent to the valve which would then operate a cylinder and push the carton aside into the box. A diagram of this setup is shown in Figure 5.

This application represents a viable solution, but it is not feasible for the system currently being used. In order to use a conveyor with a scale, production would have to be drastically changed. The conveyor used to transport the cartons to the next stage would have to be moved approximately three feet to accommodate the new scale conveyor. This would cause the other machinery to also be moved, and the labor involved would neither be practical nor justifiable.

In addition, the setup with the gate introduces the need to purchase another conveyor which would escalate the cost of installation.

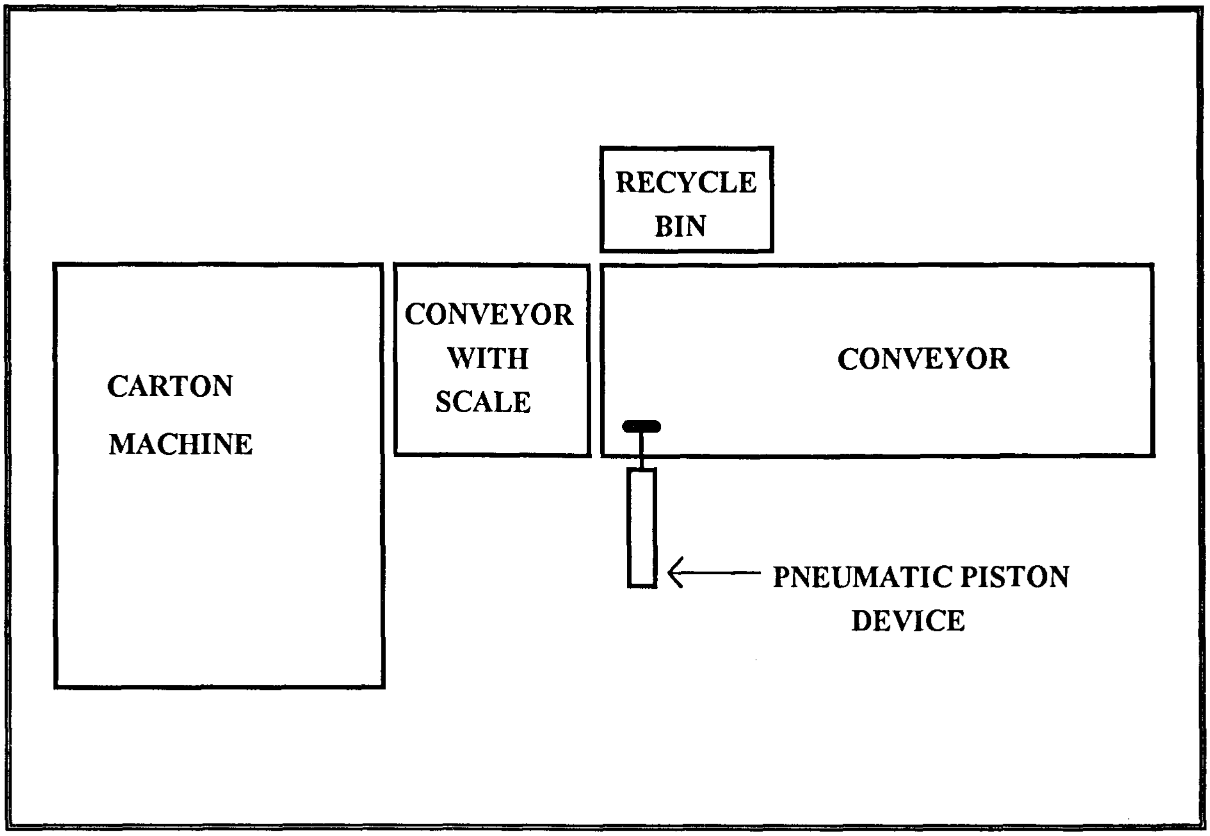


Figure 5. Conveyor with Scale and Pneumatic Piston Device

The next method that could be used to eliminate reliance on compressed air is the implementation of a metal detection device. In this case, the product that is placed into the carton has traces of metal inside it. A metal detector could be placed after the point where the carton machine closes the carton. If the metal detector does not identify the presence of an alloy as the carton passes by, it would then send a signal to a mechanical gate device that would open and push the carton aside into a recycling bin where it could later be reused. In a manner similar to the last application, a pneumatic piston device could be used to push the carton out of the way. These two setups are depicted in Figures 6 and 7.

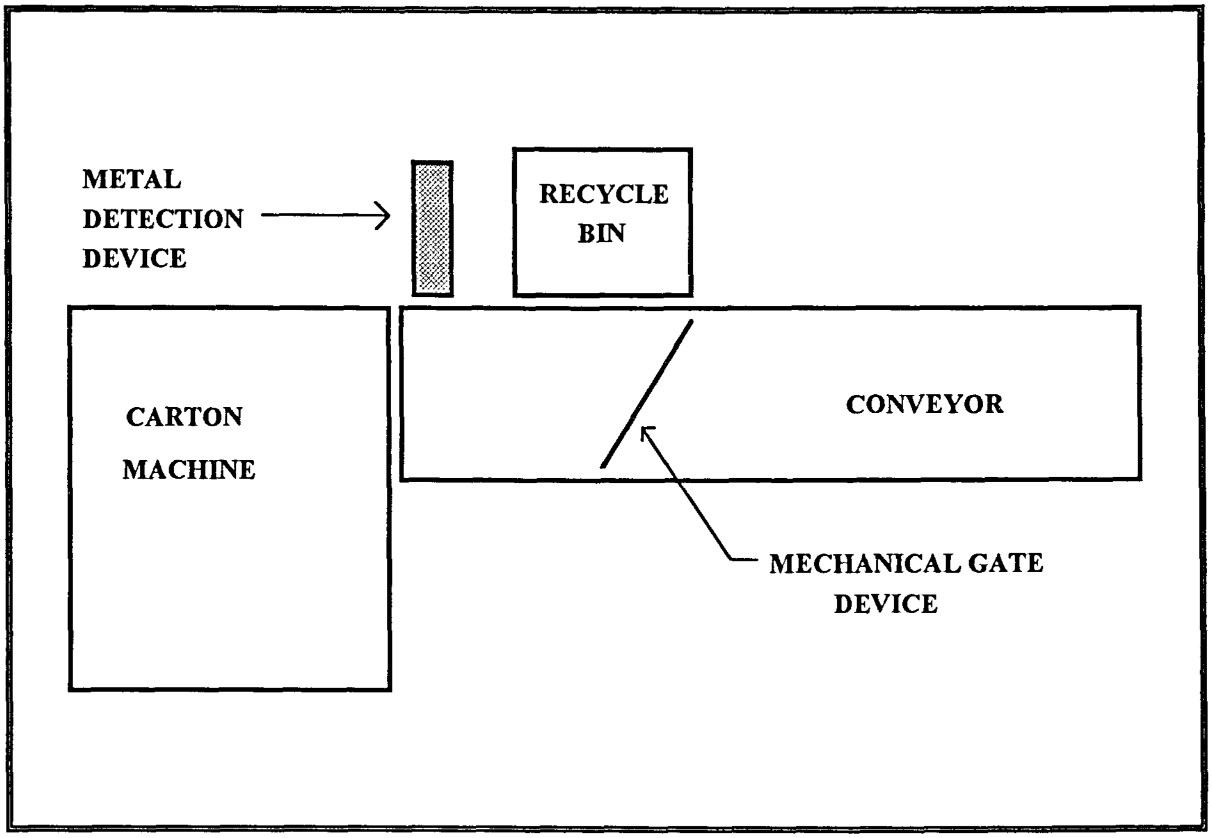


Figure 6. Metal Detection Device with Mechanical Gate Device

The high speed conveyor has been omitted in this application since there is no need to have one in place. This is true for the previous application as well, but one was inserted to consider a production line in which the carton could be damaged when dropped into a collection bin because of its fragility. Although the product in question is not specifically disclosed in this thesis, it can be said that no damage will occur to the carton when it is discarded.

This latter method was not chosen since further investigation revealed that the metal detector would not be functional in several months since, the manufacturing of the product will no longer contain the metal alloys necessary for the detector to identify if a product was or was not present in the carton. If the product was not going to change in the future, this method could have been applied successfully.

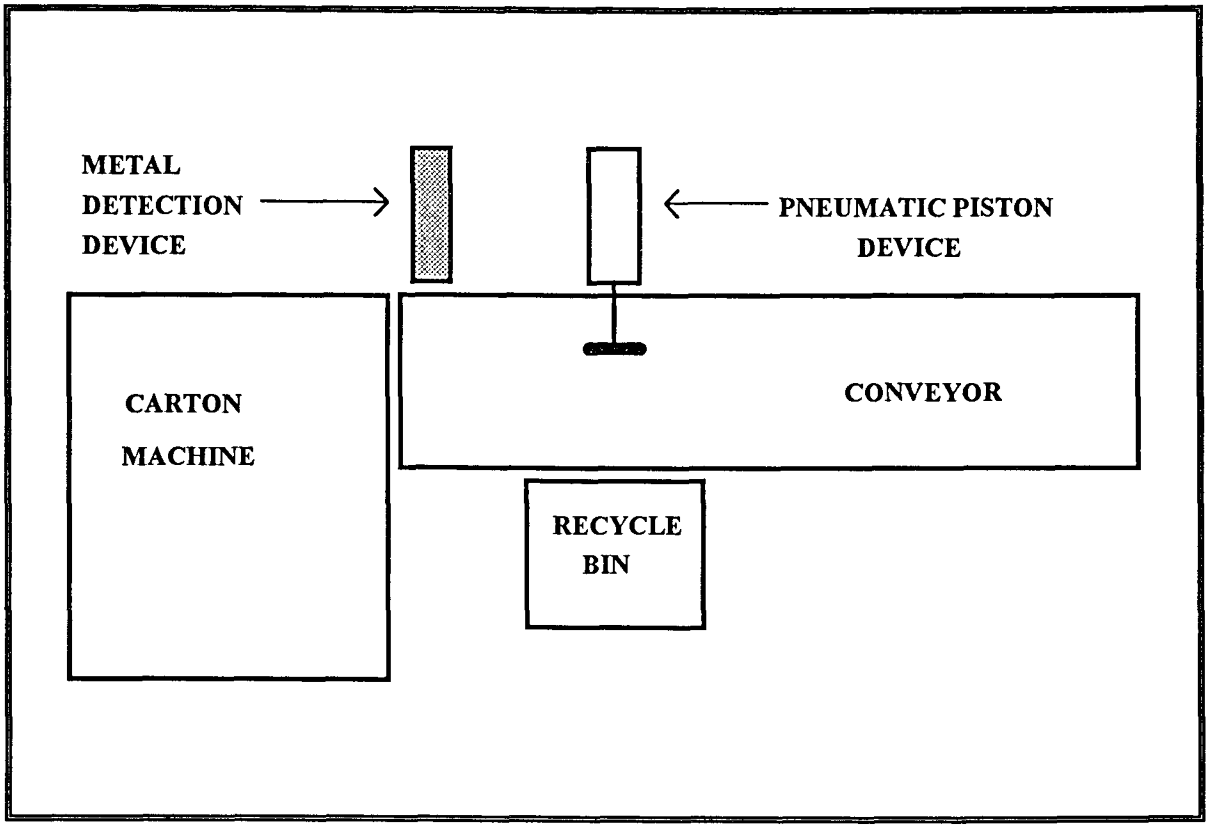


Figure 7. Metal Detection Device with Pneumatic Piston Device

The third solution that was investigated uses technology that is utilized in the final solution. The setup will be discussed in detail in the next chapter, including its individual components, present cost, and an explanation of exactly how the system operates. Although the third solution uses components used for the final solution, the discussion will give an overview of what key components are necessary for this system to operate.

Photoelectric detectors can be used to identify, for example, if the caps on cans are crooked or set too high, if a bottle has enough product inside; or it can count the number of bottles during the manufacturing process by detecting infrared (heat) radiation with an ambient light receiver. There are many applications for photoelectric controls; one must decide which control can perform the task for the process most efficiently. A photoelectric sensor is a device which detects a visible or invisible beam of light and responds to a change in the received light intensity. The first step to using a photoelectric sensor involves the determination of the best sensing mode for the application. There are a variety of sensing modes that will be discussed. These are the retroreflective, proximity (which has four variations), ultrasonic proximity, and opposed sensing modes.

The retroreflective sensor, also known as the reflex or retro mode, contains both the emitter and receiver circuitry. It uses a reflector to return the emitted light directly back to the sensor. The retroreflective sensor is used in applications when sensing is only possible from one side. This sensor is used when large objects are being detected and where the environment is relatively clean. The scanning ranges extend from two to ten feet.

The proximity mode detects an object that is directly in front of the sensor by its own transmitted light source. The emitter and receiver are located on the same side of the object in the same housing. In proximity sensing modes, an object, when present, actually establishes a beam through its reflective properties rather than interrupting the beam. There are several types of photoelectric proximity sensors which have different optical arrangements and sensing mode designations. These are the diffuser, divergent, convergent beam and background suppression.

The diffuse mode sensor emits a beam of light which strikes the surface of an object at any angle and the light that bounces off the object is received. This type of sensor works best with products that have a shiny surface and is, like all proximity sensors, relatively inexpensive, since only one is needed. Diffuse mode sensors can detect products from a few inches to a few feet away.

The divergent sensor emits a beam of light in all directions. This avoids the effects of signal loss from shiny objects. The sensor should only be used to detect products that are a few inches (or less) away. As a result, divergent mode sensors can reliably sense small objects like yarn, wire, or clear plastic bags which bounce during production.

The convergent beam is another proximity mode sensor that is effective for detecting small objects. The beam emitted reaches the object at a precise location and then is bounced back to the same place from where it was emitted. This type of sensor can be used whenever diffuse or divergent mode sensors cannot detect an object due to its low reflectivity. A typical application for this sensor would be the detection of the proper fill level of a product on a conveyor. The convergent beam sensing mode should be used when objects are a fixed distance away from the detector. If this criterion applies, the sensing range can vary as long as the emitted beam is focused at an exact location.

The background suppression sensor has the ability to sense objects at different distances. This sensor may be used to determine the presence of a component on a piece of equipment that is directly ahead of another reflective surface. The distance must be fixed at the second location so that all other surfaces will be ignored.

Ultrasonic proximity sensors vibrate with the application of electric voltage. Ultrasonic sound is sent outward from the face of the transducer as the vibration alternately compresses and expands air molecules. There are two types of ultrasonic proximity sensors; the electrostatic and piezoelectric. The electrostatic can be used to monitor the levels in large bins or tanks up to distances of twenty feet under normal conditions; while the piezoelectric can be used under harsher conditions with a range of up to three feet.

The last sensing mode, and the one that is recommended for this particular method is the opposed mode sensor. Opposed mode photoelectric sensors are used primarily when the object to be detected is opaque to light. This type of sensor offers the highest levels of excess gain. Excess gain is the minimum amount of light required to operate the sensor's amplifier based on the amount of light energy falling on the receiver of a sensing system. Excess gain guidelines are shown in Table 3. The use of high excess gain in an opposed mode arrangement should be in excess of fifty times in order to "see through" the carton.

Table 3. Excess Gain Guidelines

Operating Environment	Excess Gain Required
Clean air, no dirt buildup on lenses or reflectors	1.5
Slightly dirty, slight buildup of lint, paper, dust, moisture, or film on lenses or reflectors; lenses cleaned regularly	5
Moderately dirty. Obvious contamination of lenses and reflector, but not obscured; lenses cleaned occasionally or when necessary	10
Very dirty. Heavy contamination of lenses; fog, mist, or dust. Minimal cleaning of lenses	50

Source: Banner Engineering Corp., Handbook of Photoelectric Sensing, Banner Engineering Corp., Minneapolis, Minnesota, 1990.

The opposed mode sensors (emitter and receiver) will be set up opposite each other after operator B's position, just before the carton enters the carton machine. If operator B happens to miss placing the product into the carton, the photoelectric sensor will detect the empty carton. The sensor will then send a signal to the carton machine which will stop immediately. The operator can then place the product into the carton and restart the carton machine. Figure 8 shows the location of the photoelectric sensors in relation to those of the operators. The sensors are far enough away from the operators so that the machine does not stop inadvertently before there is a chance to drop the product into the empty carton.

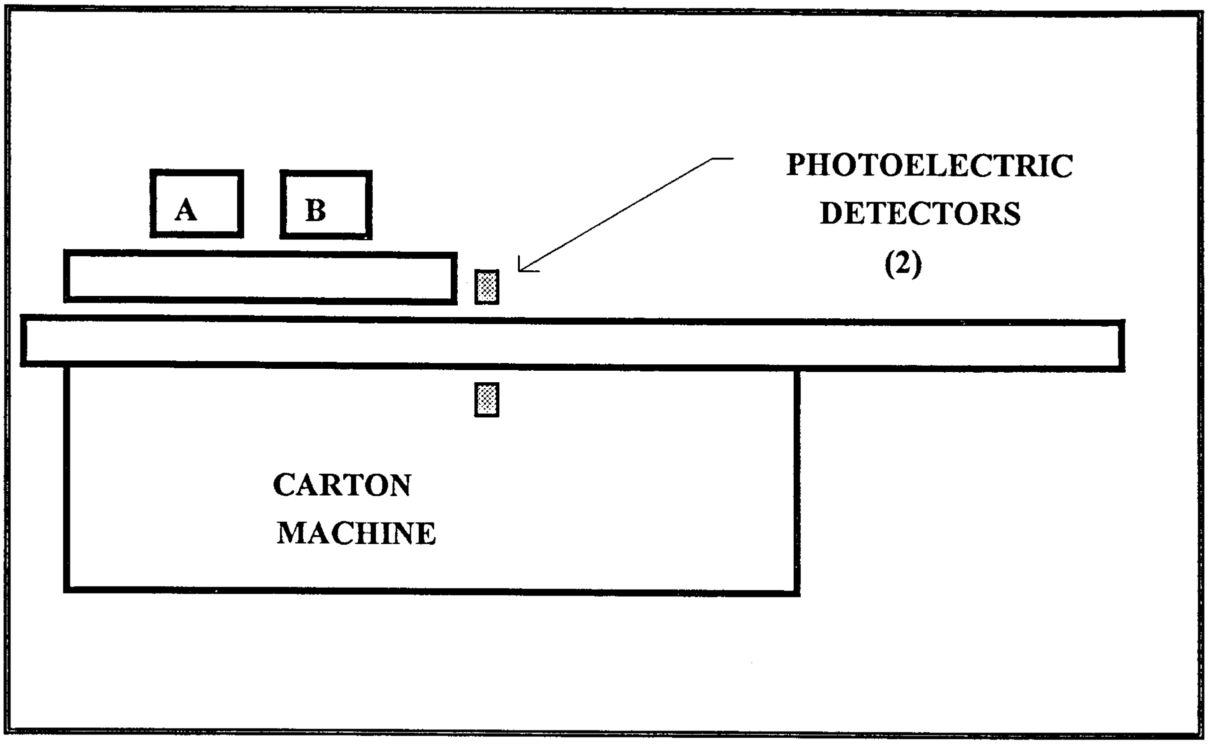


Figure 8. Photoelectric Detector Application

The use of photoelectric sensors in this application is a major step towards the final solution to the compressed air problem. Unfortunately it cannot be used because the amount of time consumed between the machine stopping and starting causes a disruption in production. The approximate time for this disruption is estimated at twenty seconds. The number of products that exit the carton machine is approximately 120 per minute; therefore, the down time will have an effect on overall production at the end of the shift. In the next chapter the complete solution of eliminating compressed air as a method to detect empty cartons is explained.

CHAPTER 4

THE SOLUTION

The optimal solution for removing compressed air, as a method to detect the absence of a product in a carton, is a culmination of the previous ideas explained in Chapter Three. This chapter focuses on the components necessary for the complete operation of the new system. The individual components will be identified and discussed in detail so that one can understand how the system functions.

The optimal solution requires both electrical and mechanical components which form an electromechanical system. The combination of the two results in a system that accomplishes the same objective as the one that is currently in place. The advantage this solution has is the elimination of any possible injurious effects to employees and the savings of thousands of dollars over the course of time. In Chapter Five, the respective costs of the two systems, both present and future, are compared through a cost-benefit analysis.

The first step taken when deciding to use photoelectric controls as a method of detection is to choose the arrangement that will perform the task with minimal error. In this case, the type favored is an opposed mode sensor with very high excess gain. The sensor must be high powered in order to "burn-through" an opaque container to determine if the contents are present. The Banner Corporation of Minneapolis, Minnesota, which manufactures photoelectric controls, offers many different types. Therefore, its catalog is a key source of data in designing this system. The specifications for all components used in the system are located in the Appendix.

The photoelectric sensors that have the ability to see through empty cartons are SM51EB6 (emitter) and SM51RB6 (receiver). These are known as the inspection sensors. These sensors are extremely high powered and have very high excess gain. In Figure 9, the excess gain that is available from this pair of sensors when used without lenses, is plotted as a function of distance. The excess gain suggests that operation of such an opposed sensor pair is acceptable in both a perfectly clean environment (excess gain ≥ 1.5x) at distances up to fifty feet apart, and in a moderately dirty area (excess gain ≥ 10x) at distances up to fifteen feet apart. At distances within two feet, this sensor pair will operate in nearly any environment. The relationship between excess gain and sensing distance for this sensor pair is governed by the inverse square law. As the sensing distance changes, the excess gain is reduced by a known factor. For instance, if the

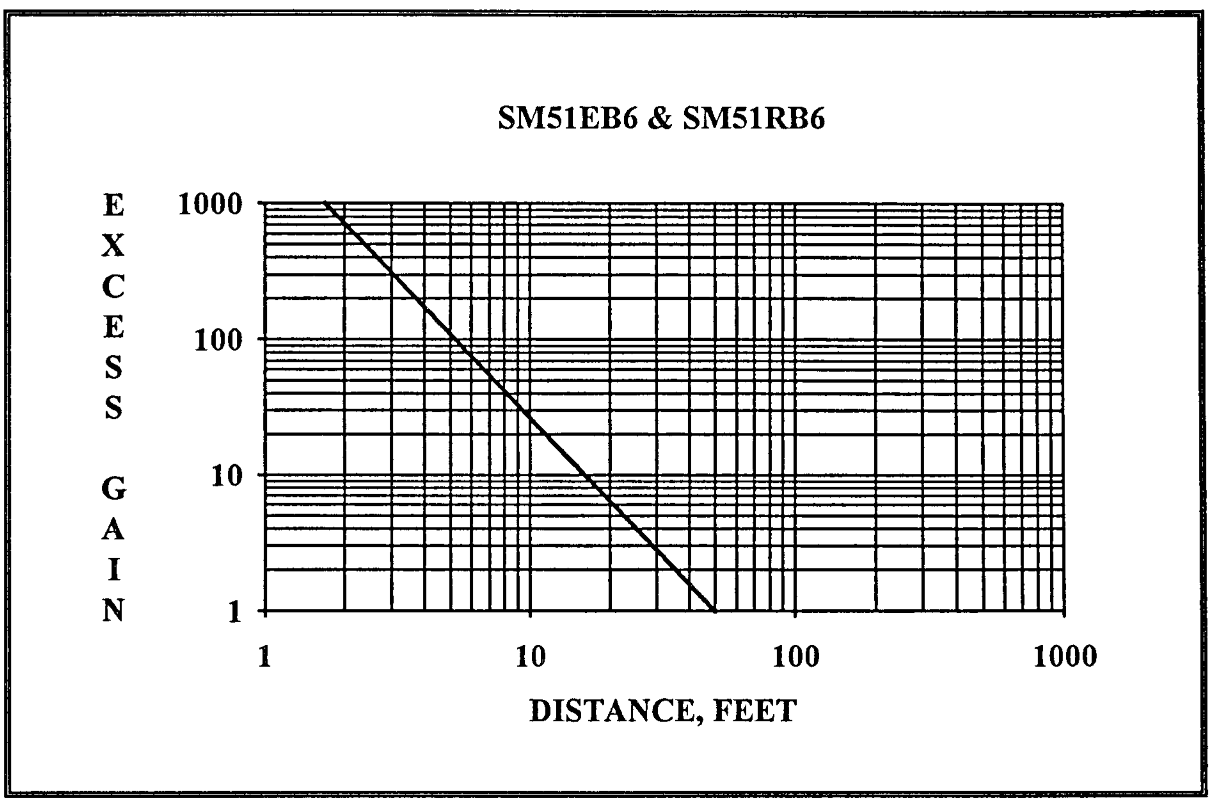


Figure 9. Excess Gain Curve for an Opposed Mode Sensor Pair

distance doubles then the excess gain is reduced by a factor of $(\frac{1}{2})^2$ = one-fourth.. At ten feet the gain is equal to 20, at twenty feet the gain is equal to five. As a result, the logarithmic excess gain curve is always a straight line. The excess gain for this application is above fifty times and is adjusted manually until enough gain is achieved to enable the sensor to see through the carton.

The beam pattern shown in Figure 10 represents the area in which the receiver will see the emitted light. The horizontal axis is the distance the receiver can be from the emitter, and the vertical axis is the width of the emitted beam. The curve represents how far the sensors can be apart from one another without interfering with other sensors. Testing revealed that the sensors for this application can be set up approximately eight inches apart eliminating interference.

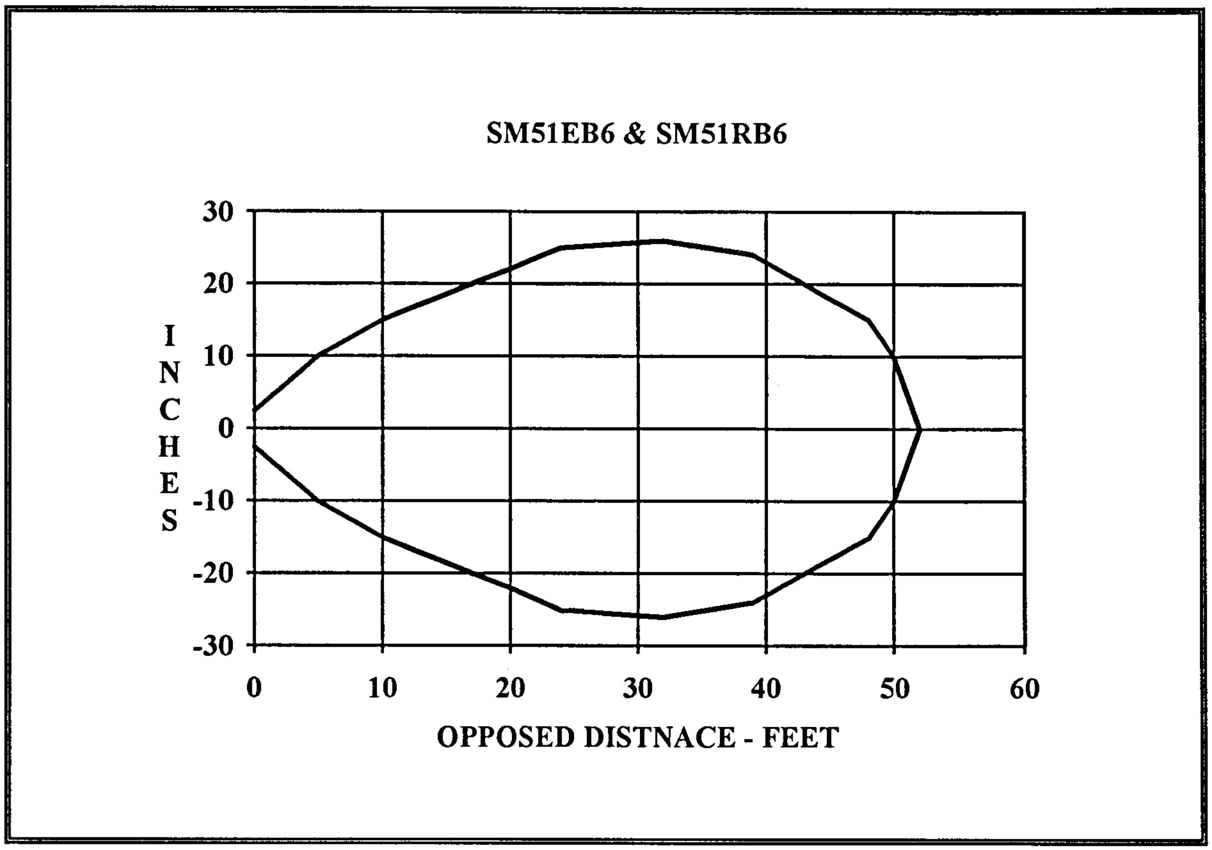


Figure 10. Beam Pattern for an Opposed Mode Sensor Pair

When choosing a sensor for any application, it is important to understand how the excess gain and beam pattern curves function.

The next step is to choose a sensor that will be used in conjunction with SM51EB6 and SM51RB6. The mini-beam sensor, SM2A312W, also known as the interrogate sensor, is used to initiate a gate signal each time its beam is broken by the leading edge of a carton. A gate is a combination logic circuit having one or more input channels. The gate signal tells the inspection sensors that a carton has just been sensed, and to check if a product is present inside. If the product is detected by the sensors during inspection at the gate window, the beam will be broken. The inspection sensors are positioned perpendicular to the conveyor at

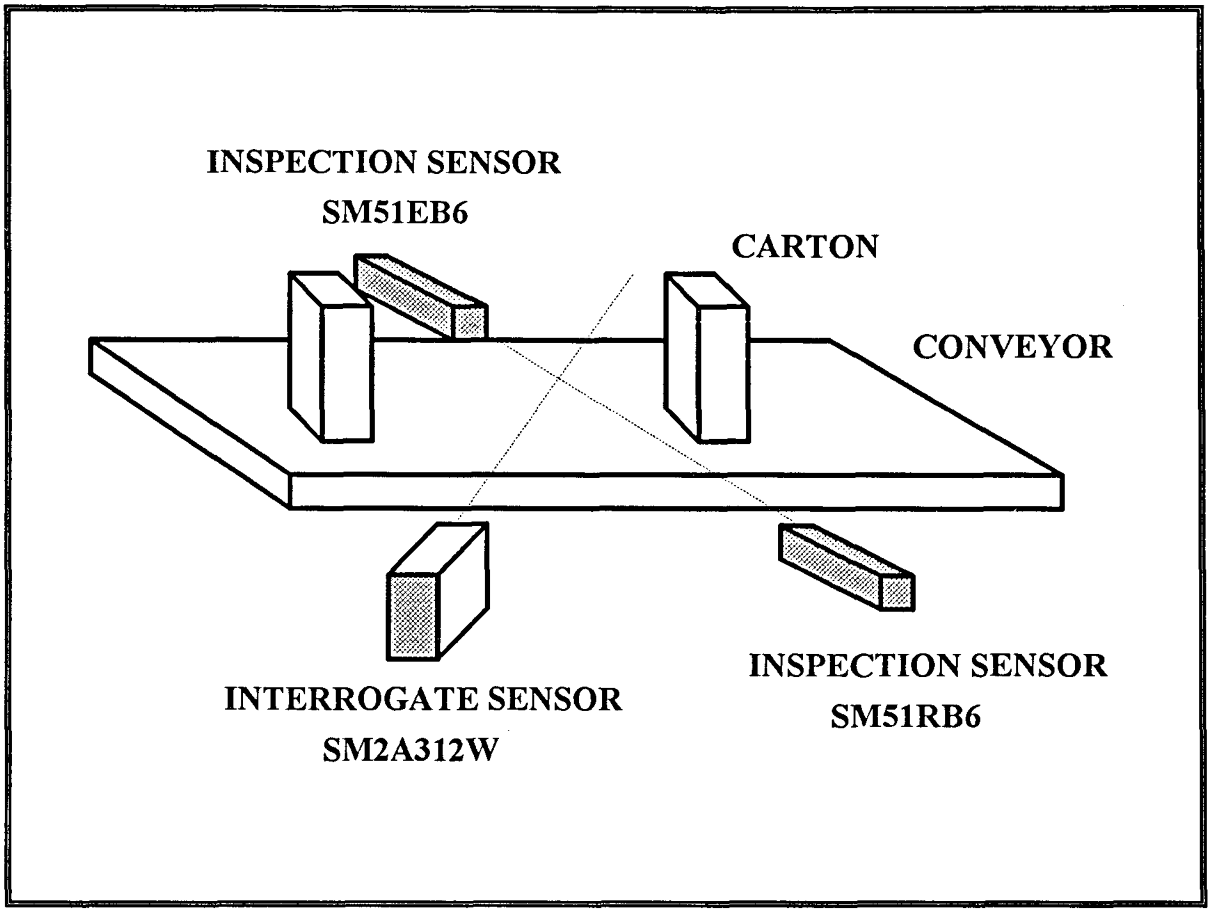


Figure 11. Inspection and Interrogate Sensor Setup

the mid-point of the carton's height so that its beam will be broken if the product is in place. The inspection sensors must also be positioned (relative to the interrogate sensor) so that the inspection beam is "looking" at the carton's position while the gate window is open. The setup for the inspection sensors and interrogate sensor is shown in Figure 11.

The LIM-2, logic inspection module, is the device necessary to coordinate the inspection and interrogate sensors. It is easily programmable through internal logic (DIP) switches which can vary input response times, signal polarities, and output characteristics. The programming options for this module are shown in Table 4. The positions of the switches used for this system are italicized.

The interrogate sensor establishes a gate signal during which the logic inspection module looks for the presence or absence of data from the inspection sensors. The data received from the sensors is interpreted by the module and the output can be programmed in two ways. If a data signal is detected, this indicates the absence of a product; and, if the data signal is not detected then the product is present. The outputs can be programmed either as a one shot pulse or as a latch. In the latch mode, the signal is switched on until another device turns it off. The one shot pulse is used in this application to supply additional information to a timing device known as a shift register. The hookup diagram for the inspection and interrogate sensors using the logic inspection module is shown in Figure 12.

The LSR-64, shift register module, is used to interpret the data which is sent from the logic inspection module. In this application, a shift register is necessary since the inspection of the carton is at one location, while the mechanism to eject the defective product is at another. The shift register module obtains its data from two sensors which use a mechanical "clocked" reference such as a cam or gear. The two sensors, SE61E and SE61R, are attached to a gear which is connected to the drive shaft of the conveyor. The sensors generate pulses from the teeth of the gear and each clock pulse represents an equal increment of movement of the carton on the conveyor. The shift register stores the data received from the sensors and

Table 4. LIM-2 Programming Options

Switch Number	"ON" Position	"OFF" Position
1	Gate input has 10 millisecond response time	*Gate input has 1 millisecond response time*
2	Data input has 10 millisecond response time	*Data has 1 millisecond response time*
3	*GATE signal is entered when pin #5 is "low"*	Gate signal is entered when pin #5 is "high"
4	*DATA signal is entered when pin #3 is "low"*	DATA signal is entered when pin #3 is "high"
5	*Gate window remains open for as long as the GATE signal is present*	Gate window occurs only at the leading edge of the gate input
6	*Data may be entered at any time during the gate window, or it may be continuous*	A data transition must occur while the gate window is open
7	Outputs latch in their last state until the end of the next gate window	*Appropriate out energizes for a one-shot pulse at the end of each gate window*
8	*Output one-shot time is adjustable from .05 to 1 second*	Output one-shot time is adjustable from .005 to .1 second

Source: Banner Engineering Corp., Handbook of Photoelectric Sensing, Banner Engineering Corp., Minneapolis, Minnesota, 1990.

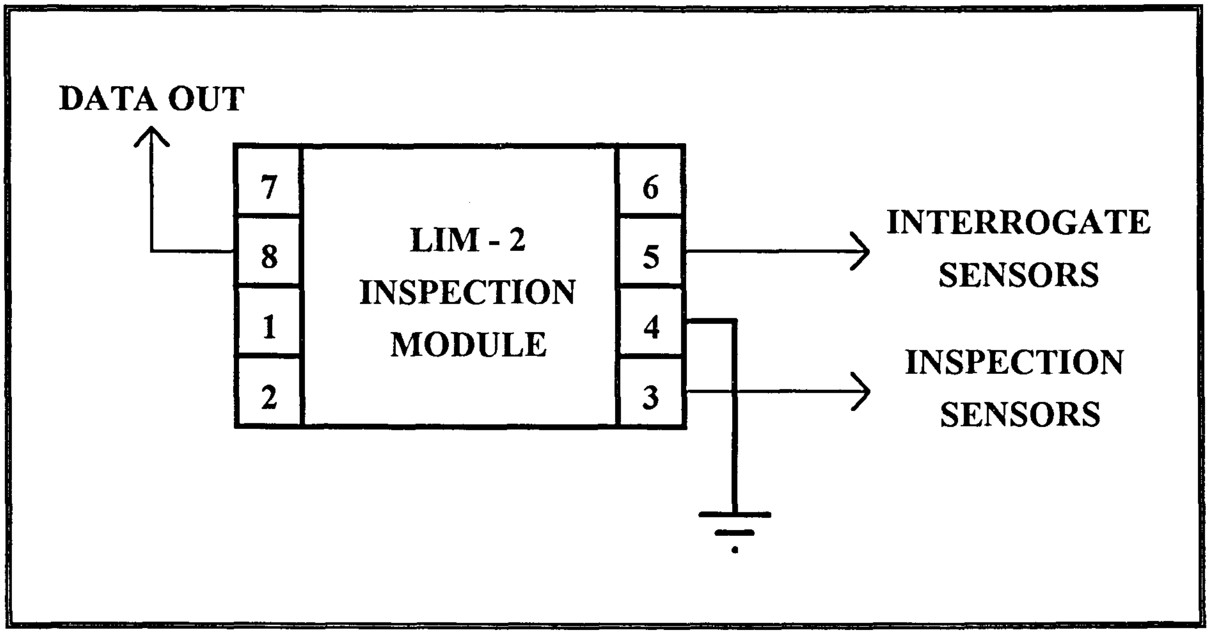


Figure 12. Hookup diagram for Logic Inspection Module LIM-2

coordinates the timing at which point the output is sent to an electromechanical relay. The hookup diagram for the shift register module and sensors is shown in Figure 13.

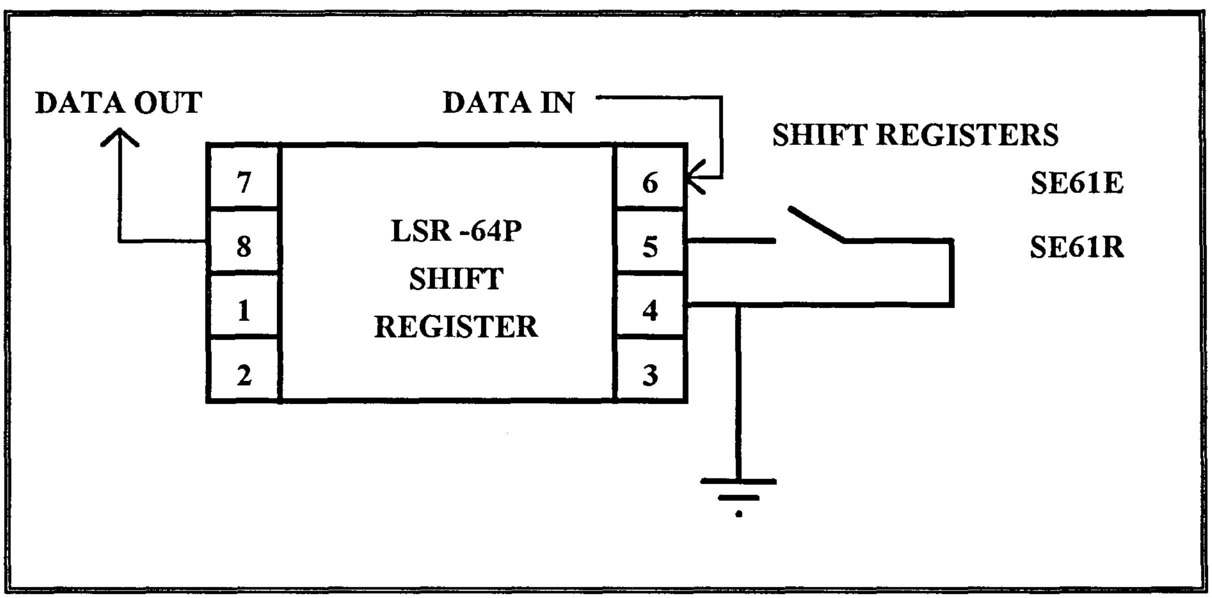


Figure 13. Hookup diagram for Shift Register Module LSR-64

The electromechanical relay device, BR-2, is the next piece of equipment needed to convert this system from electrical to mechanical. Electrical relays are used in applications where sensors directly control mechanisms such as clutches, brakes, or solenoids at a certain location. The BR-2 is used when the shift register module sends data to the relay. In turn, the relay will then send a signal to a solenoid valve.

The logic inspection module, LIM-2, the shift register module, LSR-64, and the electromechanical relay, BR-2, are connected to the OS-8 female octal (8-pin) socket. These then connect to a control chassis, MRB-L. The MRB transformer has a built-in rectifier, and supplies 15 volts directly to pins number four and seven of the first socket with a maximum of 500 milliamps. The supply voltage is 120 volts. The hookup diagram for the entire electrical system is shown in Figure 14.

The devices needed to perform the removal of a defective carton once it has been detected by the electrical components are; a four-way valve, a speed control kit, a quick exhaust valve, and a single ended double-acting cylinder which is required when the system is operating synchronously. These mechanical parts have the capability of ejecting the carton from the production line without delaying or interfering with production.

The four-way valve is connected to the output of the MRB-L control chassis. A four-way valve is used since this application needs four ports and four internal passages. The inlet port allows the compressed air into the valve when a signal is given from the electromechanical relay. The next port passes the compressed air to the cylinder which pushes the carton off the conveyor. The third port, which is commonly known as the exhaust port, allows the compressed air to exhaust. During one of the positions of the solenoid valve, the exhaust port is closed so that air is directed from the inlet port to the cylinder port. The last port is used to exhaust any excess compressed air that is not needed backwards through the valve.

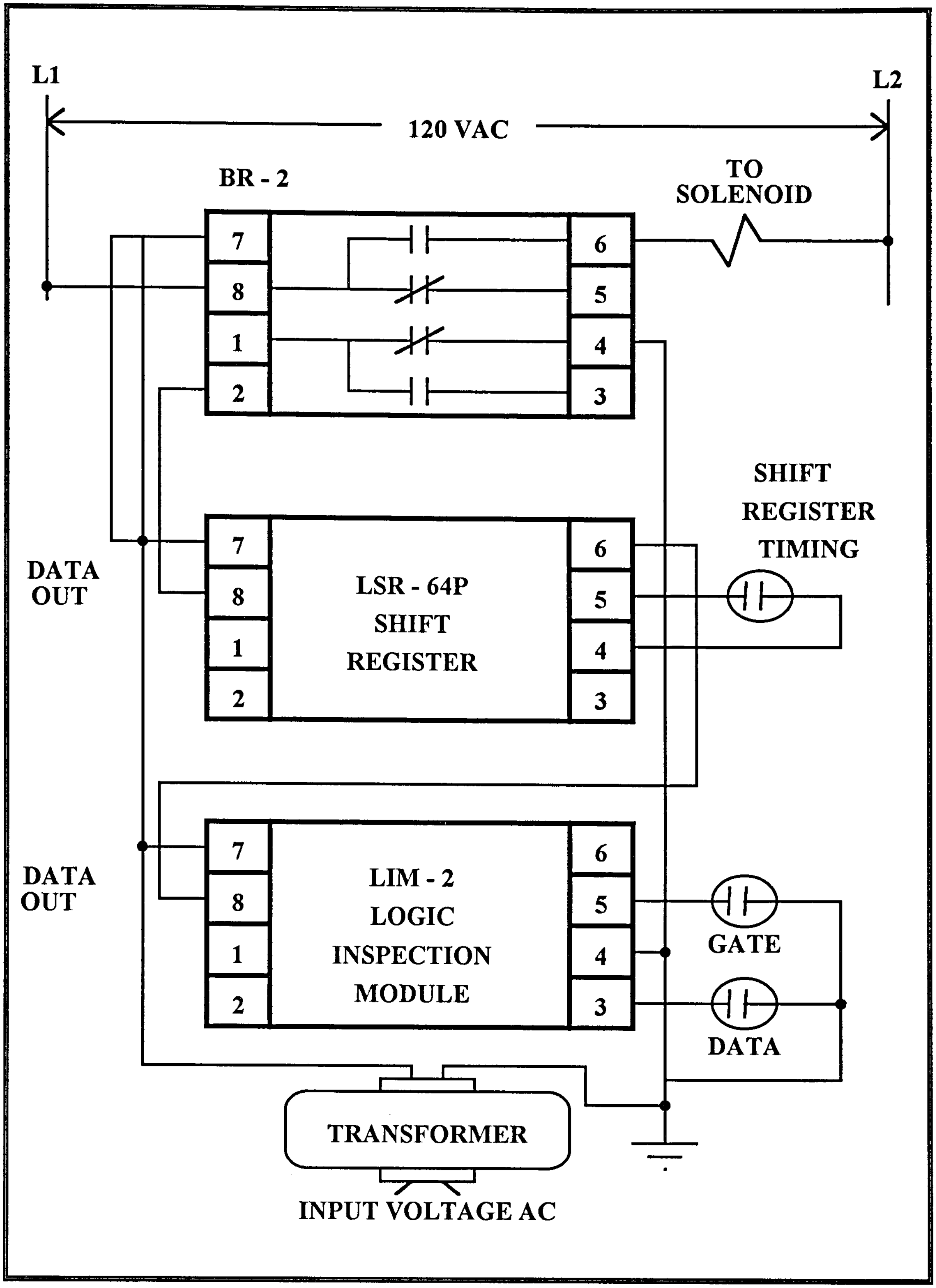


Figure 14. Hookup Diagram for Electrical System

The four-way valve used in this system is the Numatics Mark 7 model number 11SAD421C. This model is used in conjunction with a speed control kit, Numatics model number 229-310A. The speed control kit attaches to the four-way valve and is needed to adjust the throttle flow of exhaust air out of the four-way valve unit.

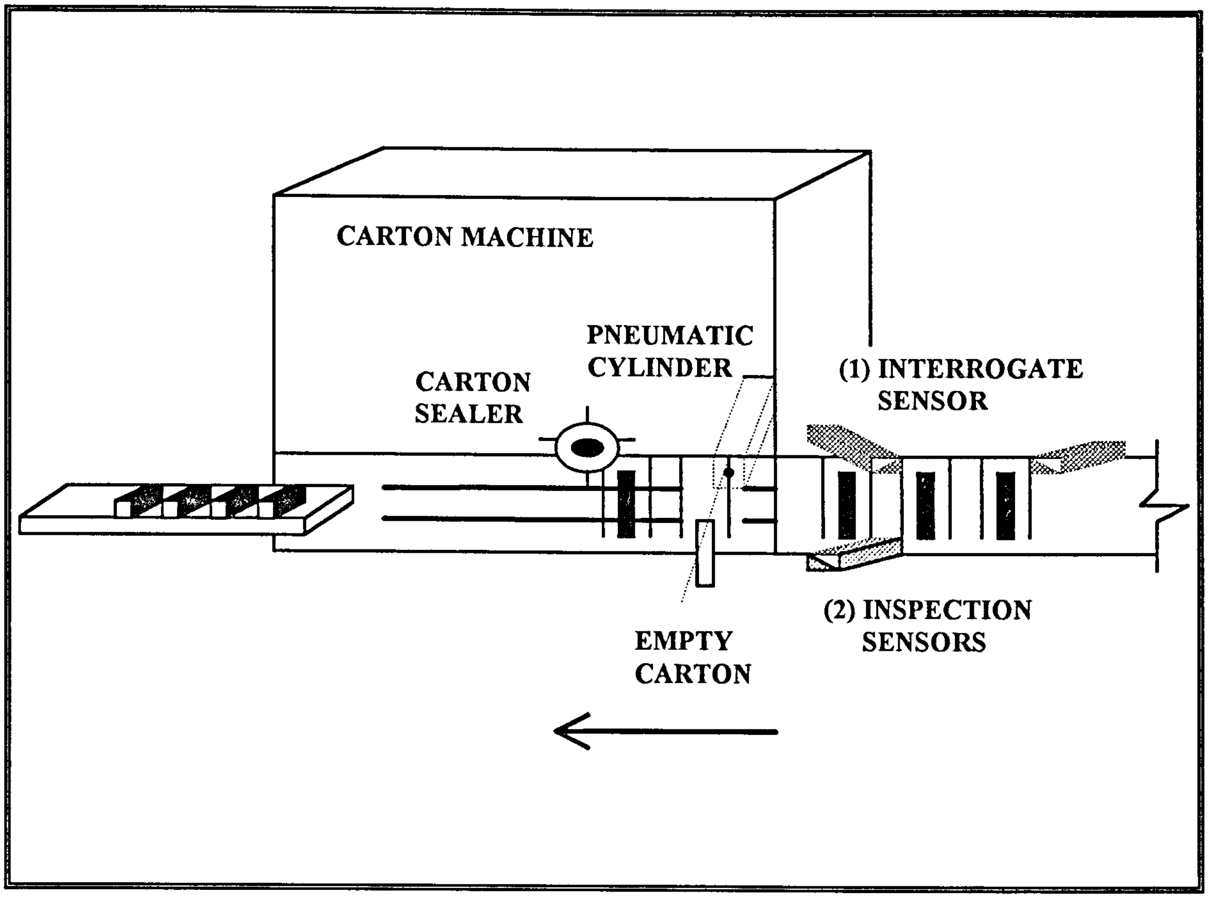


Figure 15. Electromechanical System Setup

The mechanical component that performs the work involved to remove the empty carton is a double-acting single ended piston cylinder. The compressed air which is exhausted from the four-way valve is sent to the inlet port of the cylinder. This drives the piston into the carton ejecting it from the conveyor. After the cylinder has performed this operation, air will be sent through another port to force the piston rod back into its initial position. The cylinder used is made by the Allenair Company of Mineola, New York, model SM-2x6-HTP, piston cylinder which has a two inch bore and a six inch stroke. The cylinder is mounted just before the carton enters the sealing stage. A quick exhaust valve is connected to its exhaust port. This valve allows the cylinder to reset itself in two-tenths of a second in order for it to be able to eject the next defective carton. The cartons pass the cylinder at a rate of two per second. For the system to work this quickly, a Quick Exhaust Valve model EV20A is used which is supplied by the Deltrol Company of Bellwood, Illinois. In order to eject the carton at this location, two guide rails must be cut to allow the carton to drop off the conveyor. The location for the cylinder was chosen because the process presently used by the carton machine does not allow room for the cylinder to be placed in any other area on the production line. In addition, once the cartons exit the carton machine they fall on their sides. This orientation does not permit the shift registers to accurately pinpoint their location. A setup for the electromechanical system is shown in Figure 15.

CHAPTER 5

COST-BENEFIT ANALYSIS

The costs of the present system being used and the optimal solution proposed may be compared through a cost-benefit analysis. Performing such an analysis is necessary whenever a system is altered. Its goal is to determine whether using photoelectric and pneumatic components is justifiable as a replacement for the presently used compressed air system for detecting defective products before the packaging stage.

The compressed air system does not utilize any electrical or mechanical parts other then a valve and a pipe which is routed to a location under the conveyor just beyond the carton machine. The costs for the valve and the pipe are not considered in this analysis since they were a one time purchase made over twenty years ago and have since fully amortized. The only significant cost involved with this system is the compressed air. In order to determine this cost, certain basic calculations must be performed as shown below:

For the compressed air, certain parameters are fixed,

- ¼" pipe
- 90 PSIG
- 26 hp for a basic air compressor per 100 CFM (cubic feet per minute)
- 90% efficiency for an electric motor

Discharge in CFM for ¼" pipe diameter = 95 CFM

The pipe out of which the compressed air flows has rough edges, thus the discharge is multiplied by a factor of 0.65. If the orifice edges were well rounded a factor of 0.97 would be used.

Source: Compressed Air and Gas Institute, Compressed Air and Gas Handbook, Prentice-Hall, New York, Fifth Edition, 1988, 852-853.

$$(95.0 \text{ CFM}) \times (0.65) = 62 \text{ CFM}$$

The next step is to calculate the power input based on air flow which is given by:

$$P = (\text{Power Output}) \times (\text{Discharge}) / \eta\ (\text{efficiency}) \times (100 \text{ CFM})$$

Source: Hibbeler, R.C., Engineering Mechanics Dynamics, Macmillan Publishing Company, New York, 1986, 153-154.

$$P = (26 \text{ Hp}) \times (62 \text{ CFM}) / (0.90) \times (100 \text{ CFM})$$

$$P = 17.91 \text{ hp}$$

The power is now converted into watts:

$$1 \text{ hp} = 746 \text{ W}$$

$$P = (17.91 \text{ hp}) \times (746 \text{ W})$$

$$P = 13.36\ KW$$

The present cost for electricity is approximately $0.13 per KWH according to current figures supplied by the Public Service Electric and Gas Company of Newark, New Jersey.

Thus, the cost to produce 90 psi of compressed air for 2 - 8 hour shifts a day can be calculated by:

Cost = (Power) x ($ / hour) x (Time)

Cost / Day = (13.36 KW) x ($0.13 / KWH) x (16 H / Day)

Cost / Day = $28.00

The Cost / Month is calculated based on 21 working days in one month, thus:

Cost / Month = (Cost / Day) x (21 Days / Month)

Cost / Month = ($28.00) x (21 Days)

Cost / Month = $588.00

The Cost / Year is the Cost / Month multiplied by 12 months in one year,

Cost / Year = (Cost / Month) x (12 Months / Year)

Cost / Year = ($588.00) x (12 months / Year)

Cost / Year = $7,055.00

The cost associated with the optimal solution is based on quotations received from the respective manufacturers' retail price for each component. These prices are valid at present but will increase over time due to inflation so that the total cost will fluctuate. In Table 5, each component is shown by its part name, part number, manufacturer, and cost. In Table 6, the cost of installation, which may be performed by one electrician and one machine maintenance mechanic, is shown, and the total electromechanical system cost is presented.

Table 5. Total Purchase Cost of Components

Part Name	Part Number	Mfg.	Cost
Control Chassis	MRB-L	Banner	$70.00
Logic Inspection Module	LIM-2	Banner	$113.00
Inspection Sensor - Emitter	SE51EB6	Banner	$74.00
Inspection Sensor - Receiver	SE51RB6	Banner	$97.00
Interrogate Sensor	SM2A312W	Banner	$86.00
Shift Register Module	LSR-64	Banner	$173.00
Shift Register - Emitter	SE61E	Banner	$27.00
Shift Register - Receiver	SE61R	Banner	$32.00
Electromechanical Relay	BR-2	Banner	$17.00
Female Socket	0S-8	Banner	$33.00
Solenoid Valve	11SAD421C	Numatics	$99.00
Speed Control Kit	229-310A	Numatics	$45.00
Piston Cylinder	SM-2x6-HTP	Allenair	$98.00
Quick Exhaust Valve	EV20A	Deltrol	$15.00
		TOTAL COST	**$980.00**

Table 6. Cost of Installation and of the Entire Electromechanical System

Job Title	Time	Rate	Cost
Electrician	4 hours	$40.00	$160.00
Mach. Maint. Mech.	4 hours	$40.00	$160.00
		Total Cost of Labor	**$320.00**
		Total Cost of Components	**$980.00**
		Total Cost of Electromechanical System	**$1300.00**

The electrician installs all electrical components pertinent to the system, and the machine maintenance mechanic installs the mechanical equipment. The electrical installation may be considered complete when the electrician can justify that the components provide a one-shot pulse when the absence of a product in a carton passes the inspection sensors.

The machine maintenance mechanic installs the pneumatic equipment which performs the ejection of defective cartons. The installation is complete when the mechanic can justify that all defective cartons are ejected from the conveyor before they are able to proceed to the packaging stage. It is very important that every defective carton is ejected in order to maintain a 100% production rate. Therefore, the electrician and the machine maintenance mechanic are able to work together to ensure that the system operates accurately. The total time involved for the installation is estimated at half a day, although actual time can vary.

The costs of the electromechanical and compressed air systems is shown in Figure 16. It can be seen that compressed air is approximately five times more expensive than the proposed electromechanical system in the first year of installation. In Figure 17, the cost of the two systems are projected over a period of five years in order to show the relationship between present and future expenditures. In five years, the cost to run the compressed air is approximately $32,250.00, while the electromechanical system cost is approximately $2,800.00.

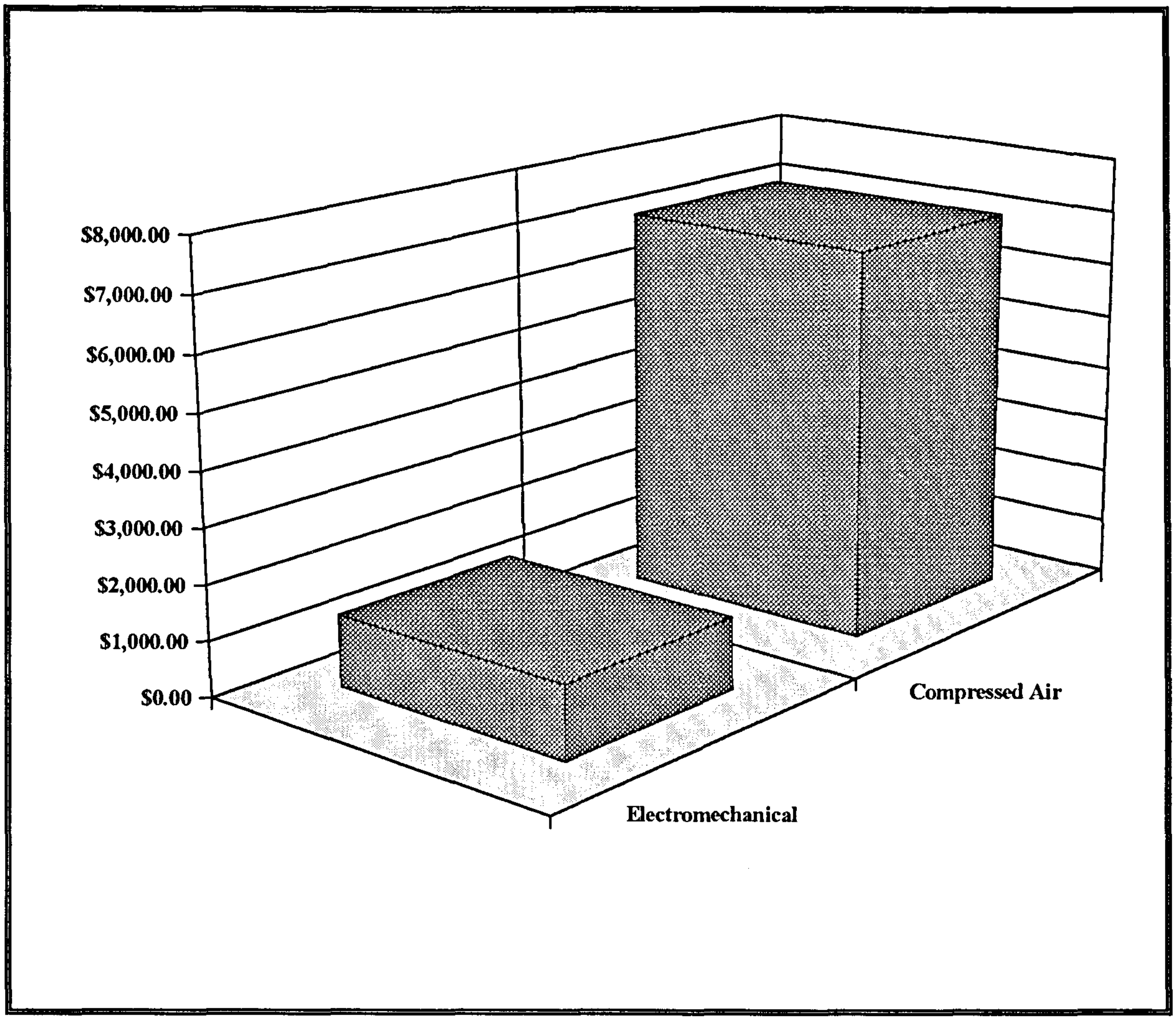


Figure 16. Cost of Systems for First Year

A maintenance cost of $300.00 a year has been added for five years in the electromechanical system to cover any labor and spare parts which might be necessary to repair or replace failed components. The possibility of not performing maintenance on the electromechanical system exists, but is dependent on environmental work place conditions (e.g. cleanliness). In this application, mechanical failure of the piston cylinder or solenoid valve is more likely then the failure of any electrical components.

The two total system costs presented in this chapter differ significantly, with the electromechanical system being far more economical. The cost-benefit analysis proves that even in the first year, the savings will be significant. In addition, the elimination of compressed air blowing constantly removes any potential health hazards related to noise exposure. In a hypothetical scenario, even if the total electromechanical system had to be replaced each year, it would still be advantageous to use instead of the present compressed air system.

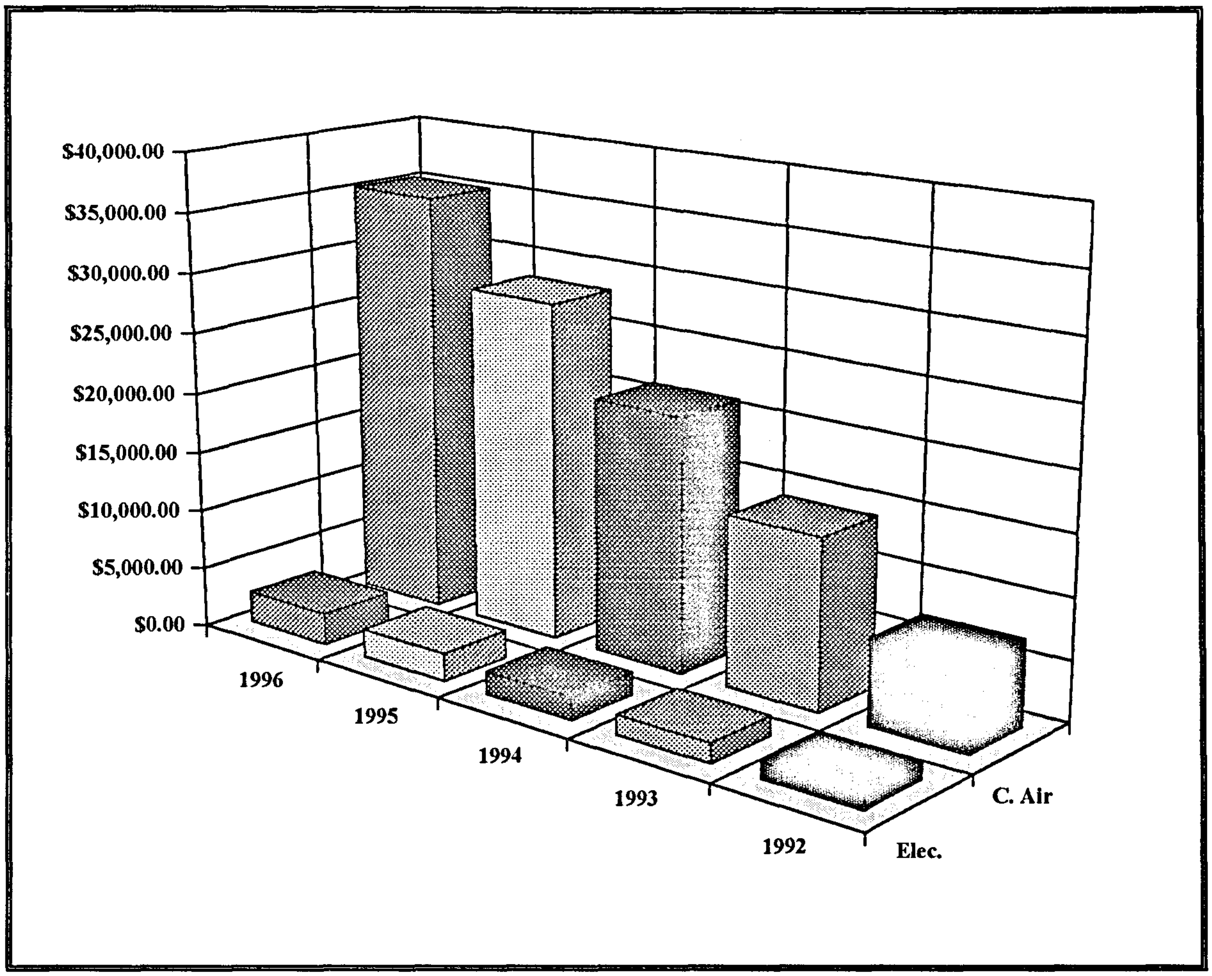


Figure 17. Total Cost of the Competing Systems Over Five Years

CHAPTER 6

CONCLUSION

The use of compressed air as a method to detect the absence of a product in a carton in a manufacturing environment poses health and safety hazards to individuals who must work in this setting. The noise level emitted from a compressed air jet used for this application exceeds the Occupational Safety and Health Administrations guidelines of 90 dBA over a time-weighted average of eight hours. According to OSHA, exposure to this level of noise necessitates the use of personal protective equipment, in this case, hearing protection devices. The steps to follow in the situation described above would be to apply, engineering controls, administrative controls, or lastly, personal protective equipment. At present, administrative controls have been implemented but have not been effective in reducing the noise exposure level. Through job rotation, administrative controls were investigated but failed to reduce the exposure levels. In the past, engineering controls were not feasible due to the lack of manpower to design a system to remove the noise source. The cost of using compressed air is yet another concern when operating a production line in which products are inserted into a carton. In one year, if a compressed air system is utilized, the cost to supply 90 pounds per square inch for sixteen hours a day is approximately $7,050.00. This cost would be divided in half if production were reduced to a single eight hour shift.

Various ideas were investigated in developing a system to eliminate the use of compressed air and thus reduce the health and safety hazards associated with detecting defective products. Developing a substitute system enabled the creation of an optimal approach that would eliminate this problem. Some of the various options presented were not feasible, but they were not entirely excluded. Constraining factors did not allow certain features to be implemented because of the necessity to restructure the production line which would significantly increase costs. The electromechanical system recommended does not preclude all applications for this type of manufacturing environment. It is presented in order to compare various alternative approaches for methods to detect defective products.

The optimal solution developed has advantages over the present system, compressed air. One of its main goals is to eliminate the risk of negative health effects due to the high sound pressure levels generated. The electromechanical system presented accomplishes this task. In addition, the cost of the system is considerably lower than the present arrangement as shown by the cost-benefit analysis in Chapter 5. The ability to perform the removal of defective products and reduce the overall cost of producing the product makes this system desirable. Also, the system eliminates any potential hearing loss to employees working in the particular area of concern. In the first year of production there is a potential savings of approximately $5,750.00 or 400%.

There are some advantages and disadvantages when deciding between the two systems and choosing the best one. The advantages of using compressed air are its ease of installation and the ability to detect defective products. Simply installing a valve and piping attached to the plant air source creates an effective system, but it has two major disadvantages, the extremely high cost of compressed air and the high noise levels generated. On the other hand, by using an electromechanical system, one can eliminate the high noise levels and accomplish the detection task at approximately one-fifth the cost. The only drawback to the electromechanical system is its installation, which requires an electrician and a machine maintenance mechanic. This factor is not considered a disadvantage since these two positions are usually found in a typical manufacturing environment. In conclusion, the electromechanical system is preferred since it reduces the health and safety risks and is more cost effective then the compressed air system.

APPENDIX

The components found on pages 40-50 are taken from the Banner Engineering Corporation catalog of 1991-1992. The company is located at 9714 10th Avenue North, Minneapolis, Minnesota 55441. For further information, their telephone number is (612) 544-3164.

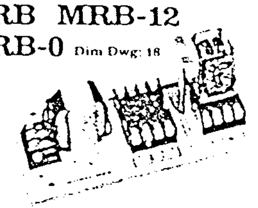
The components found on pages 51-53 are taken from the Numatics Corporation catalog of 1992. The company is located at 1450 North Milford Road, Highland, Michigan, 48357. For further information, their telephone number is (313) 887-4111.

The components found on pages 54-57 are taken from the Allenair Company catalog of 1992. The company is located at 255 East Second Street, Mineola, New York 11501. For further information, their telephone number is (516) 747-5450.

The component found on page 58 is taken from the Deltrol Company catalog of 1986. The company is located at 3001 Grant Avenue, Bellwood, Illinois 60104. For further information, their telephone number is (708) 547-0500.

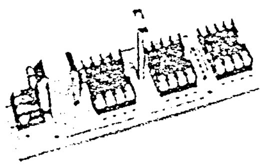
control chassis

MRB MRB-12
MRB-0 Dim Dwg: 18



The MRB is the basic control chassis, including the BR-2 output relay, for use with all "M" and "B" Series amplifier modules. The MRB transformer has a built-in rectifier, and supplies 15 VDC directly to pins 7 and 4 of the first socket, at 500 milliamps maximum. Supply voltage required is 105 to 130 VAC, 50/60 Hz. It includes a hold-down clamp for the module and the relay. MRB-0 is identical, except that it does not include the BR-2 relay; MRB-12 includes the relay, and is for either 120 VAC or 230 VAC.

MRB-L Dim Dwg: 20



The MRB-L is similar to the MRB, except that it includes a third octal socket for systems requiring a combination of amplifiers and relays. No output relay is provided.

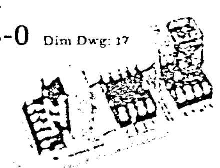
MRB-XL Dim Dwg: 22

The MRB-XL is similar to the MRB-L, except that a fourth socket and a second hold-down clamp are provided, for larger systems. The output relay is not included.

MRB-T Dim Dwg: 21
Hookup Dwg: K

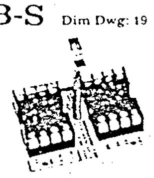
The MRB-T consists of a socket for a "B" or "M" Series amplifier, plus the Model BTR-10 optically-coupled 10 amp solid-state relay, described in the OUTPUTS section of this catalog. The MRB-T should be used in systems where an AC load such as a solenoid or motor starter is to be operated so frequently that the life of a conventional relay would limit long term operation (the BTR-10 has no moving parts, and therefore infinite life).

BRB
BRB-0 Dim Dwg: 17



The BRB is a special control chassis that provides 12 VAC to pins 1 and 2 of the first socket, and also provides 5 VAC to an additional pair of terminals, for powering incandescent light sources. It may be used only with "B" Series amplifiers, and is primarily intended for retro-fit requirements, or for use with the Model FO2-BG incandescent fiber optic interface. The BRB includes the BR-2 output relay; the BRB-O is identical, but without the relay. Both are for 120 VAC 50/60 Hz operation.

BRB-S Dim Dwg: 19

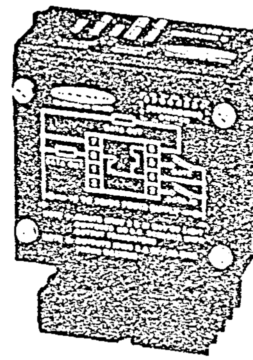


The BRB-S consists of two octal sockets mounted on an aluminum sub-plate, along with the module hold-down bracket. It is useful in systems requiring more than the four sockets provided by the MRB-XL, or in systems where low voltage power is already available.

Special Purpose Sensors & Controls

LIM-2 Logic Inspection Module

- **Coordinates a gating signal with data from an inspection sensor for accept/reject and other similar control applications**
- **Inputs may be derived from contact closures or any dc sensor (or sensing system) with NPN (sinking) output**
- **May be programmed to replace dedicated-function Banner logic modules B4-2-1500B, BIC-2, DP-1A, TL2A**



LIM-2 module shown with model OS-8 socket (sold separately).

General

The model LIM-2 logic inspection module may be used in nearly any high-speed inspection application where it is necessary to know whether an event did or did not occur within a specified time period, or "gate window". Typical LIM-2 applications include:

Missing part detection
No bottle/no fill control
Die protection
Full case inspection
Code reading ("train logic")
Rotary index table inspection
Inspecting for foreign objects
Low fill level monitoring

The LIM-2 operates on signals derived from contact closures or dc-type photoelectric or proximity sensors having an NPN sinking output transistor. Easily-accessible internal logic (DIP) switches enable customer-programming of eight different inspection variables including input response times, signal polarities, and output characteristics (see Table 1). This high level of versatility means that the LIM-2 can often replace other types of logic modules (e.g. Banner B4-2-1500B, BIC-2, DP1A, and TL2A) while providing additional capabilities not found in those original modules.

The LIM-2 module measures 3.0 x 3.0 x 1.5 inches, and plugs into a standard octal socket such as the Banner OS-8 (sold separately, see page 278). Up to 256 field-programmable operating modes are possible.

Operation

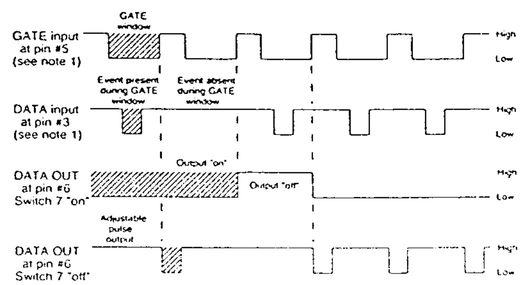
At the beginning of the GATE signal, the LIM-2 begins to look for a DATA signal caused by an external event. At the end of the gate window, either of two outputs is possible: a DATA OUT (data present = output) signal at pin #6 of the LIM-2, or a $\overline{\text{DATA OUT}}$ (data absent = output) signal at pin #8.

As is shown in Figure 1, if a DATA signal occurs during the gate window, a DATA OUT signal is put out. This DATA OUT signal is programmable to either an adjustable one-shot pulse or a latch condition. In the latch condition, the DATA OUT signal continues until a subsequent gate window does not experience a DATA signal. As shown in Figure 2, a $\overline{\text{DATA OUT}}$ (data absent = output) signal is put out if no DATA signal occurs during the gate window. Here also, the output mode is selectable to either a one-shot pulse or a latch condition.

LIM-2 Timing Diagrams

Figure 1

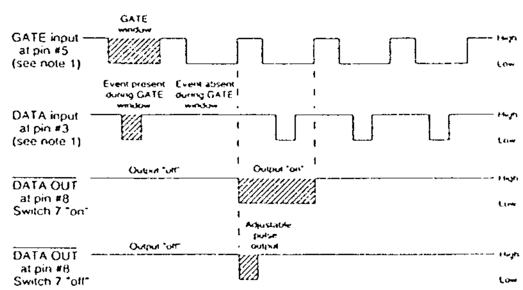
Timing Diagram for DATA OUT output at pin 6



NOTE 1: GATE and DATA inputs may be programmed to respond to either high or low-going input signals.

Figure 2

Timing Diagram for $\overline{\text{DATA OUT}}$ output at pin 8



Special Purpose Sensors & Controls

Table 1. LIM-2 Programming Options

Switch Number	"ON" Position	"OFF" Position
1	Gate input has 10 millisecond response time	Gate input has 1 millisecond response time
2	Data input has 10 millisecond response time	Data input has 1 millisecond response time
3	GATE signal is entered when pin #5 is "low" (logic 0)	GATE signal is entered when pin #5 is "high" (logic 1)
4	DATA signal is entered when pin #3 is "low" (logic 0)	DATA signal is entered when pin #3 is "high" (logic 1)
5	Gate window remains open for as long as the GATE signal is present	Gate window occurs only at the leading edge of the gate input
6	Data may be entered at any time during the gate window, or it may be continuous	A data transition must occur while the gate window is open
7	Outputs latch in their last state until the end of the next gate window	Appropriate output energizes for a one-shot pulse at the end of each gate window
8	Output one-shot time is adjustable from .05 to 1 second	Output one-shot time is adjustable from .005 to .1 second

Specifications, model LIM-2 Logic Inspection Module

Supply Voltage:
10 to 30V dc at 25mA (exclusive of loads); may be supplied by MAXI-AMP model CP12C or CP12RC power supply module (see page 246).

Outputs:
Two NPN open-collector transistors (DATA OUT and $\overline{\text{DATA OUT}}$); maximum current sink 150mA each.

In the one-shot mode, the appropriate output pulses for an adjustable time (.005 to 1 second) at the end of each GATE signal.

In the latched mode, the outputs are latched in the appropriate state (one or the other conducting) at the end of each GATE signal.

Response Time:
Selectable to 1 millisecond or 10 milliseconds.

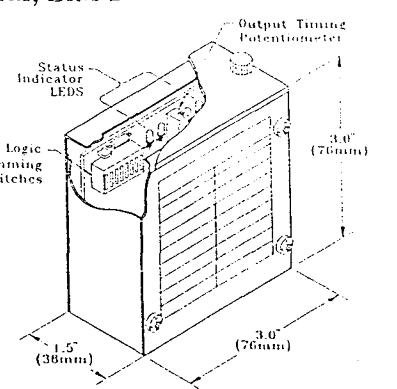
Indicators:
Four LEDs indicate the presence of the following signals: GATE, DATA IN, DATA OUT, and $\overline{\text{DATA OUT}}$.

Input Requirements:
For logic level signals, logic "low" must be less than 2V dc, and logic "high" must be an open circuit or a voltage greater than 6V dc. Input device(s) must be capable of sinking 4ma.

Construction:
3.0 x 3.0 x 1.5 inch plug-in module with standard octal base. NEMA 1 anodized aluminum enclosure.

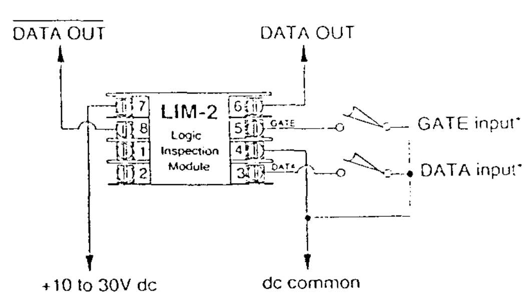
The octal base of the LIM-2 fits the Banner model OS-8 octal socket (order separately, see page 278).

Dimensions, LIM-2



LED indicators behind the transparent module top cover indicate the presence of GATE, DATA, DATA OUT, and $\overline{\text{DATA OUT}}$. Logic programming (DIP) switches and the one-shot pulse duration adjustment potentiometer are also located behind the easily-removeable top cover.

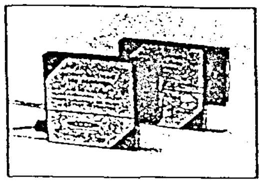
LIM-2 Basic Hookup



*NOTE: Input signals to pins 3 and 5 may be derived from limit switches, relays, or dc self-contained sensors with a current sinking (NPN) or isolated transistor output

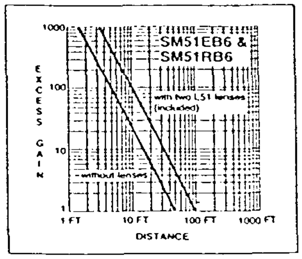
SM512 Series Sensors

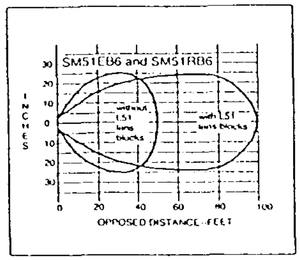
SM51EB6 & SM51RB6



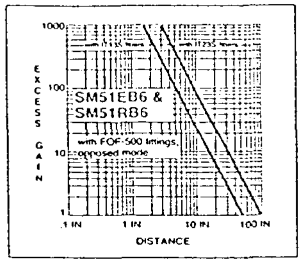
Opposed (non-fiberoptic), Opposed fiberoptic, and Diffuse fiberoptic modes

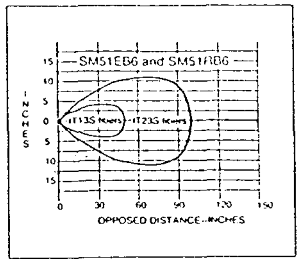
VOLTAGE: 10-30V dc
RANGE: 100 feet in opposed mode (non-fiberoptic).
See excess gain curves for fiberoptic range information.
RESPONSE TIME: 10 milliseconds
REPEATABILITY: 1 millisecond
SENSING BEAM: infrared, 880nm



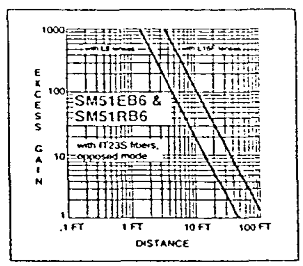


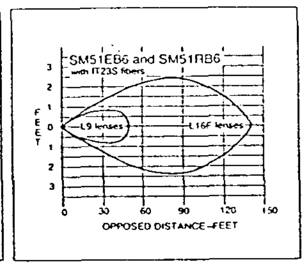
The SM51EB6/SM51RB6 opposed mode sensor pair is a very high gain emitter/receiver pair that utilizes an interconnecting synchronizing wire to "gate" the receiver to look for a signal only at the instant when the emitter sends a pulse from its LED. Because of the high power of these sensors, they are often used to "burn through" an opaque container (a cereal box, for example) to determine if contents are present. Special optics enable them to do this job even better than other sensors which may *appear* to have more excess gain (such as the MULTI-BEAM SBEX and SBRX1). NOTE: lens blocks may be removed for short-range "burn-through" applications.





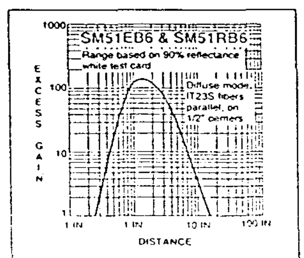
This sensor pair may also be used with fiber optics by adding the optional FOF500 fittings (or order sensor models **SM51EB6FO** and **SM51RB6FO**). When used this way, they provide several times more excess gain than the conventional SM512LBFO. Range when used in the opposed mode with IT23S individual fibers is 7 feet. Sensing range may be extended by use of L9 or L16F lenses (see excess gain curves).

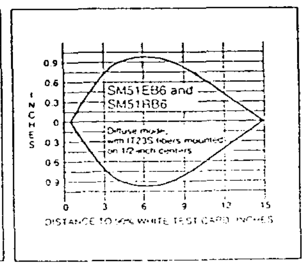




NOTE: the gain of this sensor pair is too high for use with a bifurcated fiber assembly. The very small amount of light that "leaks" through the fiber cladding within the bifurcated bundle is typically enough to operate the high-gain receiver.

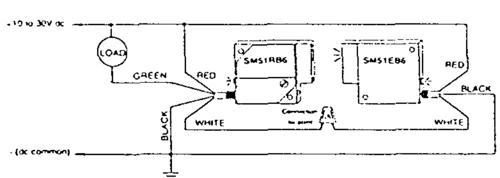
For diffuse (proximity) sensing, position two individual fibers side-by-side with the sensing tips parallel to each other or mechanically converged towards the desired sensing point.





The receiver has a normally open output only (green wire); the white wire is used to synchronize the emitter. NOTE: for normally closed output, order special receiver model SM51RB6DO (DO = Dark Operate).

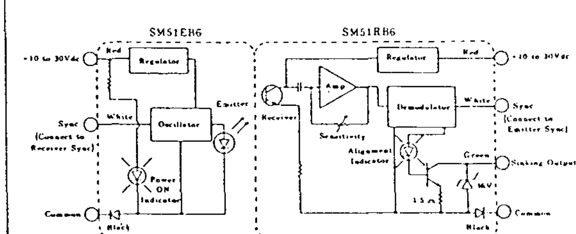
Hookup Diagram



Both the emitter and receiver have white wires which connect together to synchronize (lock on) the pair to a narrow frequency bandwidth. These white wires *must* be connected together if the sensor pair is to operate at high gain. There is only one receiver output, which is the same NPN *current sinking* circuit used in the other SM512 Series sensors.

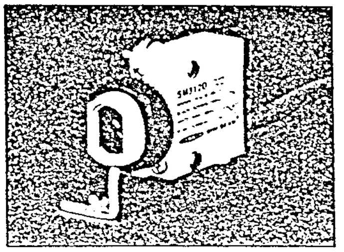
The output is normally open (or LIGHT operate). For a normally closed output, specify model SM51RB6DO (DO = Dark Operate).

Functional Schematic

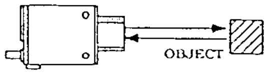


MINI-BEAM Sensors

Sensing Mode	*Models*	*Excess Gain*	*Beam Pattern*

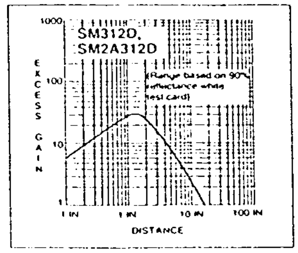


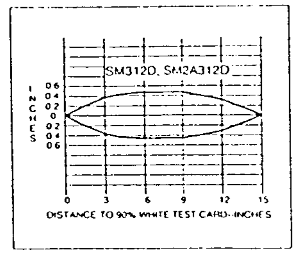
DIFFUSE Mode



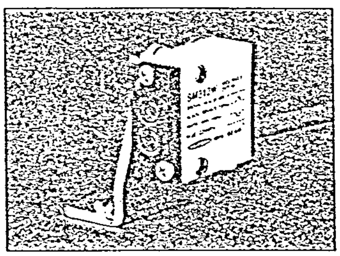
SM312D
Voltage: 10 to 30V dc
Range: 15 inches (38 cm)
Response: 1ms on/off
Repeatability: 0.3ms
Beam: infrared, 880nm

SM2A312D
Voltage: 24 to 240V ac
Range: 15 inches (38 cm)
Response: 8ms on/off
Repeatability: 2.6ms
Beam: infrared, 880nm





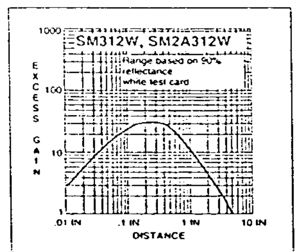
These sensors use no reflectors, but rather detect objects by sensing their own emitted light reflected from the object. They are ideal for use when the reflectivity and profile of the object to be detected are sufficient to return a large percentage of emitted light back to the sensor. *SM312W and SM2A312W models*, which use a divergent light beam, are particularly useful for sensing transparent or translucent objects such as clear plastic or glass, and are often a good choice for reliably sensing objects of very small surface area (e.g. wire or thread) at close range.

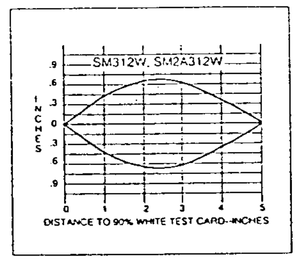


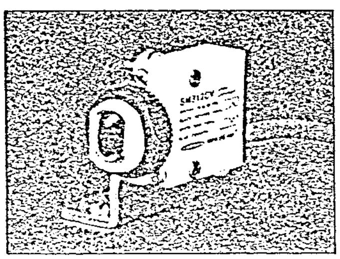
SM312W
Voltage: 10 to 30V dc
Range: 5 inches (13 cm)
Response: 1ms on/off
Repeatability: 0.3ms
Beam: infrared, 880nm

SM2A312W
Voltage: 24 to 240V ac
Range: 5 inches (13 cm)
Response: 8ms on/off
Repeatability: 2.6ms
Beam: infrared, 880nm

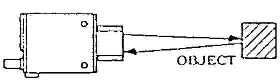
NOTE: see dimension drawing, page 145.





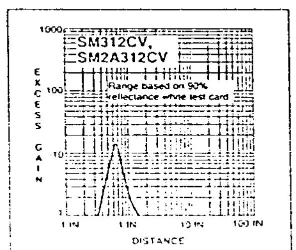


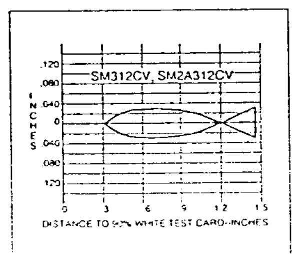
CONVERGENT Mode



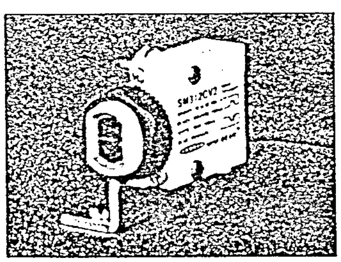
SM312CV
Voltage: 10 to 30V dc
Range: focus at .65" (16 mm)
Response: 1ms on/off
Repeatability: 0.3ms
Beam: visible red, 650nm

SM2A312CV
Voltage: 24 to 240V ac
Range: focus at .65" (16 mm)
Response: 4ms on/off
Repeatability: 1.3ms
Beam: visible red, 650nm



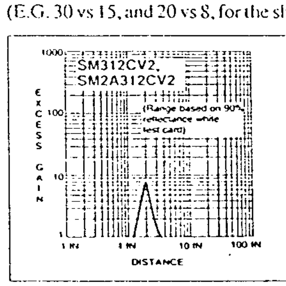


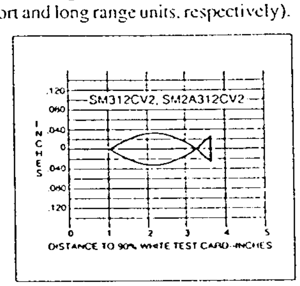
These visible red sensors are ideal for reflective sensing of very small parts or profiles (including color registration marks), and can accurately sense the position of parts approaching from the side. CV models produce a precise .05" diameter spot at a point .65" from the sensor's lens; CV2 models focus at 1.7" with a .12" spot diameter. These sensors are useful in many high-contrast color registration applications. **For applications that are suited to an infrared sensing beam,** consider models SM(2A)312C and SM(2A)312C2, which provide higher excess gain than the visible red units (E.G. 30 vs 15, and 20 vs 8, for the short and long range units, respectively).



SM312CV2
Voltage: 10 to 30V dc
Range: focus at 1.7" (43mm)
Response: 1ms on/off
Repeatability: 0.3ms
Beam: visible red, 650nm

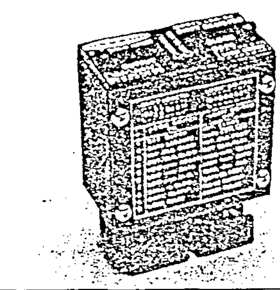
SM2A312CV2
Voltage: 24 to 240V ac
Range: focus at 1.7" (43mm)
Response: 4ms on/off
Repeatability: 1.3ms
Beam: visible red, 650nm





Special Purpose Sensors & Controls

LSR-64 and LSR-1000 Shift Register Modules



- LSR-64: 64-bit shift register (programmable 1 to 64 bits)
- LSR-1000: 1024-bit shift register (programmable 1 to 1024 bits)
- Operates from either an external CLOCK pulse input or from an adjustable internal clock
- Two output circuits: open-collector NPN transistor and ground-isolated optical coupler; adjustable one-shot pulse or latching output
- Adjustable input signal response time; adjustable internal clock period (5 milliseconds to 1 second)
- No false pulse on power-up
- LED indicators show presence of DATA, CLOCK, and OUTPUT signals

Description:

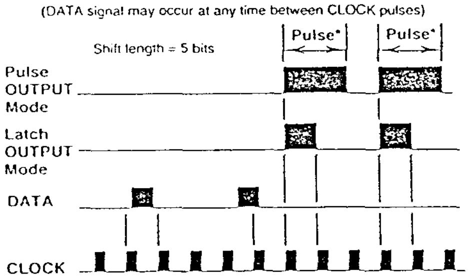
The LSR-64 and LSR-1000 are plug-in electronic shift register modules designed primarily for use with conveyors and indexing tables to coordinate the inspection of a product at one location with a desired action on that same product at a more convenient point further on down the line. The LSR-1000 is identical in performance and specifications to the LSR-64, except for its expanded shift register capacity. The LSR-64 is programmable from 1 to 64 bits; the LSR-1000 is programmable from 1 to 1024 bits.

Either externally-produced CLOCK pulses or pulses from the shift register module's own adjustable internal clock may be used to provide a time base for operation. A typical operation sequence would begin when an inspection (DATA) signal notifies the shift register module of the condition of a passing product. As the product moves on down the line, a user-programmed number of CLOCK pulses are counted. The desired action (initiated by an OUTPUT signal) occurs when the product reaches the position that corresponds to the programmed number of CLOCK pulses (called the "shift length"). The shift register module OUTPUT signal may be programmed, via easily-accessible internal DIP switches, for either an adjustable one-shot pulse (of 1.5 seconds maximum duration) or a latch condition.

The LSR-64 and LSR-1000 feature a unique "DATA Latch/No DATA Latch" mode selection switch that greatly increases their versatility and range of application (refer to the timing diagrams, below). In the "DATA Latch" mode, a momentary DATA signal that occurs between CLOCK pulses will latch data into the register until it is moved along by the next CLOCK signal. A RESET signal removes the data and empties all registers. In the DATA Latch mode, a DATA signal that is present *at any time* between adjacent CLOCK pulses is entered into the register. The "No DATA Latch" mode is particularly useful in inspection applications in which there can be a mechanical relationship between the inspection event and the CLOCK pulse, because the CLOCK pulse can also serve as an "interrogate" input for the DATA signal. This DATA signal must be present at the *leading edge* of the CLOCK signal in order to be entered into the register. DATA signals that do not overlap the leading edge of the CLOCK pulse are ignored. In the No DATA Latch mode, overlapping of the leading edge of a CLOCK pulse by the DATA signal will enter one bit into the register.

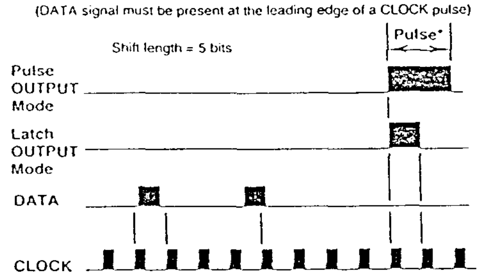
DATA Latch Mode

(DATA signal may occur at any time between CLOCK pulses)



No DATA Latch Mode

(DATA signal must be present at the leading edge of a CLOCK pulse)



*Note: length of pulse output is adjustable up to 1.5 seconds

Special Purpose Sensors & Controls

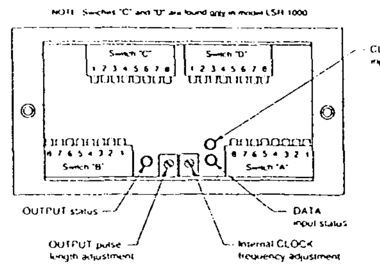
The DATA signal may be obtained from a proximity sensor, a photoelectric sensor, a mechanical limit switch or contact closure, or from the output of another Banner logic module. External CLOCK signals are typically derived from a sprocket or gear tooth mechanically coupled to conveyor motion, or from a cam switch or contact closure in indexing (intermittent motion) applications. Momentarily closing the RESET contacts (pins #3 and #4) for a minimum of 10 milliseconds empties all registers.

The LSR-64 and LSR-1000 have two output circuits: an open-collector NPN transistor capable of sinking 150mA (continuous), and a ground-isolated optical coupler (50mA dc maximum) for easy interfacing to other logic systems.

Tables 1 and 2 summarize the user-programmable variables controlled by the shift register module's internal logic DIP switches (located beneath the removeable upper cover). Note that the LSR-1000 has additional DIP switches to enable programming of its larger register capacity (see drawing, right). One-shot OUTPUT pulse duration and internal CLOCK period are adjustable at potentiometers also located beneath the cover. The presence of DATA, CLOCK, and OUTPUT signals is indicated by red LEDs, visible through the transparent cover.

The LSR-64 and LSR-1000 require 10 to 30V dc, plug into a standard octal socket, and are typically used with a Banner BRB or MRB chassis or as part of a system of other modules.

Top View of LSR Module, Cover Removed



Shift Register Module Programming

Table 1 summarizes the functions controlled by the Input and Output Logic Programming DIP switch located beneath the module top cover (see also the drawing above). Switch locations are printed on the top cover. Note: switches for latch/one-shot OUTPUT selection and long/short one-shot pulse duration (see the last two entries in Table 1) are located on the Shift Length Programming DIP switch (switch B).

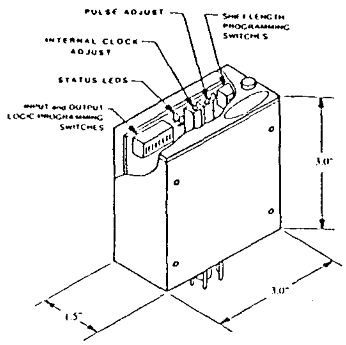
Note that the LSR-64 has two DIP switches A and B), while the LSR-1000 has four (A, B, C, and D). The LSR-1000's two

Table 1. Input and Output Logic Programming, LSR-64 and LSR-1000

Switch*	Switch "on"	Switch "off"
Switch A #1	EXTERNAL clock input (pin #5) selected	INTERNAL clock selected
Switch A #2	Data memory latch ENABLED (see text)	Data memory latch DISABLED (see text)
Switch A #3	SLOW internal clock period range selected: 50 milliseconds to 1 second *(internal potentiometer adjustment)*	FAST internal clock period range selected: 5 to 100 milliseconds *(internal potentiometer adjustment)*
Switch A #4	SLOW system response to external CLOCK signal selected: signal must be present for at least 10 milliseconds (allows use of relay closure to provide external CLOCK signal)	FAST system response to external CLOCK signal selected: signal must be present for at least 1 millisecond (allows use of logic source for external CLOCK signal)
Switch A #5	RESET signal is entered when module pin #3 is "low" (logic 0)	RESET signal is entered when module pin #3 is "high" (logic 1)
Switch A #6	DATA signal is entered when module pin #6 is "low" (logic 0)	DATA signal is entered when module pin #6 is "high" (logic 1)
Switch A #7	CLOCK signal is entered when module pin #5 is "low" (logic 0)	CLOCK signal is entered when module pin #5 is "high" (logic 1)
Switch A #8	SLOW response time to DATA signal selected: signal must be present for at least 10 milliseconds	FAST response to DATA signal selected: signal must be present for at least 1 millisecond
Switch B #A (#7 on switch B)	LATCHING output selected: if DATA signal is present, output will energize at the leading edge of the first programmed CLOCK pulse and go "off" at the leading edge of the next pulse	ONE-SHOT output selected: if DATA signal is present, output will energize for an adjustable one-shot pulse at the leading edge of the programmed CLOCK pulse *(internal adjustment, see below)*
Switch B #B (#8 on switch B)	LONG one-shot pulse duration range selected: adjustable from .05 to 1.5 seconds *(internal potentiometer adjustment)*	SHORT one-shot pulse duration range selected: adjustable from .005 to .15 seconds *(internal potentiometer adjustment)*

Special Purpose Sensors & Controls

LSR Module Dimensions



LSR-64 shown. LSR-1000 has additional SHIFT LENGTH programming switches.

additional DIP switches are required because of its expanded shift register capacity. The functions of DIP switches A and B, the three indicator LEDs, and the two internal multi-turn potentiometers are the same in both models.

Table 2 gives shift programming information for LSR modules. *As viewed from the top of the module, pressing the upper end of a DIP switch rocker down turns it "on"; pressing the lower end down turns it "off".*

Table 2. Shift Length Programming, models LSR-64 and LSR-1000

LSR-64 and LSR-1000: any combination of the switches on DIP switch B may be "on".

B #1 on = 1 bit	B #7 (see Table 1)
B #2 on = 2	B #8 (see Table 1)
B #3 on = 4	
B #4 on = 8	
B #5 on = 16	
B #6 on = 32	

LSR-1000 only: one (and only one) of the switches on DIP switches C and D may be "on".

C #1 on = B + 0	D #1 on = B + 512
C #2 on = B + 64	D #2 on = B + 576
C #3 on = B + 128	D #3 on = B + 640
C #4 on = B + 192	D #4 on = B + 704
C #5 on = B + 256	D #5 on = B + 768
C #6 on = B + 320	D #6 on = B + 832
C #7 on = B + 384	D #7 on = B + 896
C #8 on = B + 448	D #8 on = B + 960

Shift length for the LSR-64 is equal to the sum of the B switches plus 1.

Shift length for the LSR-1000 is equal to the sum of the B switches plus 1 plus any *one* of the C *or* D switches.

Shift length programming examples:

10 = B4 + B1 (8+1+1)
50 = B6 + B5 + B1 (32 + 16 + 1 + 1)
500 = C8 + B6 + B5 + B2 + B1 (448 + 32 + 16 + 2 + 1 + 1)

Voltage requirements:
10 to 30V dc at less than 40mA (exclusive of load). Power may be supplied by Banner power supply model PS120-15, or by a type MRB chassis (with PS15-1 module, or with any B or MB Series module). Note: when the LSR-64 or LSR-1000 is the only module used in an MRB chassis, a 500 mfd. (50V dc) capacitor must be installed across the secondary of the transformer (pins #4 and #7 of the power supply module) to provide adequate filtering.

Outputs: Two outputs are provided:

1) One open-collector NPN transistor (normally open) with continuous short-circuit protection, capable of sinking 150 milliamps continuously. *On-state saturation voltage* is less than 1 volt at full load and less than 0.2 volts at signal levels. *Off-state leakage current* is less than 100 microamps.

2) One ground-isolated optical coupler (normally open) capable of conducting up to 50mA dc (may not be used to switch ac) at applied voltages of up to 30V dc. *On-state saturation voltage* is less than 1V dc at signal levels. *Off-state leakage current* is less than 10 microamps.

Inputs:
Inputs for DATA, external CLOCK, and RESET signals may be derived from a switch or contact connected between the appropriate input and dc common (pin #4 of the LSR module), or from logic level signals. A logic "low" must be less than 2V dc; a logic "high" must be an open circuit or a voltage greater than 6V dc. The input circuit must be capable of sinking 4 milliamps. Momentarily grounding the RESET terminal (pin #3 of the LSR module) empties all registers. The LSR module is automatically reset whenever power to the module is switched "off" and "on".

Programming and adjustments:
Input and output logic and shift length are programmed by setting the appropriate combination of DIP switch positions inside the module (see Tables 1 and 2). These switches are easily accessed by removing the module top cover. Shift length may be any number from 1 to 64 (for model LSR-64) or from 1 to 1024 (for model LSR-1000). *Actual shift length is equal to the number of bits set plus one.*

In addition to the DIP switches, two multi-turn clutched potentiometers are located beneath the module top cover:

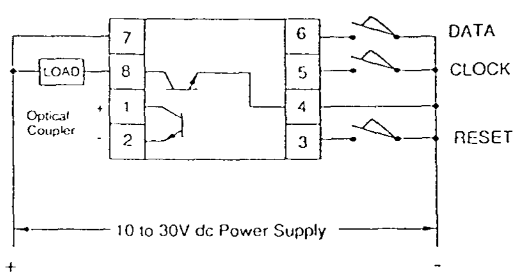
1) OUTPUT pulse length adjustment (adjustable up to 1.5 seconds)
2) Internal CLOCK period adjustment (adjustable up to 1 second)

Indicators:
LED indicators are provided for the DATA input (lights when a DATA signal occurs), CLOCK input (lights when a CLOCK signal input occurs, and OUTPUT (lights as long as either output is conducting).

Operating temperature: 0 to 50°C (32 to 122°F)

Construction:
3.0 x 3.0 x 1.5-inch plug-in module with standard octal base. NEMA-1 rated anodized aluminum enclosure.

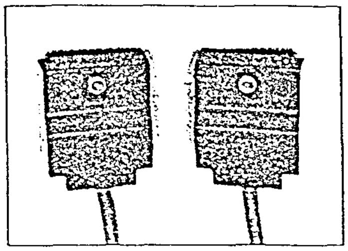
Generalized Hookup Diagram



See specifications above for input and output requirements.

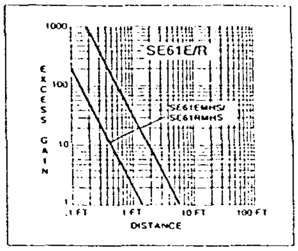
ECONO-BEAM Miniature Self-contained DC Sensors

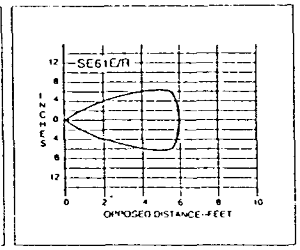
Sensing Mode	*Models*	*Excess Gain*	*Beam Pattern*



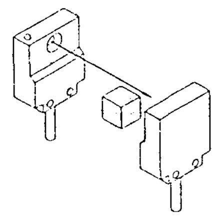
SE61E & SE61R

Voltage: 10 to 30V dc
Range: 6 feet (1,8 m)
Response: 10 ms on/off
Beam: infrared, 880nm
Effective beam: .12" dia.
Indicator LED: on SE61R only. LED is ON when SE61R senses modulated light from SE61E.



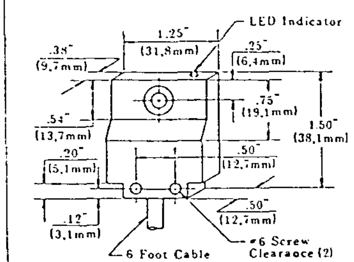


OPPOSED MODE

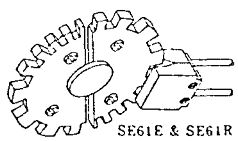


Outputs: SE61R has bipolar outputs: one open-collector NPN (current sinking) and one open-collector PNP (current sourcing) transistor solid-state dc switch, each rated for 150mA maximum (both may be used at the same time). Both outputs conduct when SE61R senses modulated light from SE61E (light operate). Dark operate model SE61-RNC is available by special order (see "ECONO-BEAM Modifications"). **NOTE: discontinued Banner SM61 series emitters and receivers are compatible with the SE61 series emitters and recievers.**

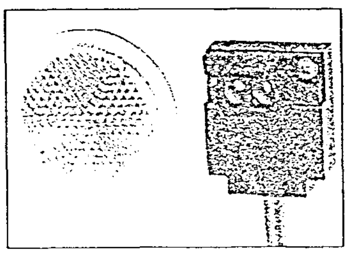
Dimension Drawing
models SE61E & SE61R



Due to their small size, right-angle design, and unique shape, the ECONO-BEAM opposed mode sensor pair is ideal for mounting against the side rails of conveyors for use in flow control and product sensing, and are an excellent choice for use on supermarket checkout stands. They may be bolted together, directly face-to-face, to form a powerful slot sensor for edgeguiding of opaque materials or for sensing gear teeth, timing rings, or "flags" (see diagram at left). In this slot-sensor configuration, they have enough excess gain to operate even in the dirtiest sensing environments. Special order models SE61EMHS and SE61RMHS are available with 1 millisecond response, and with a range of 1-1/2 feet (1/16th the amount of available excess gain).

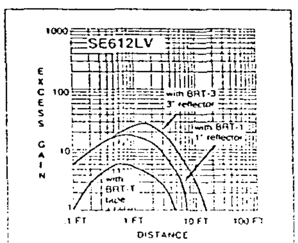


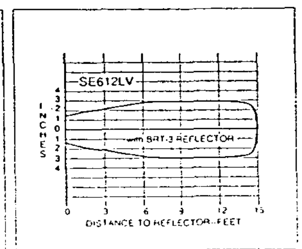
SE61E & SE61R
USED AS A SLOT SENSOR



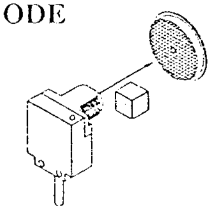
SE612LV

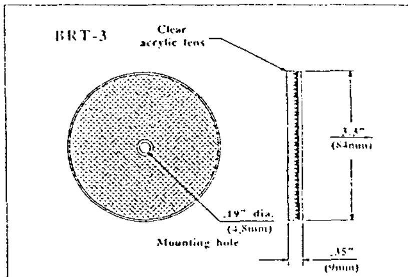
Voltage: 10 to 30V dc
Range: 15 feet (5 m) with BRT-3 reflector
Response: 10 ms on/off
Beam: visible red, 650nm
Outputs: conduct when SE612LV senses its own modulated light (light operate). Dark operate model SE612LVNC is available by special order.





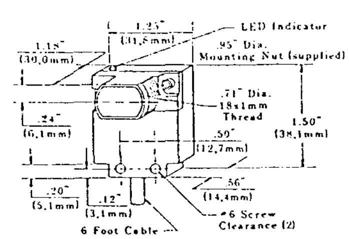
RETROREFLECTIVE MODE



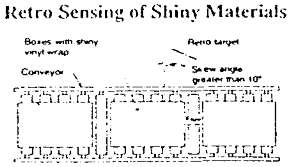


For detailed information on retroreflective target materials, see pages 279-280.

Dimension Drawing,
model SE612LV



Retro Sensing of Shiny Materials

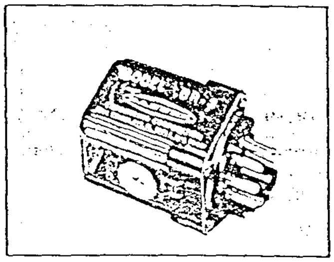


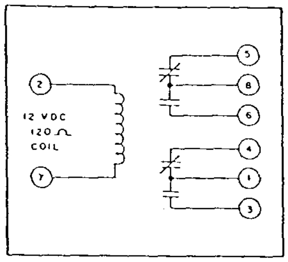
The 1/2" diameter effective beam of retroreflective model SE612LV, measured at 1 foot from the lens, makes it a good choice for sensing relatively small objects when opposed sensing is not possible. The visible beam makes alignment to the retroreflective target very easy. Use as large a retroreflective target area as possible. If sensing materials which have highly reflective (shiny) surfaces, scan at an angle of at least 10 degrees to the shiny surface to minimize false light return ("proxing" effect).

Special Purpose Sensors & Controls

Output Devices

The devices listed on pages 277 and 278 allow sensors and amplifiers to interface to loads for which they are not otherwise suited. Dimensions of all output devices (except model BTR-10) are 1.4" x 1.4" x 2.2" (x 2.8" including base/plug).

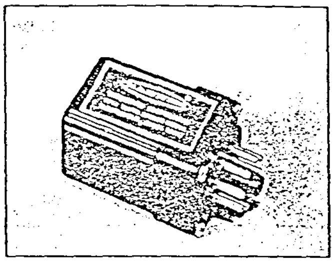


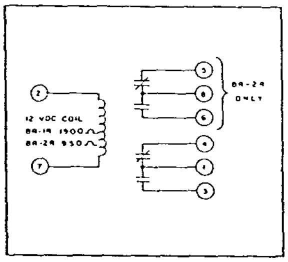


BR-2 DPDT relay

Model BR-2 is a double-pole double-throw plug-in relay. Contact rating is 10 amps at 120V ac (or 1/6 HP). Mechanical life is 10,000,000 cycles; life at full rated load is 300,000 cycles. Maximum operate time is 15 milliseconds; maximum release time is 20 milliseconds. Contacts are gold-flashed silver and cadmium oxide. Standard male octal base. The BR-2 is supplied as standard equipment with BRB and MRB control chassis.

NOTE: Relay contacts "bounce" many times while closing. Special precautions must be taken when using contacts or limit switches as inputs in counting, latching, or one-shot circuits.

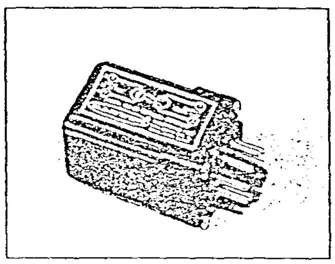


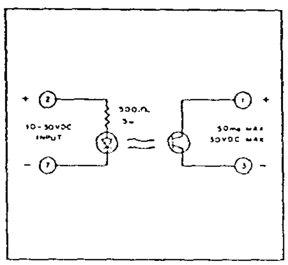


BR-1R and BR-2R reed relays

Models BR-1R and BR-2R are SPDT and DPDT (respectively) dry reed relays for use where fast response time and long life are important, such as in computer or logic interfaces. They are not for use with inductive loads such as solenoids or other relays.

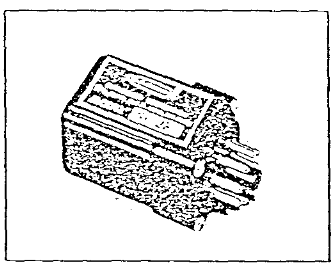
Response time is less than 1 millisecond. Contacts are rated for 110V ac maximum or 30V dc maximum. Total load power (volts x amps) may not exceed 30 VA. Life expectancy is 100,000,000 cycles at signal levels and 10,000,000 cycles at full load. The BR-1R and BR-2R have a standard male octal base.

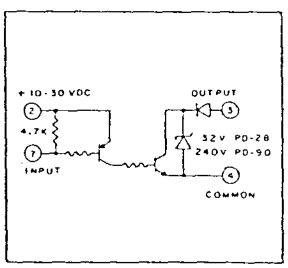




OC-12 optical coupler

Model OC-12 is an optical coupler used to interface the outputs of amplifiers and amplified scanners to other logic systems, particularly computers, programmable controllers, solid-state totalizers, preset counters, speed controls, and other controls that must be isolated from ground. The output of the OC-12 is a phototransistor capable of conducting up to 50 mA dc at applied voltages of up to 30V dc. The OC-12 may not be used with ac. Response time is less than 100 microseconds. Life is infinite. ON state saturation voltage is less than 1V dc; OFF state leakage current is less than 10 microamps. Base is standard male octal.

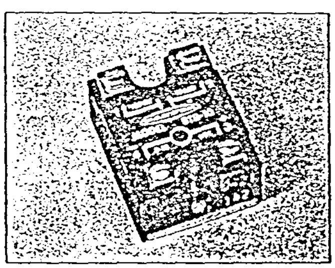


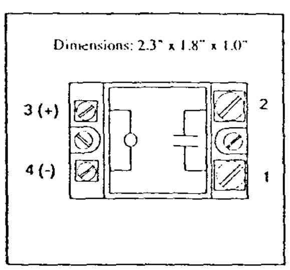


PD-28 and PD-90 dc solid-state relays

Models PD-28 and PD-90 are solid-state relays for dc-only loads such as solenoids, clutches, and brakes. The PD-28 can operate at up to 30V dc and .75 amps maximum, the PD-90 at up to 200V dc and .25 amps maximum. The power must be supplied by the customer, and must have its negative side common to ground.

Response time is less than 1 millisecond, and life is infinite. OFF state leakage current is less than 10 microamps. The PD-28 and PD-90 have a standard male octal base.





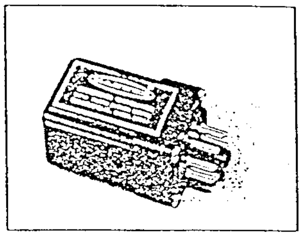
BTR-10 ac solid-state relay

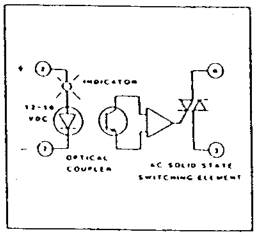
Model BTR-10 is a normally open ac solid-state relay for use with 120V ac loads up to 10 amps. There is complete, optically-coupled isolation between input and output. In order to minimize electrical noise, turn-on and turn-off take place at the zero crossing of the ac power.

Maximum inrush current is 35 amps for 1 second. Response time (on and off) is 8.5 milliseconds. The BTR-10 is energized by 3-32V dc.

Special Purpose Sensors & Controls

Output Devices

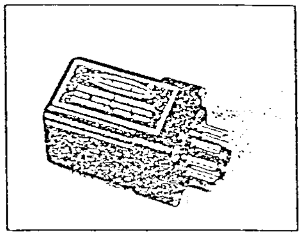


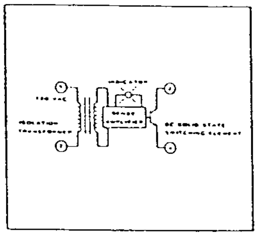


BTR-1A ac output module

Model BTR-1A is an optically-coupled, solid-state relay capable of driving 120V ac loads of up to 1 amp. The input is driven by logic levels of 12 to 18V dc. An indicator LED shows that the output is energized. The output has an inrush capability of 10 amps and an off-state leakage current of less than 100 microamps. This permits the BTR-1A to interface most programmable controllers directly. The BTR-1A has a standard male octal base.

Response time is 1 millisecond ON and 8.3 milliseconds OFF.



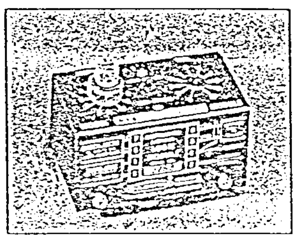


OC-120 ac input module

Model OC-120 converts a 120V ac signal to an isolated dc solid-state switching transistor. It is used when it is necessary to monitor ac loads and use the ac voltage as an input to a solid-state logic system such as the LIM-2, LSR64, LSR1000, or programmable controllers with dc input interfaces. Unlike some other interfaces, the OC-120 does not require any source of dc power.

The output can conduct up to 50 milliamps at applied voltages up to 30V dc. Response time is 15 milliseconds ON, 15 milliseconds OFF. The OC-120 has a standard male octal base.

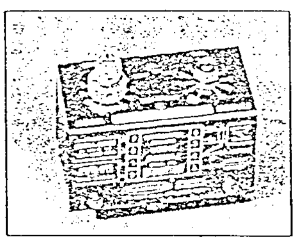
Amplifiers



B3-4 on/off amplifier

Model B3-4 is a high-sensitivity on/off amplifier whose output "follows the action" of the input signal. This amplifier is designed for operation with non-modulated remote sensors such as the model LP510CV. A diagram on page 269 shows the appropriate hookup for a model LP510CV to a B3-4 amplifier module. NOTE: With non-modulated sensors, care must be taken so that ambient light does not interfere with amplifier operation. The B3-4 has a standard male octal base.

Dimensions: 3.8" x 2.0" x 2.0"



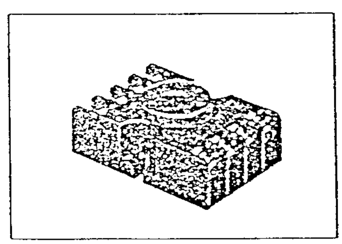
B4-6 ac-coupled amplifier

Model B4-6 is an ac-coupled amplifier used to detect very small signal changes. A typical application is register mark sensing using fiber optics and the model FO2BG fiber optic interface. The B4-6 is also used with the SM53E/SM53R opposed mode "flat pack" sensor combination (information and hookup for these sensors appear on page 186). Response time of this amplifier is 1 millisecond. Grounding pin #3 inhibits operation of these modules. NOTE: Objects must be moving at a rate of at least 1 inch per second to be detected reliably by the B4-6. The B4-6 has a standard male octal base.

Dimensions: 3.8" x 2.0" x 2.0"

OS-8 female octal (8-pin) socket

Model OS-8 is a keyed female octal (8-pin) socket that may be used with any 8-pin module or amplifier described in this catalog section. The OS-8 has lift-up pressure-plate type terminals to simplify wiring.

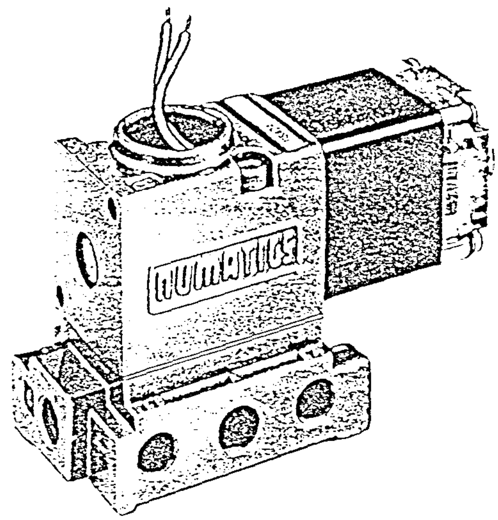


NUMATICS®
MARK 7 LINE

DESCRIPTION

MARK 7 valves are a series of heavy duty, multi-purpose, 4-way, 5-ported power valves tapped 1/8 NPTF or 1/4 NPTF. Metric ports are available. They are direct solenoid actuated valves. Valves may be mounted on individual sub-bases or on FlexiBlok manifold mountings and may be mounted in any position.

Regulators and various options are available (See pages 21 and 22).



OPERATING DATA

AIR PRESSURE RANGE: 28" Hg. vacuum to 150 PSIG (for pressures over 150 to a maximum 300 PSIG, consult factory).

TEMPERATURE RANGE: -10° F to +115° F ambient.

SERVICE: Valves can be used on the following properly filtered media:

Lubricated air, dry (oil-free) air, vacuum, and noncorrosive, nontoxic, nonflammable dry gases. See Numatics' Engineering and Technical Data for a list of recommended lubricants and filtration requirements for unlubricated service.

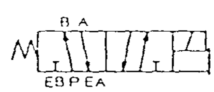
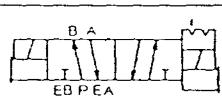
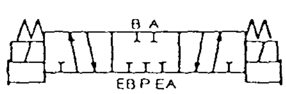
FLOW CAPACITY: MARK 7 valves have Cv of 0.4. See Numatics' Engineering and Technical Data For complete flow chart.

ELECTRICAL SPECIFICATIONS

Solenoids: All solenoids are continuous duty rated for dual Hz operation. Standard A.C. voltages are 100-115/50; 110-120/60 or 200-230/50; 220-240/60. 24/50/60 is available on special order. 12VDC and 24VDC are standard.

	Inrush current (amps)	Holding Current (amps)	D.C. Watts, Inrush and holding, All Voltages (max)	Time to Energize (Seconds)	Time to de-energize (Seconds)
120/60	.40	.09	-	.012	.018
12VDC	.50	.50	6.0	.032	.012
24VDC	.25	.25	6.0	.032	.012

MODEL SELECTION CHART

BASIC MODEL NUMBER	A.N.S.I. SYMBOLS
11SAD4	
11DSA4	
11DSA5	
11DSA6	

NOTE: Ports are available tapped G 1/8 or G 1/4.

MOUNTING MEANS
Add to the basic model number listed.

- 00 = Valve Unit Only (No Base)
- 01 = Valve Unit with Speed Control
- 02 = Valve unit Only with Extra Long Screws
- 11 = miniBlok, Side Ports
- 15 = miniBlok, Side and Bottom Ports
- 21 = miniBlok No. 11 with Speed Control
- 25 = miniBlok No. 15 with speed Control
- 41 = Individual Base, Side Ports - 1/8 NPTF
- 43 = Individual Base, Side and Bottom Ports - 1/8 NPTF
- 44 = Individual Base, Side Ports, Common Exhaust - 1/8 NPTF
- 46 = Base No. 41 with Speed Control
- 48 = Base No. 43 with Speed Control
- 49 = Base No. 44 with Speed Control
- 54 = Individual Base, Side and Bottom Ports, Common Exhaust - 1/8 NPTF
- 55 = Base No. 54 with Speed Control
- 4A = Individual Base, Side Ports - 1/4 NPTF
- 4B = Individual Base, Side & Bottom Ports - 1/4 NPTF
- 4C = Base No. 4A with Speed Control
- 4D = Base No. 4B with Speed Control

WIRING OPTIONS
Add to the mounting means selected.
Specify volts and hertz.

- O = Hardwired, Standard A.C., Volts and Hertz
- B = Hardwired, Standard D.C., (12 and 24 VDC)
- C = Plug-In, Standard A.C., Volts and Hertz
- E = Plug-In, Standard D.C., (12 and 24 VDC)

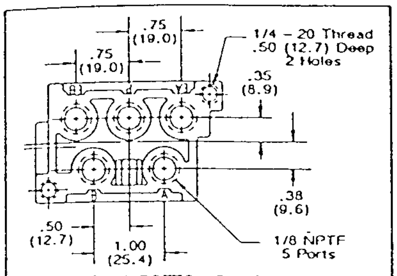
(See page 21)

Top Dimension = Inches
Bottom Dimension
(In Parentheses) = Millimeters

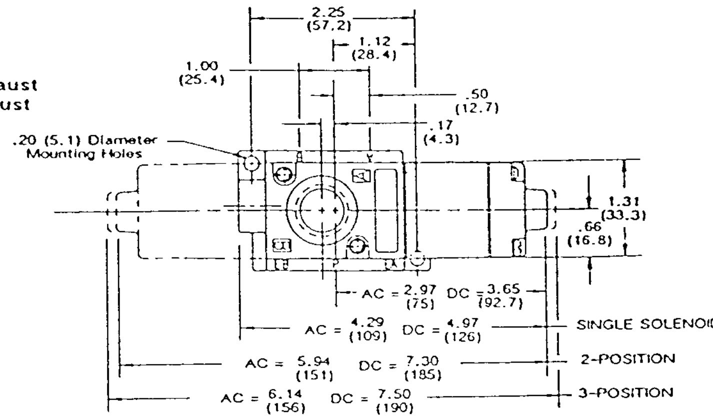
VALUE AND BASE DIMENSIONS AND PART NUMBERS

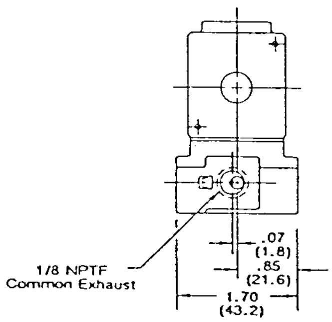
1/8 NPTF BASE

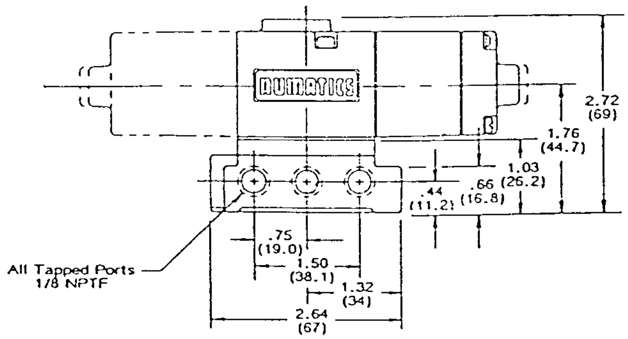
103-165B Side Ports, Individual Exhaust
103-166B Side Ports, Common Exhaust
203-154A Side and Bottom Ports, Individual Exhaust
203-155A Side and Bottom Ports, Common Exhaust



OPTIONAL BOTTOM PORT LOCATIONS

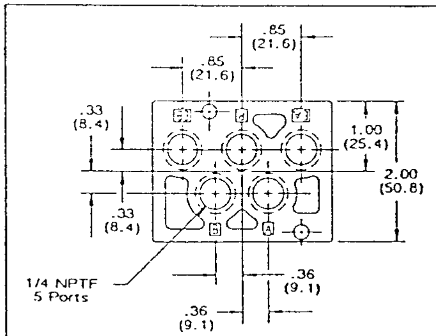




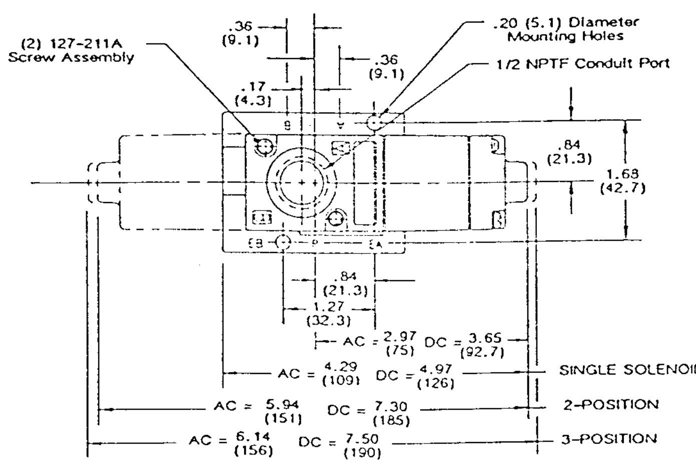


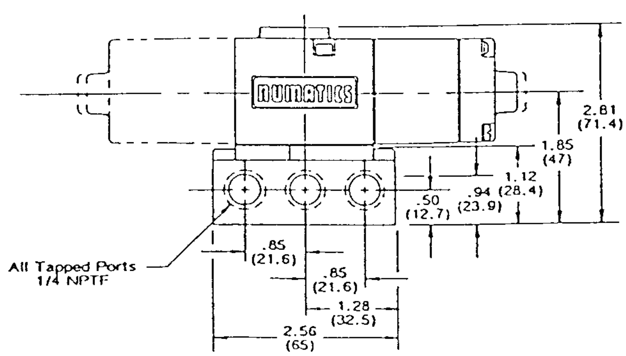
OPTIONAL 1/4 NPTF BASE

103-397B Side Ports
203-340A Side and Bottom Ports



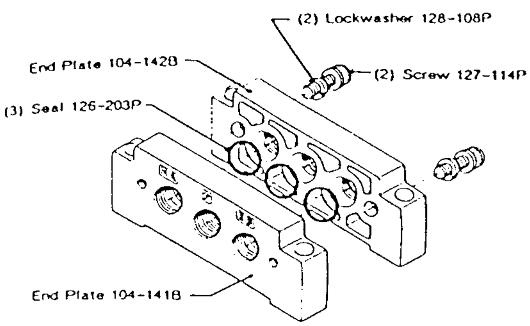
OPTIONAL BOTTOM PORT LOCATIONS



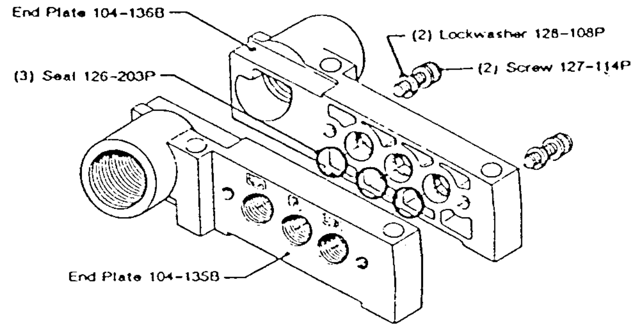


SERVICE PARTS		
SERIES	REPAIR KIT	SLEEVE ASSEMBLY
11SAD4	MK7-K1	209-135A
11DSA4	MK7-K2	209-136A
11DSA5	MK7-K3	209-244A
11DSA6	MK7-K3	209-245A

BASIC END PLATE KIT No. 229-311A
(For use on assemblies without conduit cover.)

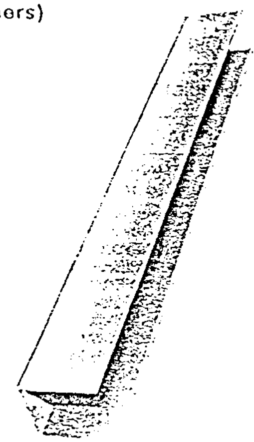


CONDUIT END PLATE KIT No. 229-309A
(For use on assemblies with conduit cover.)

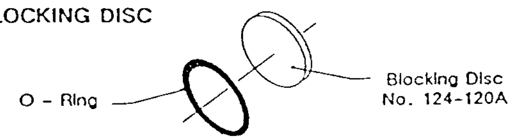


CONDUIT COVER ASSEMBLY
(Includes Screws and Washers)

1	Station	229-315A
2	Station	229-316A
3	Station	229-317A
4	Station	229-318A
5	Station	229-319A
6	Station	229-320A
7	Station	229-321A
8	Station	229-322A
9	Station	229-323A
10	Station	229-324A
11	Station	229-325A
12	Station	229-326A
13	Station	229-327A
14	Station	229-328A
15	Station	229-329A

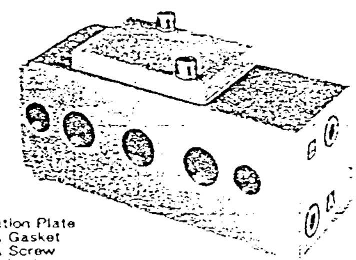


BLOCKING DISC



Used to block the P gallery to permit, for example, a different pressure to be supplied to either end of the FlexiBlok Assembly.

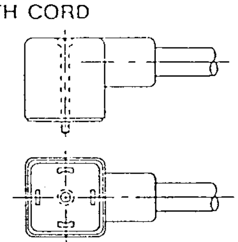
BLANK STATION PLATE KIT - 229-314A



Includes:
(1) Blank Station Plate
(1) 113-175A Gasket
(2) 127-218A Screw
(2) 128-144P Lockwasher

Block Not Included

SUPERSTRUCTURE PLUG WITH CORD
(Per DIN spec. No. 43650)

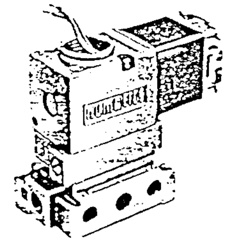


For Plug-In Solenoids.
Options C and E. Order Cord Assembly Separately.

Plug w/4' Cord, No. 230-213A
Plug w/6' Cord, No. 230-215A

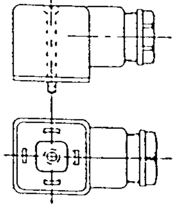
SPEED CONTROL KIT NO. 229-310A

The MARK 7 Speed Control Kit mounts between any MARK 7 line valve and any base or FlexiBlok mounting means. The EB and EA ports of this unit contain needle valves which can be adjusted to throttle the flow of exhaust air out of the valve unit. Thus, the speeds of the two strokes of a cylinder piston can be adjusted independently. the needle valves are vibration proof, nylon locking units. the kit adds .59" (15.0 mm) to the overall height of any assembly.



Includes:
Speed Control
(1) 113-175B Gasket
(3) 127-212A Screw Ass'y.

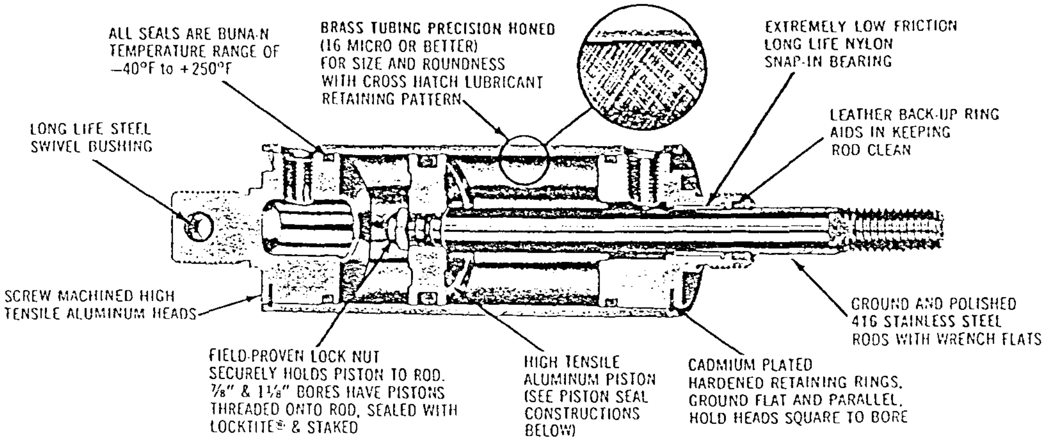
PLUG ASSEMBLIES FOR WIRING OPTIONS C AND E ACCEPTS CABLE DIA. .310 TO .410
(Per DIN spec No. 43650)



PART NO	DESCRIPTION
230-369A	Grey (A) Plug. Ass'y.
230-370A	Black (B) Plug Ass'y.
230-371A	Plug with 24VDC Light
230-372A	Plug with 110VAC Light
230-373A	Plug with 220VAC Light

CYLINDERS
ALLENAIR CORPORATION

DESIGN FEATURES & MATERIALS



STANDARD STROKE LENGTHS: WHOLE-INCH INCREMENTS FROM 1" THROUGH 20" AND ½", 1½", 2½" & 3½".
SPECIAL STROKES AVAILABLE FROM ⅛" TO 130".

BASIC CONSTRUCTION (DOUBLE ACTING)

TYPE A SINGLE ENDED

All Type "A" Cylinders, with the exception of the 4" bore, are constructed using "O"-Ring Seals. The 4" bore uses "O"-Ring Rod Seals and "U" Cup Piston Seals. These all-purpose units are used for most pneumatic applications. Optional Double Rod Packings are recommended for heavy duty and hydraulic applications.

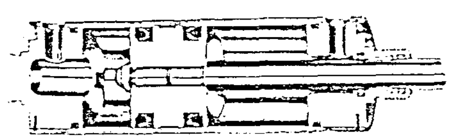
Pressure Rating: 150 P.S.I. Pneumatic, 350 P.S.I. Hydraulic.
Breakaway: Approximately 5-8 P.S.I.
Bore Sizes Available: ⅞", 1⅛", 1½", 2", 2½", 3" & 4".

FOR DIMENSIONS & MOUNTS SEE PAGES 10 THROUGH 14

TYPE C SINGLE ENDED

Type "C" Cylinders are constructed using low friction "U" Cup Seals and include a wear strip on the piston. These Cylinders are primarily used on low pressure applications and where low minimum breakaway is required.

Pressure Rating: 150 P.S.I. Pneumatic only.
Breakaway: Approximately 2-3 P.S.I.
Bore Sizes Available: ⅞", 1⅛", 1½", 2", 2½", 3" & 4".

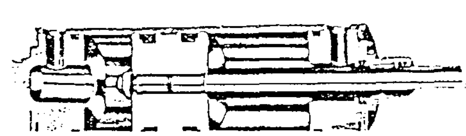


FOR DIMENSIONS & MOUNTS SEE PAGES 10 THROUGH 14

TYPE E SINGLE ENDED

Type "E" Cylinders are constructed using Block-Vee Seals and include double rod seals in the front head. A heavy duty wear strip (bearing) on the piston minimizes friction and piston seal wear, and on side load conditions prevents metal-to-metal contact. These Cylinders are generally used on low pressure hydraulics and where side load conditions are present.

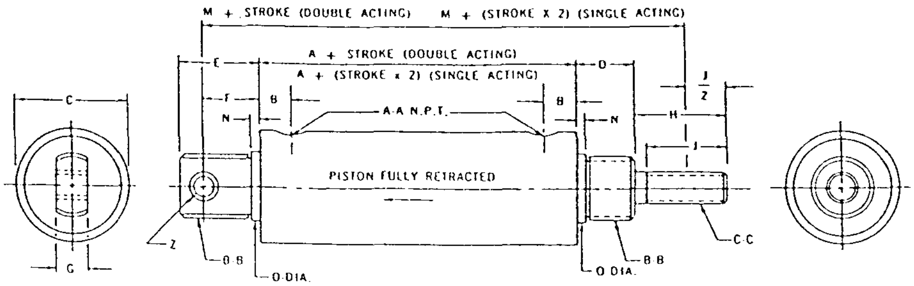
Pressure Rating: 200 P.S.I. Pneumatic, 500 P.S.I. Hydraulic.
Breakaway: Approximately 10-15 P.S.I.
Bore Sizes Available: ⅞", 1⅛", 1½", 2", 2½", 3" & 4".
5" BORE AVAILABLE—Consult Factory for Details.



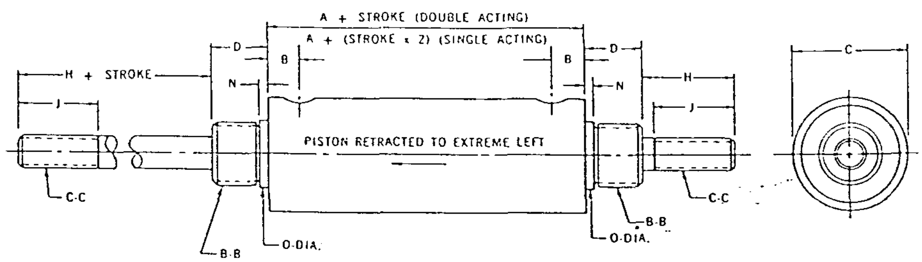
FOR DIMENSIONS & MOUNTS SEE PAGES 10 THROUGH 14

CYLINDERS DIMENSIONS

TYPES A C E SINGLE ENDED



TYPES AD CD ED DOUBLE ENDED



CYL. BORE SIZES	A TYPE A	A TYPES C & E	B	C	D Std	D OS (Front only)	E	F	G	H	J	M TYPE A Std	M TYPE A OS	M TYPES C & E Std	M TYPES C & E OS	N	O Std	O OS (Front only)	Z
7/8"	2 1/16	3 1/16	3/8	1 1/8	5/8	X	1"	11/16	3/8	1"	7/8	3 15/16	X	4 15/16	X	1/8	3/4	X	1/4
☆ 1 1/8"	2 1/16	3 1/16	3/8	1 3/8	5/8	5/8	1"	11/16	3/8	1"**	7/8**	3 15/16	4 1/8	4 15/16	5 1/8	1/8	3/4***	7/8	1/4
1 1/2"	2 5/8	3 5/8	1/2	1 3/4	7/8	7/8	1 1/4	7/8	1/2	1 7/16	1 1/4	5 3/16	5 3/16	6 3/16	6 3/16	3/16	1 1/16	1 1/16	5/16
2"	2 5/8	3 5/8	1/2	2 1/4	7/8	7/8	1 1/4	7/8	1/2	1 7/16	1 1/4	5 3/16	5 3/16	6 3/16	6 3/16	3/16	1 1/16	1 3/8	5/16
2 1/2"	2 7/8	3 7/8	9/16	2 3/4	1"	1"	2"	1 3/8	5/8	1 11/16	1 1/2	6 3/16	6 3/16	7 3/16	7 3/16	1/4	1 3/8	1 1/2	7/16
3"	2 7/8	3 7/8	9/16	3 1/4	1"	1"	2"	1 3/8	5/8	1 11/16	1 1/2	6 3/16	6 3/16	7 3/16	7 3/16	1/4	1 3/8	1 1/2	7/16
4"	*4 7/8	*4 7/8	13/16	4 3/8	1 1/8	1 7/8	2 3/16	1 7/16	3/4	2 1/4	1 7/8	9 1/4	10"	9 1/4	10"	3/16	1 3/4	2 1/4	1/2

CYL. BORE SIZES	A-A	B-B Std	B-B OS (Front only)	C-C Std	C-C OS	ROD DIA. Std	ROD DIA. OS
7/8"	1/8	3/4-16	X	3/8-16	X	3/8	X
1 1/8"	1/8	3/4-16***	7/8-14	3/8-16	1/2-13	3/8	1/2
1 1/2"	1/4	1" -14	1" -14	1/2-13	5/8-11	1/2	5/8
2"	1/4	1" -14	1 3/8-12	5/8-11	3/4-10	5/8	3/4
2 1/2"	3/8	1 3/8-12	1 1/2-12	3/4-10	1" -14	3/4	1"
3"	3/8	1 3/8-12	1 1/2-12	3/4-10	1" -14	3/4	1"
4"	1/2	1 3/4-12	2 1/4-12	1" -14	1 1/4-12	1"	1 1/4

NOTES:

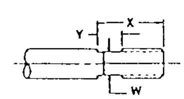
*5 3/8 on Single Ended Cylinders having tail section, except types AN, CN & EN.

**On Oversize Models, H = 1 3/8 & J = 1 1/4.

***3/4-16 Both ends on Types "A" & "E". 3/4-16 Rear and 7/8-14 Front on Type "C".

Omit dimension E when laying out Cylinder with tail section omitted. N dimension remains except on 7/8", 1 1/8" and 4" bores.

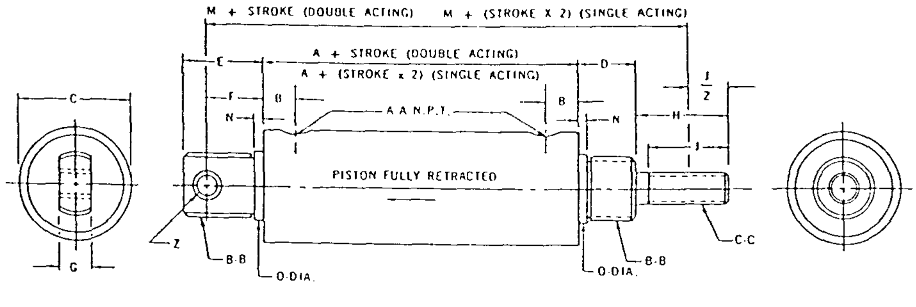
STANDARD WRENCH FLATS



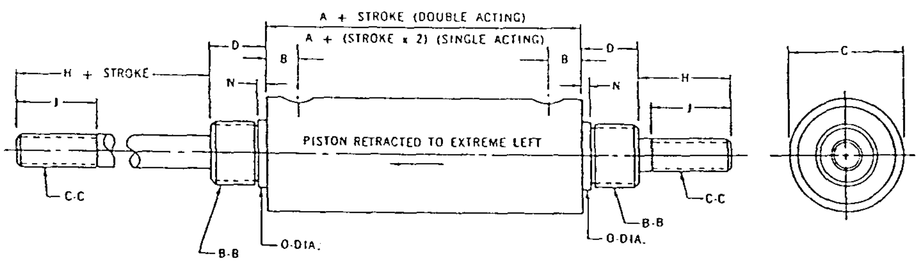
ROD DIA.	W	X	Y
3/8"	5/16	15/16	5/16
1/2"	7/16	1 3/8	5/16
5/8"	1/2	1 3/8	5/16
3/4"	5/8	1 5/8	5/16
1"	7/8	2 1/8	3/8
1 1/4"	1 1/8	2 1/8	3/8

CYLINDERS DIMENSIONS

TYPES A C E SINGLE ENDED



TYPES AD CD ED DOUBLE ENDED



CYL. BORE SIZES	A		B	C	D		E	F	G	H	J	M				N	O		Z
	TYPE A	TYPES C & E			Std	OS (Front only)						TYPE A		TYPES C & E			Std	OS (Front only)	
												Std	OS	Std	OS				
7/8"	2 3/16	3 1/16	3/8	1 1/8	5/8	X	1"	11/16	3/8	1"	7/8	3 15/16	X	4 15/16	X	1/8	3/4	X	1/4
1 1/8"	2 3/16	3 1/16	3/8	1 3/8	5/8	5/8	1"	11/16	3/8	1"**	7/8**	3 15/16	4 1/8	4 15/16	5 1/8	1/8	3/4***	7/8	1/4
1 1/2"	2 5/8	3 5/8	1/2	1 3/4	7/8	7/8	1 1/4	7/8	1/2	1 7/16	1 1/4	5 3/16	5 3/16	6 3/16	6 3/16	3/16	1 1/16	1 1/16	5/16
2"	2 5/8	3 5/8	1/2	2 1/4	7/8	7/8	1 1/4	7/8	1/2	1 7/16	1 1/4	5 3/16	5 3/16	6 3/16	6 3/16	3/16	1 1/16	1 3/8	5/16
2 1/2"	2 7/8	3 7/8	9/16	2 3/4	1"	1"	2"	1 3/8	5/8	1 11/16	1 1/2	6 3/16	6 3/16	7 3/16	7 3/16	1/4	1 3/8	1 1/2	7/16
3"	2 7/8	3 7/8	9/16	3 1/4	1"	1"	2"	1 3/8	5/8	1 11/16	1 1/2	6 3/16	6 3/16	7 3/16	7 3/16	1/4	1 3/8	1 1/2	7/16
4"	*4 7/8	*4 7/8	13/16	4 3/8	1 1/8	1 7/8	2 3/16	1 7/16	3/4	2 1/4	1 7/8	9 1/4	10"	9 1/4	10"	3/16	1 3/4	2 1/4	1/2

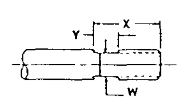
CYL. BORE SIZES	A-A	B-B		C-C		ROD DIA.	
		Std	OS (Front only)	Std	OS	Std	OS
7/8"	1/8	3/4-16	X	3/8-16	X	3/8	X
1 1/8"	1/8	3/4-16***	7/8-14	3/8-16	1/2-13	3/8	1/2
1 1/2"	1/4	1" -14	1" -14	1/2-13	5/8-11	1/2	5/8
2"	1/4	1" -14	1 3/8-12	5/8-11	3/4-10	5/8	3/4
2 1/2"	3/8	1 3/8-12	1 1/2-12	3/4-10	1" -14	3/4	1"
3"	3/8	1 3/8-12	1 1/2-12	3/4-10	1" -14	3/4	1"
4"	1/2	1 3/4-12	2 1/4-12	1" -14	1 1/4-12	1"	1 1/4

NOTES:

*5 3/8 on Single Ended Cylinders having tail section, except types AN, CN & EN.
**On Oversize Models, H = 1 3/8 & J = 1 1/4.
***3/4-16 Both ends on Types "A" & "E".
3/4-16 Rear and 7/8-14 Front on Type "C".

Omit dimension E when laying out Cylinder with tail section omitted. N dimension remains except on 7/8", 1 1/8" and 4" bores.

STANDARD WRENCH FLATS



ROD DIA.	W	X	Y
3/8"	5/16	15/16	5/16
1/2"	7/16	1 3/8	5/16
5/8"	1/2	1 3/8	5/16
3/4"	5/8	1 5/8	5/16
1"	7/8	2 1/8	3/8
1 1/4"	1 1/8	2 1/8	3/8

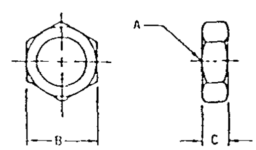
CYLINDERS MOUNTING BRACKETS & DIMENSIONS

CYL. BORE SIZES	FOOT STD	FOOT OS** (Front Only)	FLANGE STD	FLANGE OS** (Front Only)	ROD CLEVIS, NUT & PIN STD	ROD CLEVIS, NUT & PIN OS	ROD NUT ONLY STD	ROD NUT ONLY OS	SWIVEL BRACKET & PIN	TRUNNION	BLOCK MOUNT	MOUNTING NUTS STD	MOUNTING NUTS OS** (Front Only)
7/8"	132	X	129	X	145	X	126	X	139	T-7/8	BM-7/8	A-114	A-114
1 1/8"	132*	132-OS	129*	129-OS	145	1545	126	1526	139	T-1	BM-1	A-114*	A-114-OS
1 1/2"	232	232	229	229	1545	245	1526	226	239	T-1.5	BM-1 1/2	A-214	A-214
2"	232	232-OS	229	229-OS	245	345	226	326	239	T-2	BM-2	A-214	A-314
2 1/2"	332	332-OS	329	329-OS	345	445	326	426	339	T-2.5	X	A-314	A-314-OS
3"	332	332-OS	329	329-OS	345	445	326	426	339	T-3	X	A-314	A-314-OS
4"	432	432-OS	429	429-OS	445	445-OS	426	526	439	T-4	X	A-414	A-414-OS

*1 1/8" bore Type "C" Cylinders require OS Mount or Mounting Nut on front and standard on rear.
**All Single Ended OS Cylinders take standard Mounts or Mounting Nuts on rear end.

MOUNTING NUTS

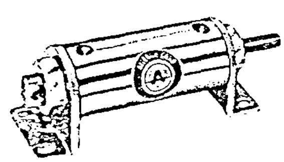
Mounting Nuts are supplied only with Flange or Foot Mounts and are included in the price of those Mounts. However, they may be purchased as a separate item.

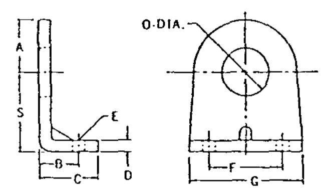


PART No.	A	B	C
A-114	3/4-16	1 1/16	3/8
A-114-OS	7/8-14	1 1/2	25/64
A-214	1"-14	1 1/2	1/2
A-314	1 3/8-12	1 3/4	5/8
A-314-OS	1 1/2-12	1 13/16	5/8
A-414	1 3/4-12	2 1/4	3/4
A-414-OS	2 1/4-12	3.0	1"

MOUNTING BRACKET DIMENSIONS

FOOT MOUNT





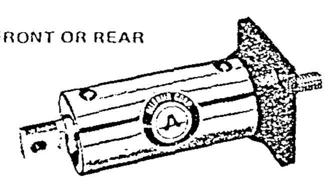
DIM.	132 STD	132 OS	232 STD	232 OS	332 STD	332 OS	432 STD	432 OS
A	11/16	11/16	1 1/8	1 1/8	1 3/8	1 3/8	1 7/8	1 7/8
B	7/8	7/8	7/8	7/8	1 1/4	1 1/4	1 3/4	1 3/4
C	1 3/8	1 3/8	1 9/32	1 9/32	1 29/32	1 29/32	2 17/32	2 17/32
D	3/16	3/16	1/4	1/4	5/16	5/16	3/8	3/8
E	9/32	9/32	9/32	9/32	13/32	13/32	15/32	15/32
F	1 11/16	1 11/16	1 5/8	1 5/8	2 1/4	2 1/4	3 1/4	3 1/4
G	2 1/2	2 1/2	2 1/2	2 1/2	3 1/2	3 1/2	5"	5"
O	3/4	7/8	1 1/16	1 3/8	1 3/8	1 1/2	1 3/4	2 1/4
S	1 9/32	1 9/32	1 3/4	1 3/4	2 3/8	2 3/8	3 3/16	3 3/16

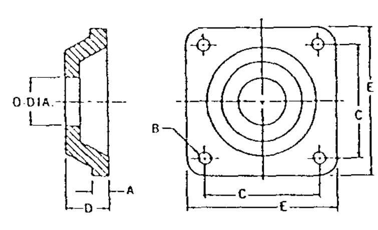
(PART NUMBERS)

NT OPTION SUGGESTED WHEN USING FRONT FOOT MOUNT ONLY.

FLANGE MOUNT

FRONT OR REAR





Front Flange Mounting **NT** Option suggested

Rear Flange Mounting **J2** Option suggested provides tail flush with flange mounting surface.

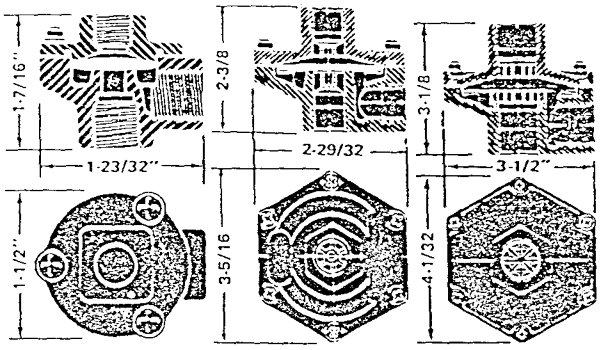
DIM.	129 STD	129 OS	229 STD	229 OS	329 STD	329 OS	429 STD	429 OS
A	9/32	9/32	11/32	11/32	13/32	13/32	7/16	1 29/32
B	9/32	9/32	9/32	9/32	13/32	13/32	15/32	15/32
C	2"	2"	2 1/2	2 1/2	3 3/8	3 3/8	4"	4"
D	5/8	5/8	7/8	7/8	1"	1"	1 1/8	1 29/32
E	2 1/2	2 1/2	3 1/4	3 1/4	4 1/2	4 1/2	5 1/4	5 1/4
O	3/4	7/8	1 1/16	1 3/8	1 3/8	1 1/2	1 3/4	2 1/4

(PART NUMBERS)

■ FAST AIR DUMPING ACTION PERMITS USE OF SMALLER VALVES AND PIPING

■ INCREASES SYSTEM EFFICIENCY & SPEEDS

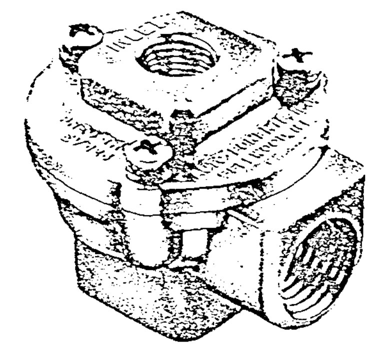
Quick Exhaust Valves



Model EV125-2
EV125

Model EV20A
EV25A

Model EV30A
EV35A

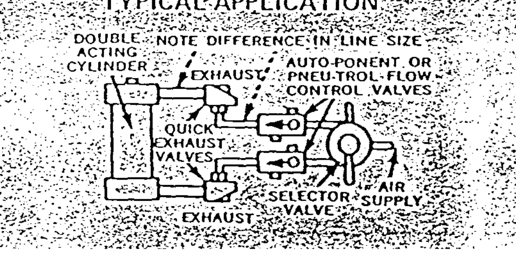


Pneu-Trol Quick Exhaust Valve design includes smooth, over-size, unrestricted, internal passages to prevent clogging from contaminated air lines, and a diaphragm of exclusive design, to give instantaneous and complete venting of the exhaust air of cylinders, air presses and other air-operated equipment.

By providing quick-dumping of exhaust air at the cylinder Pneu-Trol Quick Exhaust Valves eliminate the need for large selector valves ordinarily required to accomodate exhaust air moving back through the system. The initial savings and operating efficiency made possible by the use of smaller air system components are of considerable importance. In addition, smoother, faster cylinder operation and wider application of air powered motions are obtained.

The simple 1-piece diaphragm is molded of a tough, oil and abrasion-resistant synthetic compound for long service life. Its unique design compounds the pressure against the entire diaphragm area to provide a fast, flutter-free opening and closing action. For most effective air evacuation from the cylinder, it is important that the Quick Exhaust Valve be installed in the air line at the cylinder being vented. The valves will operate in any position, and may be mounted to suit installation convenience.

TYPICAL APPLICATION



OPERATING PRINCIPLE

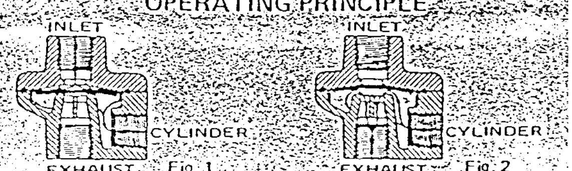


Fig. 1 Fig. 2

In "at rest" position, the diaphragm rests on exhaust port. As control valve is opened, air passes through the inlet Port (Fig. 1) deflecting the diaphragm, thus permitting air to pass through the passages around the periphery of the diaphragm and to the cylinder port. This is accomplished with a minimum of resistance, as the combined area of these passages is greater than the area of the inlet or outlet ports.

As inlet pressure is relieved (by actuating valve in the control circuit) air exhausting is instantaneous (Fig. 2). The cylinder return pressure building up over the entire diaphragm area, closes the inlet hole and snaps the diaphragm off the exhaust port, closing the inlet port and allowing quick evacuation of exhaust air from the cylinder. When cylinder air is evacuated, diaphragm returns to "at rest" position.

ORDERING INFORMATION

Model Number	Inlet Port	Inlet CV	Cylinder Port	Exhaust Port	Exhaust CV
†EV125	1/8"	.50	1/4"	1/4"	1.0
EV125-2	1/4"	.50	1/4"	1/4"	1.0
EV20A	1/4"	1.30	1/4"	3/8"	1.95
EV25A	3/8"	3.39	3/8"	3/8"	4.68
EV30A	1/2"	4.25	1/2"	3/4"	8.25
EV35A	3/4"	6.0	3/4"	3/4"	8.25

Operating Pressure: Min. 20 PSI; Max. 125 PSI.
Maximum ΔP to shift diaphragm is 1 PSI.
† 5 PSI

REFERENCES

Banner Engineering Corporation., *Handbook of Photoelectric Sensing,* Minnesota: Banner Engineering Corporation, 1990.

Beer, Ferdinand P., and Johnston, Russell E., *Mechanics of Materials,* New York: Mc-Graw Hill Inc., 1981.

Compressed Air and Gas Institute, *Compressed Air and Gas Handbook,* 5th ed., New York: Prentice-Hall Inc., 1988.

Dasguata, Ajit K., and Pearce, D. W., *Cost-Benefit Analysis: Theory and Practice,* New York: Macmillan Press Ltd., 1974.

Gramlich, Edward M., *A Guide to Benefit-Cost Analysis,* 2nd ed., New Jersey: Prentice-Hall Inc., 1990.

Hibbeler, R.C., *Engineering Mechanics Dynamics*, New York: Macmillan Publishing Company, 1986.

Neklutin, C. N., *Mechanisms and Cams for Automatic Machines,* New York: American Elsevier Publishing Company, Inc., 1969.

Occupational Safety and Health Administration, 1992 Code of Federal Regulations, *Title 29 Occupational Safety and Health Act.*

Ogata, Katsuhiko, *System Dynamics,* New Jersey: Prentice-Hall Inc., 1978.

Public Service Electric and Gas Company, 1993 Monthly Statement, April 1993.

Rinefort, Foster C., *The Economics,* Professional Safety, May 1992:42-45.

Stewart, Harry L., *Pneumatics and Hydraulics,* New York: Macmillan Publishing Company, 1987.