5-31-1992

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ABSTRACT

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The design of a Material Handling System for the Shower Head assembly is proposed. The working principle of complete automation and individual workstation is presented using "I-DEAS" software. Alternative equipments and their usage in the automation of the assembly is also proposed. Custom made fixtures, workcarriers, orienters, magazines, part feeders are designed for the assembly. Analysis of design for assembly in terms of cost and efficiency is performed by generating a Coding System Technique.

DESIGN OF A MATERIAL HANDLING SYSTEM FOR THE AUTOMATIC ASSEMBLY OF A SHOWER HEAD

by

IRSHAD MEHERALLY

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 Manufacturing Engineering
October 1992

APPROVAL PAGE

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**This thesis is dedicated to
my wife and parents**

ACKNOWLEDGEMENT

The author is deeply indebted to Dr. Raj S Sodhi, for his continuous guidance and courage in the completion of this thesis.

The author thanks Dr. Sanchoy Das, for the many discussions with him on the strategy for the design and development of the thesis.

Special thanks to his wife, Fouzia Meherally, who encouraged the author during the long hours spent in the lab and provided the understanding and support needed to pursue the objectives of thesis work.

The author sincerely wishes to thank his colleagues, Zafar Kamal, Waseem Azam and Muhammad Anwar Ansari for their support in providing information on the software I-DEAS and careful review of the manuscript.

And last but not the least, his parents, for their encouragement throughout the duration of studies.

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CHAPTER ONE
INTRODUCTION

Manufacturers throughout the world are currently facing their greatest challenge-to survive in an intensely competitive world market. Quality, productivity, cost, manufacturing efficiency, service, strategic planning, and implementation for the automated factory have become prime concerns of corporate management today. Concentration on design, engineering, manufacturing, service, and meeting customer demands are just a few of the competitive conditions that contemporary manufacturers must face to survive and grow in the global marketplace.

Manufacturing strategies now require development from the systems perspective. Computer Integrated Manufacturing (CIM), MRP, JIT, TQM, Computer-Aided Design (CAD), CAM, CAE, and Flexible Manufacturing Systems (FMS) are all individual pieces of a medley that tie the automated factory together into an efficient and effective system.

1.1 Introduction to Automated Assembly

A major area of interest in manufacturing industries today is product assembly. Statistics show that for most companies, assembly operations account for more than half the production cost for a product because of factors such as, overseas competition and continually increasing cost of labor, many companies need to increase assembly productivity in order to maintain competitive.

The increasing need for finished goods in large quantities has, in the past, led engineers to search for and to develop new methods of production. Many individual developments in the various branches of manufacturing technology have been made and have allowed the increased production of improved finished goods at lower cost. One of the most important manufacturing processes is the assembly process. This process is required when two or more component parts are to be brought together to produce the finished product.

In the past few years, certain efforts have been made to reduce assembly costs by the application of automation and modern techniques, such as ultrasonic welding and die-casting. However, success has been very limited and many assembly operators are still using the same basic tools as those employed at the time of the Industrial Revolution.

1.2 Choice of Assembly Method

When considering the assembly of a product, a manufacturer has to take into account the many factors that affect the choice of assembly system. For a new product, the following considerations are generally important:

1. Cost of assembly
2. Production rate required
3. Availability of labor

4. Market life of the product

If an attempt is to be made to justify the automation of an existing operator assembly line, consideration has to be given to the redeployment of those operators who would become redundant. If labor is plentiful, the degree of automation depends on the reduction on cost of assembly and the increase in production rate brought about by the automation of the assembly line. However, it must be remembered that, in general, the capital investment in automatic machinery has to be amortized over the market life of the product unless the machinery may be adopted to assemble new product. It is clear that if this is not the case and market life of the product is short, automation is generally not justifiable.

1.3 Difference Between Manual and Automated Assembly Lines

Manual assembly lines, or more generally, manual flow lines, are used in high-production situations where the work to be performed can be divided into small tasks (called work elements) and the tasks assigned to the workstations on the line. One of the key advantages of using manual assembly lines is specialization of labor. By giving each worker a limited set of tasks to do repeatedly, the worker becomes a specialist in those tasks and is able to perform them more quickly and more consistently.

The term automated assembly refers to the use of mechanized and automated devices to perform the various functions in an assembly line or cell. It is imperative to make design changes in order to assemble a part automatically. Product's design has a significant impact on the ease with which its assembly can be automated.

1.4 Advantages of Automatic Assembly

Following are some of the advantages of automation

1. Reduction in the cost of assembly
2. Increased productivity
3. A more consistent product
4. Removal of operators from hazardous operations

A reduction in costs is often the main consideration and, except for the special circumstances listed above, it could be expected that automation would not be carried out if it was not expected to produce a reduction in costs.

Productivity in an advanced industrial society is an important measure of operating efficiency. Increased productivity, although not directly beneficial to a manufacturer unless labor is scarce, is necessary to an expanding economy because it releases personnel for other tasks. It is clear that when put into effect, automation of assembly lines generally reduces the number of operators required and hence increases productivity.

Some of the assembly tasks that an operator can perform easily are extremely difficult to duplicate on even the most sophisticated automatic workhead. An operator can often carry out a visual inspection of the part to be assembled, and parts that are obviously defective can be discarded. In automatic assembly, however, unless the part has been rejected by the feeding device, an automatic workhead will probably stop and time will then be wasted locating and eliminating the fault.

In some situations, assembly by operators would be hazardous due to high temperature and the presence of toxic substances and other material. Under these circumstances, assembly by mechanical means is obviously advantageous.

An automatic assembly machine usually consists of transfer system for moving the assemblies from workstation to workstation, automatic workheads to perform the simple assembly operations, vacant workstations for operators to carry out the more complicated assembly operations, and inspection stations to check that the various operations have been completed successfully. The automatic workheads are either fed manually with individual or magazine-stored component parts or are supplied with parts from an automatic feeder (often a vibratory bowl feeder) through a feed track. The workheads themselves usually consist of either a fastening device or a parts-placing mechanism.

1.5 Assembly in Industries

Following examples will demonstrate the improvements that is going on in the field of automated assembly in industries.

1.5.1 An Operation Partitioning Problem for Automated Assembly System Design

An operation partitioning problem (OPP) is presented that arises from the design of an automated assembly system. In order to reduce the traffic flow of the system, the OPP assigns operations to machines so that the total number of movements of jobs between machines is minimized. The problem has applications in flexible manufacturing and very large scale integration (VLSI) design.

In flexible manufacturing, the OPP relates to a part grouping problem in which different parts are grouped into families. In VLSI design, the problem is related to a VLSI design problem in which a large circuit is partitioned into layers of small circuits. A simulated annealing heuristic is developed that finds a near-optimal solution. Random problems are generated for evaluating the effectiveness of the heuristic.

1.5.2 Using AI in Automated Assembly

AEG Westinghouse Industrial Automation Corp.'s Assembly Expert Series 2000 combines machine logic, motion control, and data collection into a single system. It consists of standard software modules for Cartesian and SCARA robots, Vision systems, pick-and-place mechanisms, a conveyor system for material handling, and an integrated control system. With the help of a large scoreboard-size annunciator and video display unit that identify the exact location and reason for each fault, operators can remove the cause of the fault. The series 2000 assembly system uses an machine logic and rule-based artificial intelligence (AI) approach called Zone Logic. Zone Logic is driven by mechanism characteristics, which are "go no- go" rules and algorithms that must be obeyed to move from one zone to another to reach a goal or successful exit point.

1.5.3 Simulate, Then Automate

Western Digital, a manufacturer of microcomputer hard disk drives, used personal computer (PC)-based simulation during the planning and design of its automated assembly and test facility in Singapore. The proposed production system included robotic assembly cells and gantry robots for automatic test loading in a Class 10 clean room. Conveyors were proposed for material handling between assembly, test, and rework operations. According to the manager of the factory automation, the estimated investment for the project was $5 million to $7 million. Rather than guessing, the firm needed to thoroughly evaluate alternative material handling equipment, identify potential bottlenecks, and evaluate throughput based on varying yield and equipment uptime.

1.6 Thesis Outline

The part that is selected for the automatic assembly is presently assembled by a local company. At present the assembly of the Shower Head is done manually and the company, keeping in mind the rapid growth in this field and the competitive environment of todays manufacturing industry wants, to go for the automation of the assembly.

1.6.1 Assumptions

In designing the material handling system and the automatic assembly for the equipment, few assumptions were made. One, the different parts for the equipment are made and supplied by a vendor. Second, the parts are inspected 100% before they are send out. Third, any design changes that has to be made for the automatic assembly the vendor will be responsible to supply that redesigned part.

The chapter content of thesis is broadly defined to be germane to the context in which the automated assembly system exists. The breakdown of the chapters are as follows:

First chapter describes what is going on in the field of automation in industry, what steps the industries are taking to remain competitive, these are demonstrated with the help of examples taken from some industrial magazines. The basic requirement to go for automated assembly system and its advantages are also discussed.

Chapter two describes the different elements of a automated material handling system. For any automatic assembly to be effective, it must be supported by a proper and well designed material handling system, otherwise the time saved with the automation of the assembly will only be lost due to improper material handling. The chapter discusses the important elements used in conjunction with the assembly like, Robotics, AGVS, Conveyor systems, AS/RS and the use of automatic assembly in FMS environment.

In chapter three, a complete physical description of the equipment is explained with the help of figures. The chapter also describes the function of each part.

Chapter four describes the complete automated assembly for the shower head. Different equipments that are employed for the automation and their functions are explained. Different alternative equipments are also mentioned. An "IDEAS" developed drawing explains each workstation and several workheads that are specifically designed for this particular assembly.

Chapter five describes Design For Assembly principles and the steps taken to make the necessary design changes for the automated assembly. These changes are explained with the help of figures

In chapter six a coding system is generated for both the old and the redesigned part and is analyzed for the suitability for the automated assembly in terms of the cost of part handling, part insertion and the efficiency for the assembly.

CHAPTER TWO

TRENDS IN MATERIAL HANDLING-FOR THE NEXT DECADE

A decade ago, manufacturing experts were envisioning the "lights out" factory, with minimal manpower and automated machinery every where. These automated factories would run twenty four hour a day, with no manual intervention.

Before making predictions as to where material handling will be ten years from now, let's first review developments in the ten years. Material handling systems are closely tied to other elements of automation-including robotics, flexible manufacturing, automatic test equipment, and controls-and developments in each area affect the others. Therefore, let's look at what was predicted in each area, what actually happened, and then analyze what probably will occur in the future.

2.1 Robotics

Ten years ago, robots were heralded as the answer to automation. Experts envisioned robots doing all jobs that involved lifting, moving products from machine to machine, repetitive assembly operations, and a host of other mostly manual functions.

Unfortunately, initial attempts to add robots to existing product lines by plunking down a robot here and there were largely unsuccessful. It became quickly evident that products had to be designed with robot assembly in mind form the beginning. This turned out to be a major hurdle.

In many cases, robot assembly required total redesign of a company's products. It also meant that product design couldn't take place in vacuum. Product designers had to work with, and accept input from, the manufacturing engineer. The old concept of the product designer "throwing his design over the wall" to the manufacturing group didn't work any more.

It is also learned that highly automated production lines are very expensive. The cost seemed to go up exponentially, depending upon the percent of automation that the plant wanted to implement.

It is also known that successful robot systems required upgraded support-such as faster and smarter material handling systems. A robot that can assemble parts into a finished product every 10 seconds doesn't do you any good if it takes 20 or 30 seconds to get all the parts to the robot. Support systems have to keep parts flowing continuously, track all the parts, and make sure the right part arrives at the robot at the right time, and in the right orientation.

The result of all this is that robotics didn't take off as was initially predicted. However, the early failures have led to greater success in recent years.

Today, better planning is going into robot installations. On the material handling side, we've developed methods that ensure that parts are maintained in the proper orientation for robot handling. In some cases, this requires that parts be shipped from suppliers in the proper orientation, and that they stay that way through various machining and assembly operations, until they reach the robot.

As products are being redesigned for automatic assembly, companies are finding that manual assembly is being improved as well. Design for automation means eliminating springs, screws, and miscellaneous fasteners in favor of slide-together, snap-together assemblies, which can be done automatically or manually. In fact, companies are finding that a blend of robotic and manual assembly is an effective solution.

It is expected that robot applications in automated assembly to grow at four to five times the current rate over the next 10 years.

2.2 Evolution in FMS

Flexible manufacturing systems (FMS) have gone through an evolution similar to that of robotics. 10 years ago, the concept of an automated system that could build multiple versions of a product seemed to be the answer to many problems.

Combining a computer-controlled flexible machining center with robots, material handling systems, just-in-time manufacturing techniques, MRP II inventory control and all the other buzzwords of the day looked like the answer to a plant manager's dream. By just pushing a button, they thought they could make alarm clocks today and refrigerators to-morrow.

One problem in the beginning was that people overreached what they could afford, and proposed very large and complex systems. At one point in the early 1980s, almost all the FMSs existing in the world could be seen on floor of the Machine Tool Show. Vendors had assembled them, in hopes of convincing people that the technology was workable.

In other cases, companies went ahead with an FMS without the proper understanding of the complexities involved, the time required, and the eventual cost. Some of these early systems were outright failures; others were less than total successes. In the FMS area, as in other areas automation, the "leading edge" of technology often is the "bleeding edge."

From those early beginnings, we've come to a better understanding of what an FMS can do and-just as important-what it can't do. Also, companies have done a better job of determining what manufacturing problems they are trying to solve, and if an FMS is the answer.

One concept that has spurred the growth of FMS in the past few years is the manufacturing cell. By implementing an FMS one cell at a time, a system can be done in manageable pieces, with minimal disruption to existing production facilities and at a reasonable cost.

This is not to say that plant wide FMSs won't be built. Such very large mega-systems can't be done one cell at a time, and often require new grassroots plants to house them. However, it is predicted that the majority of FMSs built in the future will be smaller, cell-level installations.

It is also agreed with the general consensus that flexible manufacturing systems will grow at a rate of 40% during the next 10 years. One reason is that our plants must become more competitive in the world market.

Another reason is that an FMS can be of great value to small-and medium-sized businesses. Until recently, most automation has been done in large plants, mostly in the automotive and electronics industry. Today, however, smaller manufacturers are beginning to install FMSs.

2.3 Material Handling and Storage System in FMS

Material movement within an FMS is a key factor in its total productivity. Without controlled material movement within the manufacturing shop, wasted utilization occurs in manpower, factory space, and machine tools. Material handling systems (MHS) must integrate a variety of equipment in the FMS and also be reliable, fast, and easy to maintain. They should be capable of providing transportation for raw materials, parts and final products, storage for work pieces, empty pallets and fixtures, and disposal systems for chips and other waste materials.

2.4 Automated Material Handling

Automated material handling (AMH) is a major player in allaspects of the Computer Integrated Manufacturing (CIM) environment. In many respects, AMH is the glue that ties the CIM pieces together. Material handling system carry products from cell to cell, feed robots, and move products form storage to manufacturing to test to the shipping dock. Without effective material handling, a just-in-time system becomes an "almost-in-time" system.

Material handling has been around for a long time. Conveyors made it possible for Henry Ford to build his first automobile assembly lines, and conveyors were the mainstay of manufacturing production for the first 50 years of this century.

Conveyor technology improved gradually over the years, with occasional developments such as power-and-free and accumulating roller conveyors.

In the 1960s, new devices such as Automated Guided Vehicles (AGV), Automatic Storage and Retrieval Systems (AS/RS), and Automated Monotractor Systems (AMS) were added. With computer control, these systems began to expand the scope of modern material handling technology.

Real strides began in the 1970s, as programmable logic controllers (PLCs) became reliable and cost effective. The PLC made it possible to upgrade material handling control systems form a series of ON/OFF push buttons and relays to advanced real-time control.

With the PLC becoming more entrenched in plants, other advanced equipment, such as bar code readers, was installed to identify and track products and parts. More and more information was being acquired and kept by material handling systems, and was made accessible at the stroke of a key.

Material handling systems in the 1970s were hard pressed to keep up with the demands of high-volume production for accurate, on-time delivery of parts, where older systems could easily keep up and sometimes overwhelm traditional production methods, newer manufacturing lines called for faster feed rates and higher speeds, and older systems couldn't keep up.

In the 1980s, personal computers hit the factory floor and brought a whole new set of capabilities. Now, even more information was available to operators, allowing closer control of the production environment. Personal computers made it possible to implement JIT techniques, better quality control, maintenance monitoring , MAP communications, and a host of other programs.

All these new concepts left many customers and suppliers confused. Some plants felt that they were the only company in town that wasn't robotized, computerized, conveyorized, and modernized. Tremendous pressure was put on manufacturing engineers to quickly implement new programs.

By the 1980s, the stampede was on to install automated production equipment. Many of these systems, large and small, were installed without proper planning. Boards of directors were unhappy to find that the programs they authorized did not result in the promised return on investment. Overly complex systems took very long to debug, or were never fully realized.

Some "successful" systems were actually done with mirrors. For example, the plant a 4th inventory of parts and a JIT delivery system sometimes had a contractor down the street who held 10 days' worth of their inventory. In other cases, so-called flexible manufacturing systems were installed that required a 6th manual setup to change over to making a new part.

In the next 10 years, we expect to see a much more realistic view of computer integrated manufacturing and automation in general. The industry has learned its lessons, and understands that projects must be planned carefully.

Material handling systems must be fully integrated into projects from the beginning, so that high-speed, automated assembly and fabrication machinery can work properly.

The prognosis for the automated material handling market is good. It is foreseen, the market doubling in the next five years, and we may see more advanced products being developed to handle the higher speeds and increased flexibility of modern production machinery.

2.5 Conveyer System

Conveyors will continue to be the mainstay of modern manufacturing. To meet the needs of flexible, just-in-time manufacturing, specialized conveyors have been developed, and will be more widely used in the future.

In the auto industry, for example, just-in-time manufacturing requires that vehicles roll off the line in the same sequence they began, to make sure that parts arrive at assembly points in time to be installed on the proper vehicle.

Inverted power-and free conveyors are also becoming more popular because of reduced floor space requirements and their ability to provide positive control over every carrier in the system. Loads can be stopped, started, and accumulated without disrupting the flow of other carriers, which is ideal when dealing with manufacturing cell. Reduced floor space requirements make the conveyors usable in smaller plants, especially in the electronics industry.

Because of the increased number of manufacturing cell, it is expected to see more modular-type conveyors operating at higher speeds. As had been the trend for the past few years, conveyor controls will become more sophisticated, and more packaged software will be available for inventory control, parts identification, and plant floor control. Conveyor manufacturers will begin supplying such software as part of their overall system, rather than relying upon outside vendors.

Automated conveyor systems will continue to grow as a market, but at a more controlled pace. We've learned to build conveyors that are more maintainable and easier to install. The concept of Continuous Flow Manufacturing, where product assembly is a continuous, single-line operation, will be used more, especially in high-volume manufacturing enterprises.

2.6 Robust Growth in AGVs

The AGV market has enjoyed substantial growth over the past 10 years. Early applications were limited to warehousing operations, where the AGVs towed trains of carts from one area of a warehouse to another. This began to change 10 years ago, when AGV manufacturers developed auto-load units.

These AGVs had the ability to pick up a load and deliver it elsewhere in the plant, without human intervention. Smaller mini-load AGV installations have been very effective.

Advanced controls make it possible to track the vehicle and the product being carried. This capability led some automotive manufactures to install very large AGV systems, using the AGV itself as the production platform.

Other developments in AGVs, such as telemetry guidance instead of imbedded wires, are now well advanced. What effect this will have on AGV sales is yet to be seen. It is expected that overall AGV sales will grow at a rate similar to that of the material handling industry in general.

2.7 Changes in AS/RS

The storage and retrieval market has seen many changes since its inception three decades ago. It began as primarily a unit load device that could handle full sized pallets (40x48in) with loads weighing from 2,500 to 4,000 pounds. Many AS/RS machines were 50 to 100 feet high.

The next development was mini-stackers that could handle smaller loads up to 1,000 pounds. These machines were 20 to 40 feet high. The most recent development is the micro-stacker, designed to handle tote boxes weighing up to 150 pound in heights to 25 feet.

In the AS/RS market, the most dramatic trend has been the shift away form large system to the mini-and micro-stackers. These units are being primarily used in manufacturing plants as work-in-process buffers at point-of-use areas.

We expect to see increased use of the small stackers as a support for on-line manufacturing. But, because the trend is away form large in-plant part storage areas, we do not expect the overall stacker market to grow at the same rate as the overall material handling market.

2.8 Automated Monorail Systems

Electrified monorail systems have been used extensively in Europe for many years, but U.S manufacturers started using them in earnest only five to seven years ago. The big user in the U.S so far is the automotive industry, but it remains to be seen if other industries will adopt the technology.

As with other material handling equipment, monorails have benefited greatly by advanced controls. However, their heavy reliance on controls make monorails harder to modularize than conveyor systems, and therefore more difficult to adapt to manufacturing cells.

It is expected that the monorail market will continue to grow at a steady pace. It is also expected that monorail manufacturers to develop modularized controls in the near future, which will make the system more flexible and give it wider market appeal.

2.9 Effective Material Handling

As it is noted throughout, improvements in controls have had dramatic effects on material handling systems in the past few years. The ability to control product flow, keep inventory, track parts, respond to machine stoppages, and monitor activity in all parts of a plant are what make today's CIM systems work.

However, advanced control is a two-edged sword. With all the capability available from programmable controllers, plant-floor industrial computers, and communications such as Manufacturing Automation Protocol (MAP) between control systems, it's possible to get carried away by technology.

One of the biggest problems in a plant control system is "creeping elegance," especially when large projects are designed by committees. By the time everyone on the committee gets the particular control function, display, printout, or special feature that's absolutely, positively needed in their particular area, the control system may be literally "out of control."

Material handling system manufacturers address such control problems through a combination of detailed planning and standard products.

In the next five to ten years, we expect to use computer simulation much more extensively, especially in large, complex installations.

Standard software packages, supplied by material handling manufacturers, will simplify a customer's need for inventory control, product tracking, and control system software.

For example, control packages are currently available now for AS/RS machines, AGVs, conveyors, and complete material handling systems. Today, customers can buy all the software needed to control, monitor, and track all aspects of a material handling system.

In the next few years, it is expected that standards will emerge-such as MAP communications-that will make it easier to interface the material handling software with other control systems in the plant.

CHAPTER THREE
PART DESCRIPTION

The Shower Head apparatus as the name implies is commonly used for sprinkling water in a controlled direction. It is mainly used in bathroom tubs or it may also be used in building offices, schools, factories and other areas where there is a need for spraying a continuous flow of water.

3.1 Components of Shower Head

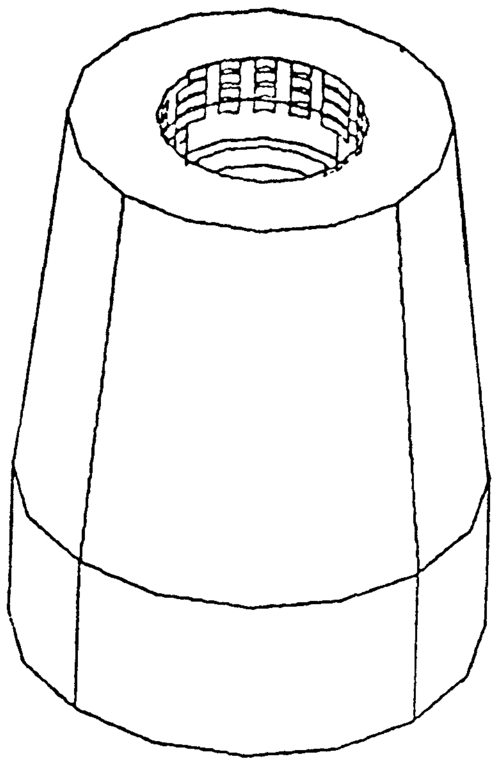
The device basically consists of seven parts as shown in figure 1.

1. **Shower Head**
2. **Spraying Plate or Sprinkler**
3. **O Ring**
4. **Valve Holder**
5. **Valve**
6. **Directional Ball**
7. **Faucet Connector**

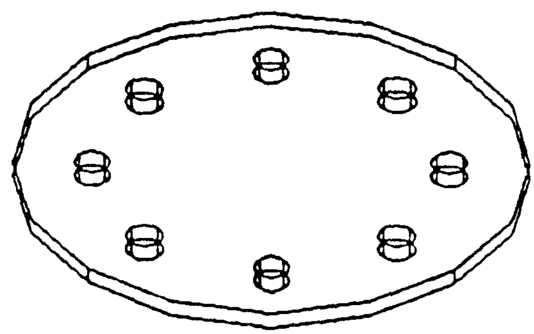
These parts are described in detail as:

3.1.1 Shower Head

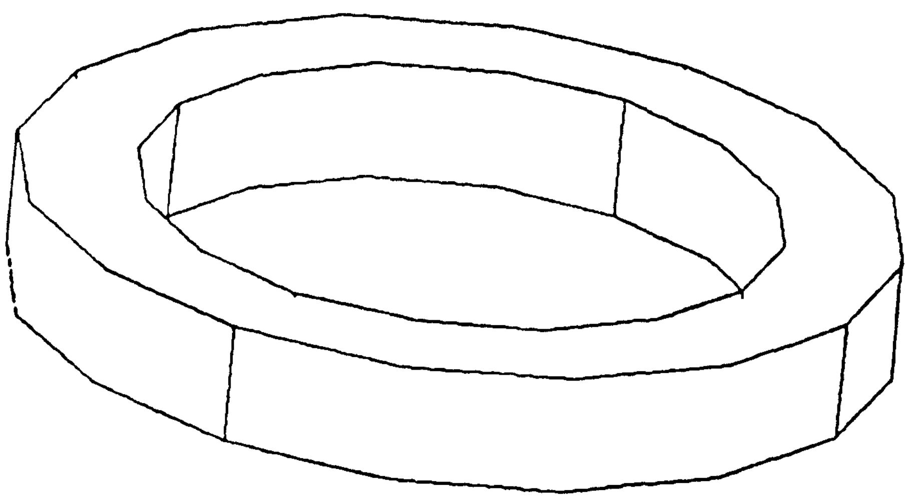
This part is conical in shape. It restricts the flow of water in the desired portion. The material for this part is solid brass with Chrome plated and it is die cast. It is the base part of our assembly. The conical shape has diameter of 32 m.m which gradually reduces to 22 m.m. The converging



Shower Head



Sprinkler



O Ring

Figure: 1a Components of Shower Head Assembly height is 26.5 m.m, after that it remains constant with external diameter of 22 m.m and internal diameter of 15 m.m. The total height of this part is 37.5 m.m. The top portion is threaded from the inside so that it can be fixed with the valve holder. There is also a projection from inside so that the spray plate and the O ring can rest on it. The part is shown in figure 1a.

3.1.2 Spraying Plate or Sprinkler

This part is made of brass and it is chrome plated. The plate has 10 evenly spaced holes and rests on to the projection inside the shower head. It restricts the flow of and lets the water to flow through the small holes so that the water is sprayed evenly in all direction.

The plate has a diameter of 14 m.m and is 0.5 m.m thick. The part is shown in figure 1a.

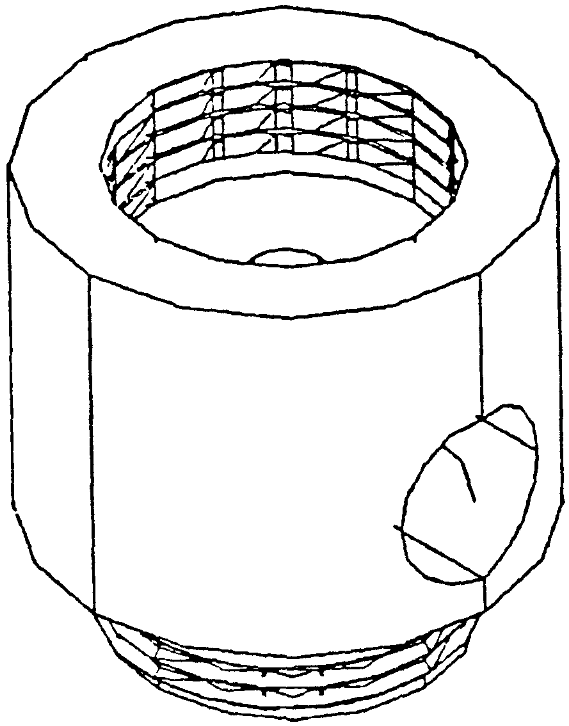
3.1.3 O Ring

This part is made of rubber. It acts as a sealer against water leaks and also maintains the necessary water pressure. It rests on the inside projection of shower head on top of the sprinkler.

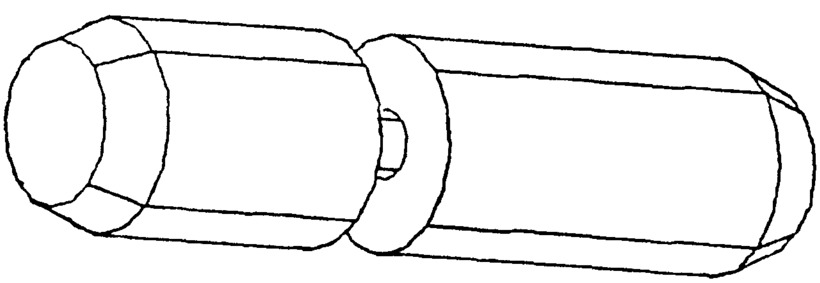
The ring has an external diameter of 15 m.m and has a thickness of 2.0 m.m. The part is shown in figure 1a.

3.1.4 Valve Holder

This part is also solid brass and chrome plated. It acts as



Valve Holder



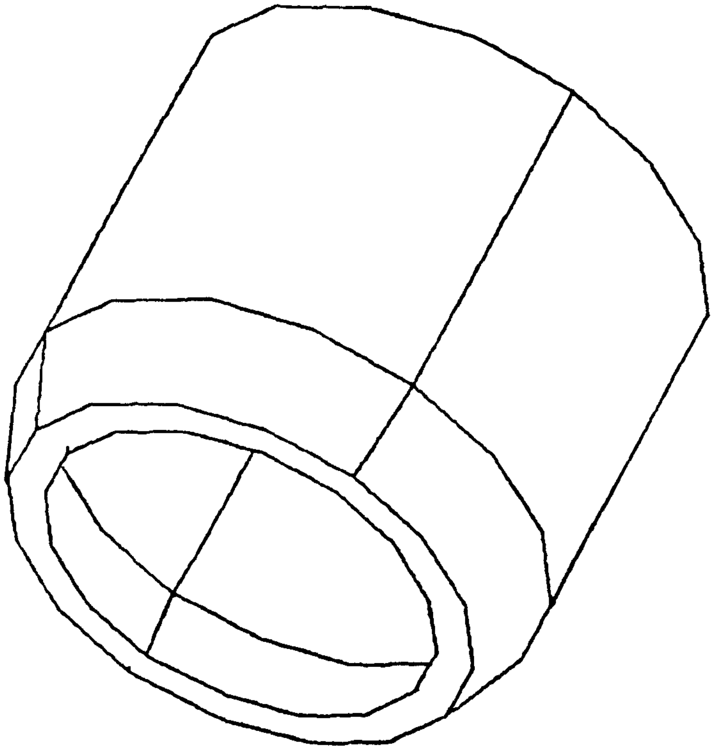
Valve

Figure: 1b Components of Shower Head Assembly a connection between the directional ball and the shower head. At the center of the body a hole is drilled with a diameter of 8.0 m.m which supports the valve, the face of the drill is smoothed out so that the valve can slide in without restriction. This Part is shown in figure 1b.

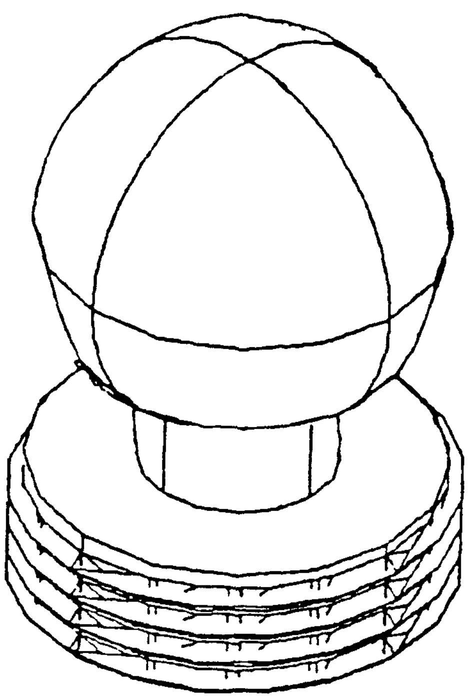
The cylindrical part is made in two dimension, the bottom portion has a diameter of 15.0 m.m which is threaded uptil the height of 6.0 m.m. This threaded portion fits inside the shower head. The top portion has diameter of 22.0 m.m and is threaded from inside to fit with the direction ball. The height of this portion is 18.0 m.m. A very small hole of 3.7 m.m is drilled along the axis of insertion throughout the part to allow the water to pass through it

3.1.5 Valve

The material for the valve is die cast with brass and chrome plated. The shape of the valve is like a rod the middle portion has gap which allows the water to pass. It is inserted in the valve holder and the initial position is such that it restricts the flow of water but as it is displaced from that position the gap allows the water to pass, the flow of water may be controlled by reducing or increasing the gap. On each side of the gap there is a rubber fit around the valve so that the valve does not slip out of the holder, the threads on each side is also for the same purpose. The part is shown in figure 1b.



Faucet Connector



Directional Ball

Figure: 1c Components of Shower Head Assembly

The valve has a diameter of 7.25 m.m and it is 32.0 m.m long. The edges of the valve is tapered to allow easy insertion into the body of valve holder. A clip is put on the ends of the valve which restricts the valve to come out of the valve holder completely.

3.1.6 Directional Ball

The material for the directional ball is die cast with brass and chrome plated. The top portion of the part has a sphere which goes inside the faucet connector from only one side, the converging faucet connector restricts the ball part to come out from the other side. The bottom portion of the part has a cylindrical block with threads on its outer surface this allows the whole part to be joined with the valve holder. The part is shown in figure 1c.

The diameter of the sphere is 17.3 m.m and that of cylindrical block it is 15.0 m.m. The height of the part is 17.2 m.m. The top of the ball has an hexagonal shape hole in order to mechanically tighten the part. This hole runs along the entire body of the part to allow water flow through it and has a diameter of 3.7 m.m.

3.1.7 Faucet Connector

The material for the faucet connector is also die cast with brass and chrome plated. The part allows the entire assembled part to be connected to the water line it also allows the directional ball to rest inside it which gives the whole assembly 360 degrees free rotation around the plane of insertion. The part is shown in figure 1c.

The part has an external diameter of 24.0 m.m and an internal diameter of 18.5 m.m. The base of the part is slightly converging to an external diameter of 19.0 m.m and an internal diameter of 15.7 m.m. The height of the converging section is 4.0 m.m and the total height of the part is 19.0 m.m.

CHAPTER FOUR
DESIGN FOR AUTOMATIC ASSEMBLY

The design of components and products to facilitate assembly has become increasingly important over the last decade. Many researchers have developed working rules to guide designers with respect to component and product design that facilitates assembly.

Different principles for the Design For Assembly will be discussed in detail. Appropriate considerations will be made to the Design For Assembly for the shower head assembly.

4.1 Product Design for Automated Assembly

Product design is the first step in the manufacturing process. All of the opportunities for, and limitations on efficiency in manufacturing, are established at the product design level.

When a product is designed, consideration is generally given to the ease of manufacture of its individual parts and the function and appearance of the final product. Although for obvious reasons it must be possible to assemble the product, little thought is usually given to those aspects of design that will facilitate assembly of the parts and great reliance is often placed on the dexterity of the assembly operators.

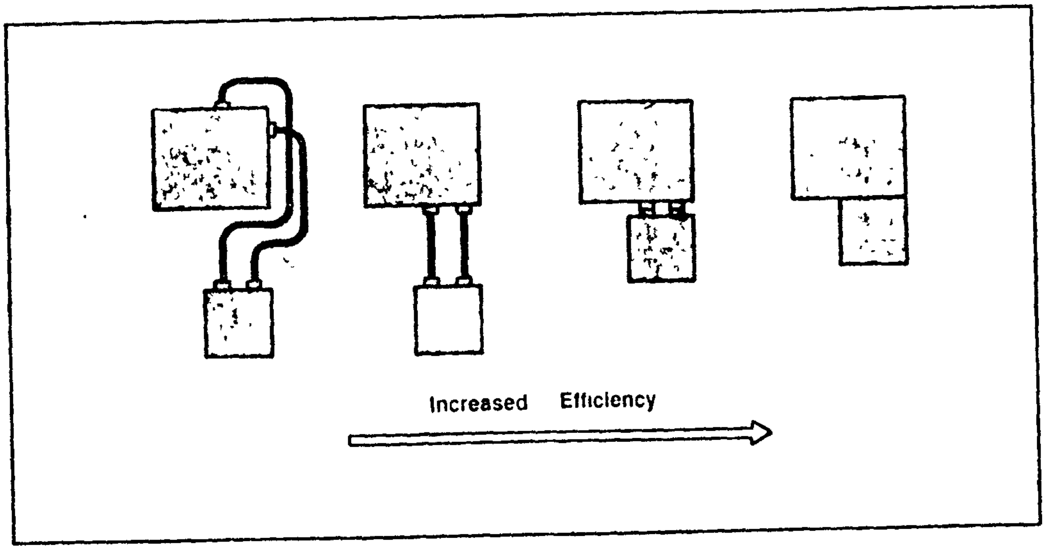
An operator is able to select, inspect, orient, transfer, place, and assemble the most complicated parts relatively easily, but many of these operations are difficult, if not impossible, to duplicate on a machine. Thus, one of the first steps in the introduction of automation in the assembly process is to reconsider the design of the product so that the individual assembly operations become sufficiently simple for a machine to perform.

As a result of applying design for assembly analyses to wide range of products, it has been possible to develop a set of rules or guidelines which are important on design for manual assembly. These are listed below in decreasing order of importance.

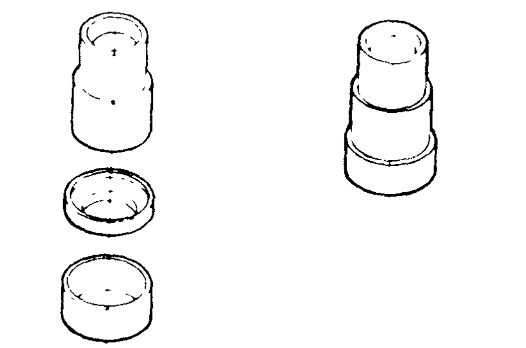
1. Reduce part count and part types
2. Strive to eliminate adjustments
3. Design parts to be self-aligning and self-locating
4. Ensure adequate access and unrestricted vision
5. Ensure the ease of handling of parts from bulk
6. Minimize the need for reorientations during assembly
7. Design parts that cannot be installed incorrectly
8. Maximize part symmetry if possible or make parts obviously asymmetrical.

4.1.1 Reduce Part Count and Part Types

The most obvious way in which the assembly process can be

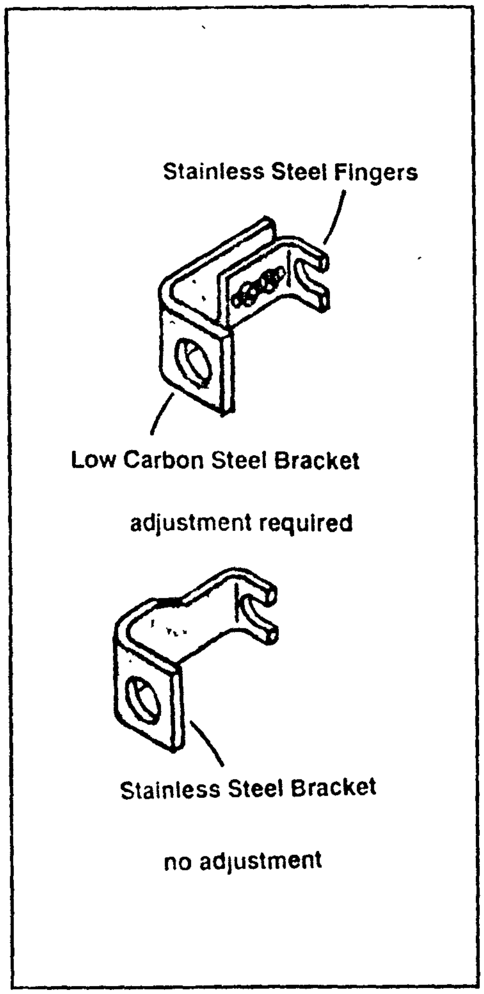


(a) Simplification or Elimination of Conduits



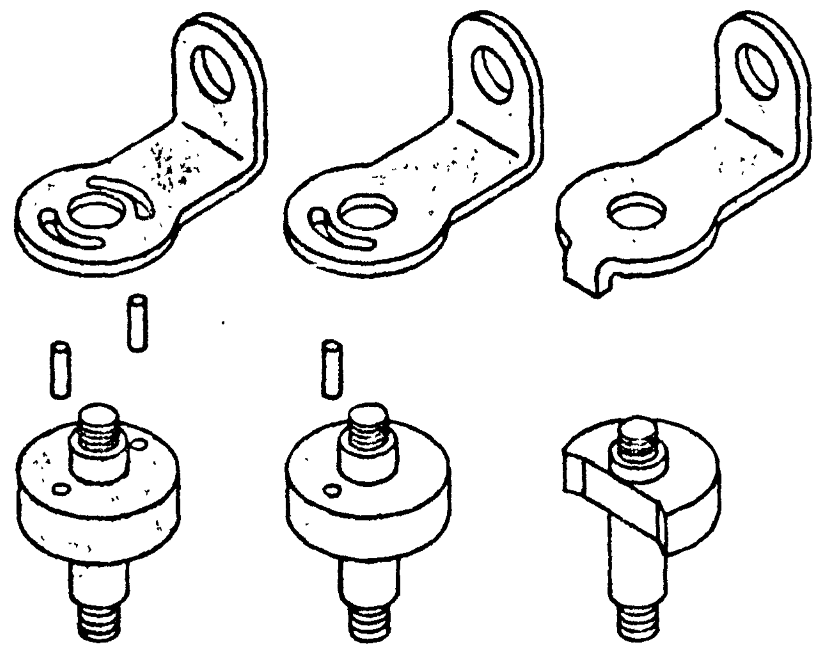
(b)

Figure 2



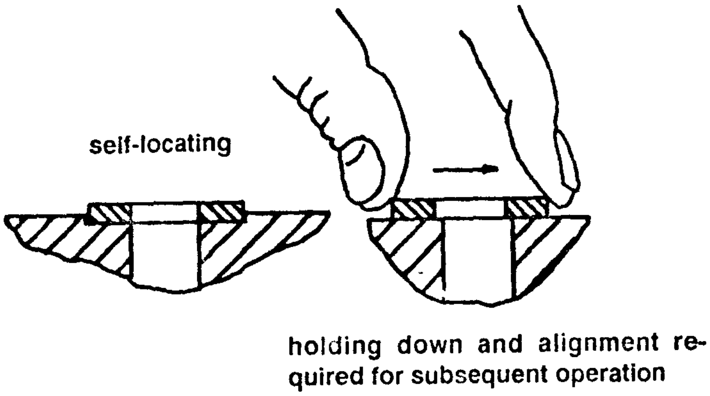
Elimination of Adjustment

Figure: 3

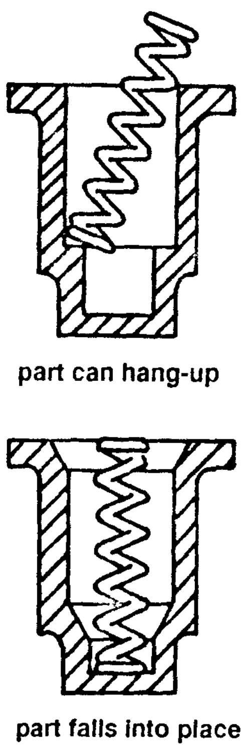


Follow Kinematic Design Principles as an aid to Product Simplification

Figure: 4

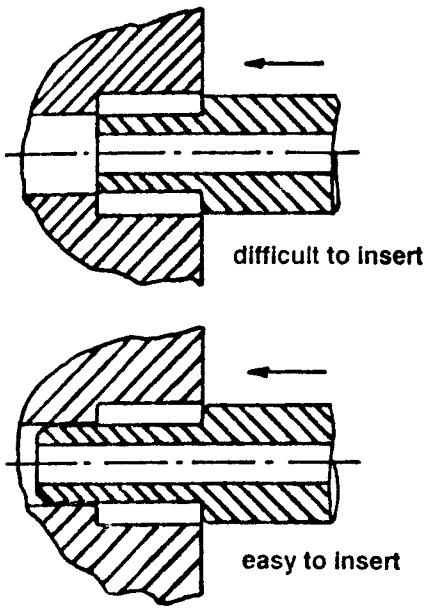


(a) Design with Self-Locating Features

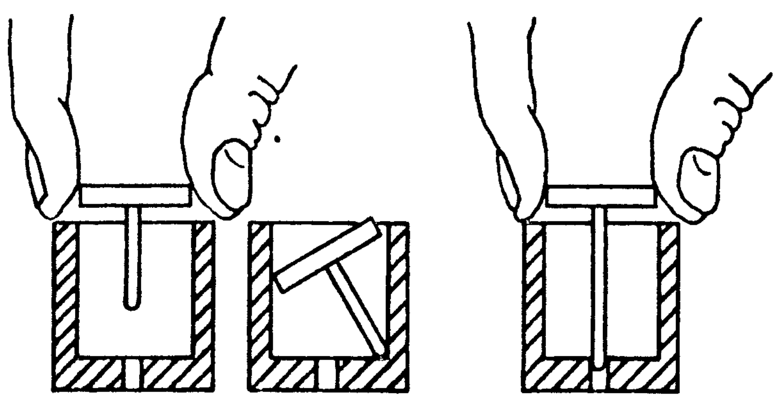


(b) Provide Alignment Features

Figure: 5



(a) Include Chamfers and Avoid Simultaneous Mating Difficulties



Ensure that parts can reach Mating Locations

(b)

Figure: 6

facilitated at the design stage is by reducing the number of different parts to a minimum. See figure 2a and b. Functionally separate parts are required for only a few simple reasons:

* Required differences in material property
* Required relative motion between mating parts
* Required access for assembly
* Required disassembly of the product for maintenance or repair

4.1.2 Strive to Eliminate Adjustments

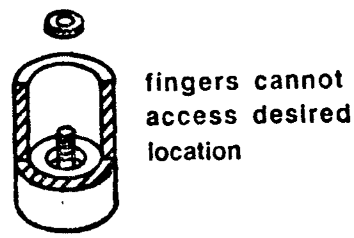
Adjustments and similar processes which require judgement or decision-making during assembly are costly and a detriment to reliability. An example of this is shown in figure 3 and figure 4.

4.1.3 Design Parts to be Self Locating and Aligning

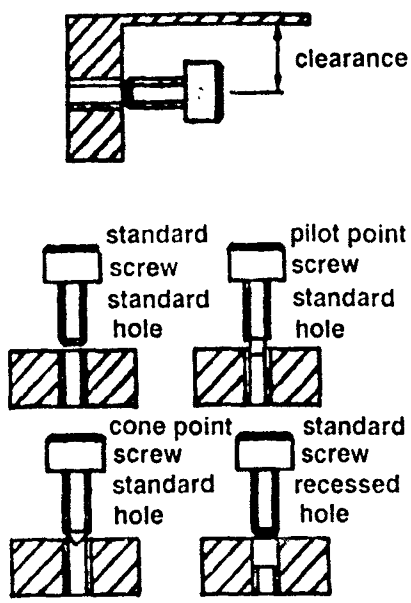
Parts should be designed so that mating surfaces "fall into place". Features to accomplish this should always be included when utilizing near-net shape processes such as casting and molding. For machined parts the added cost of alignment features should he considered as part of the total cost trade-offs for the product. Examples are shown in figure 5a, 5b and figure 6a, 6b.

4.1.4 Consider Access and Visibility for each Operation

Inadequate access or restricted vision can make a seemingly



(a) Ensure Adequate Access for Part Insertion



(b) Effects of Obstructions and point Type on Thread Engagement Times

Figure: 7

simple operation both time consuming and frustrating. These aspects of a design are often overlooked and are seldom corrected once a design had entered production. Examples are shown in figure 7a and 7b.

4.1.5 Consider the Ease of Handling of Parts from Bulk

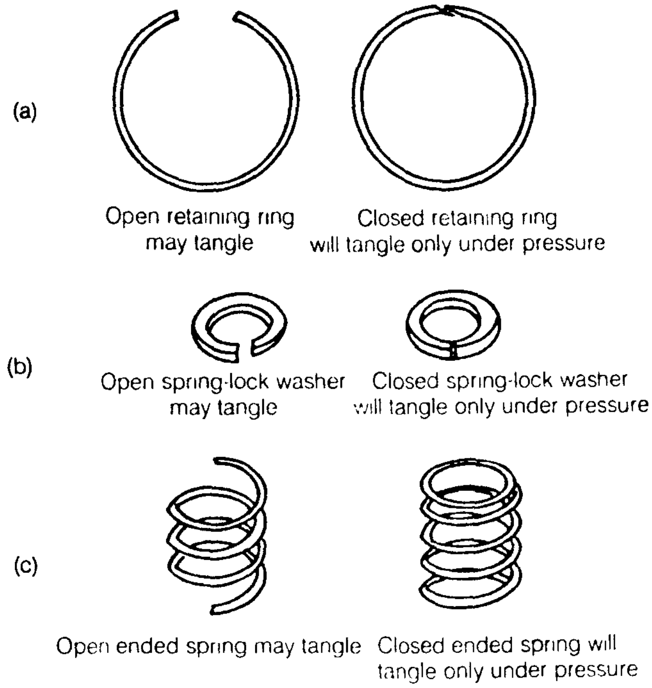
Some parts may be assembled into the product with ease but nevertheless carry severe time penalties due to difficulties in handling them or separating them from bulk.

4.1.6 Design Parts that Cannot be Installed Incorrectly

Eliminate situations where a part can be installed in orientations which would not permit correct operation of the product.

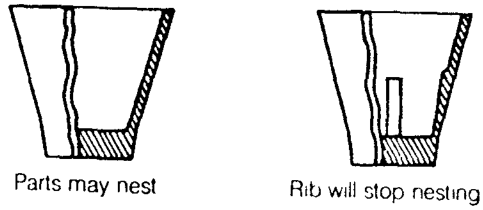
4.1.7 Eliminate the need for Reorientations during Assembly

Although reorientations of the assembly are not as costly with manual assembly as in automated assembly systems, they should still be avoided. Any required reorientation or manipulation of parts already assembled is an operation which adds no value to the assembly process. If possible provide for progressive assembly about one axis of reference. Exclusive use of vertical insertion is ideal. However, parts can be inserted sideways in manual assembly with high efficiency and the main requirement is to avoid the need for manipulating the assembly of previously assembled parts at any stage.



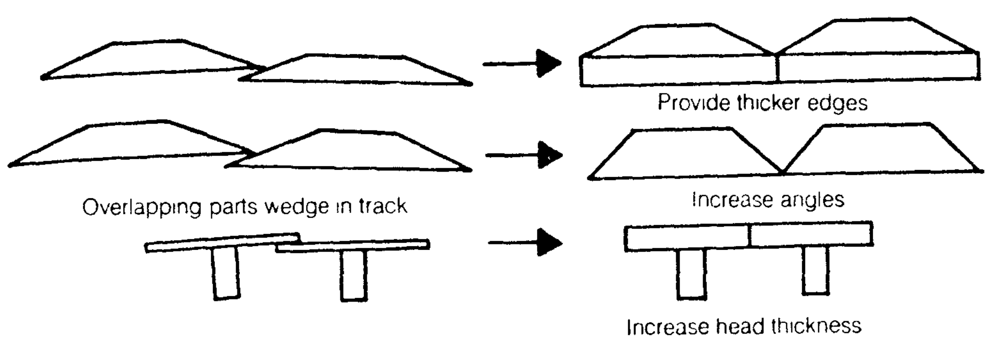
Tangling can be minimized through part redesign

Figure: 8



Use of a nonfictional rib to prevent nesting

Figure: 9



Shingling or Overlapping Can be Avoided by Providing Thicker Contact Edges, or Increased Angles, or Thicker Heads.

Figure: 10

4.1.8 Maximize Part Symmetry or Emphasize Asymmetry

The more symmetrical a part is, the more quickly it can be oriented during the handling phase of assembly.

4.2 Part Feeding

The ability to feed and orient parts is critical in automatic assembly. The design of the part dictates how easily a part can be fed and the amount of additional hardware needed to determine orientation. Parts with improper design can meet all functional requirements but may tangle, causing a stoppage in assembly.

For ease of feeding, a part should have adequate rigidity to withstand feeding without bending or distortion. Components to be avoided include brittle ones and those with thin sections. Also, the number of surfaces with strict requirements on surface finish should be minimized to avoid damage during feeding.

Parts which tangle should be avoided, figure 8 illustrates several examples of simple design changes that do not influence part function but avoid tangling. As figure 8a shows, open retaining rings and lock washers have a high propensity to tangle. Closing the configuration will eliminate tangling. A similar idea may be applied to springs. An open-ended spring will tangle, a closed-end spring, where the ends are formed close to the coil, will only tangle under pressure.

The nesting of parts may also present difficulty in feeding. Parts which nest, one inside the other, may jam and stop the assembly process. The inclusion of a nonfunctional rib as shown in figure 9 will prevent nesting.

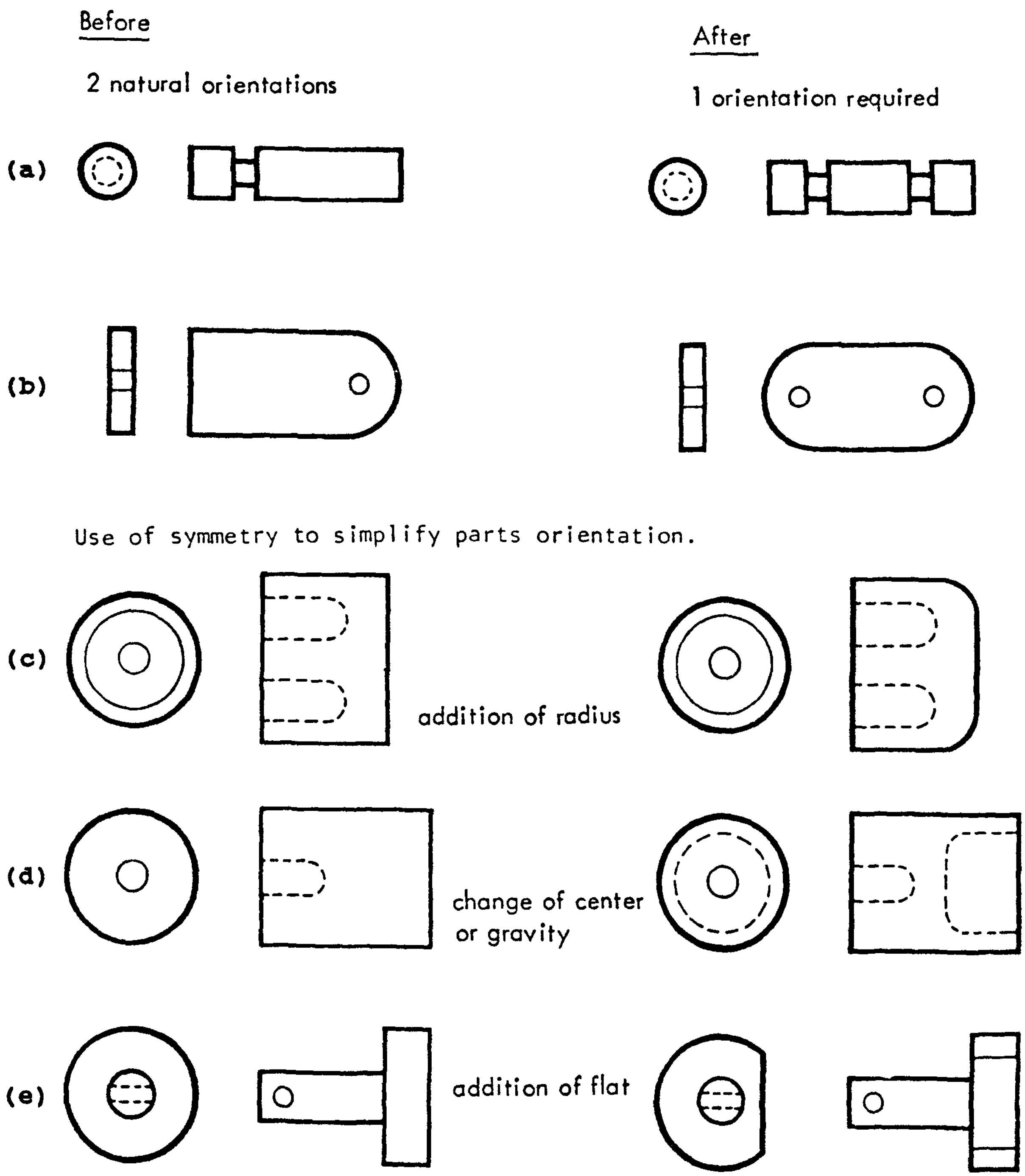
Parts with thin or tapered edges have a tendency to climb and overlap each other, which then causes wedging of parts in the tracks on which they feed, and leads to subsequent jamming. Steeper angles or thicker edges will minimize overlap, as shown in figure 10. Overlapping in thin edge parts can be minimized by bending the edge upward.

4.3 Part Orientation

Feeding of certain parts may also require that they be presented to the machine in a particular orientation. When possible, component symmetry decreases orientation requirements. The addition of nonfunctional features such as holes, illustrated in figure 11a to 11e, or extension of a slot, figure 12, eliminates some of the difficulties in orientation. When this is not possible, then increased asymmetry may aid in orientation. Figure 13 illustrates this concept for several parts. In each case, adding a feature to add asymmetry to the component makes orientation easier and does not change the part's functionality.

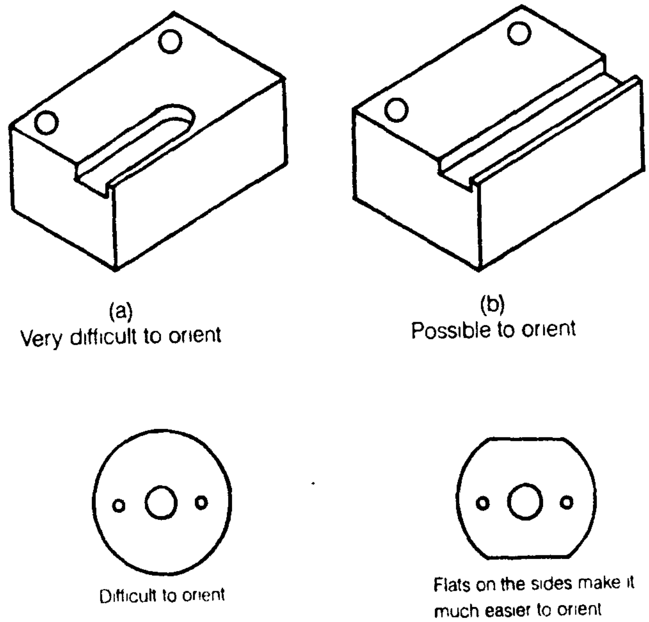
4.4 Fastener Selection

The influence of fastener selection and design on the ease of automatic assembling has been cited by several



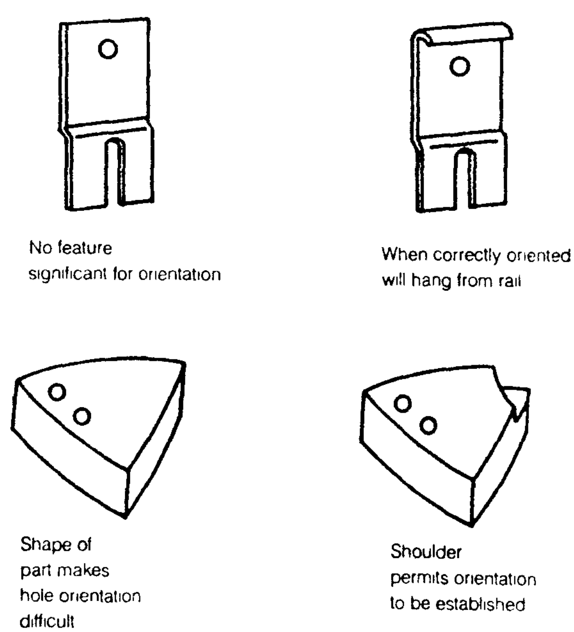
Addition of External Features to Reduce Difficulty of Sensing Orientation

Figure: 11



Extension of a slot to facilitate orientation

Figure: 12



Part asymmetry is used to facilitate orientation

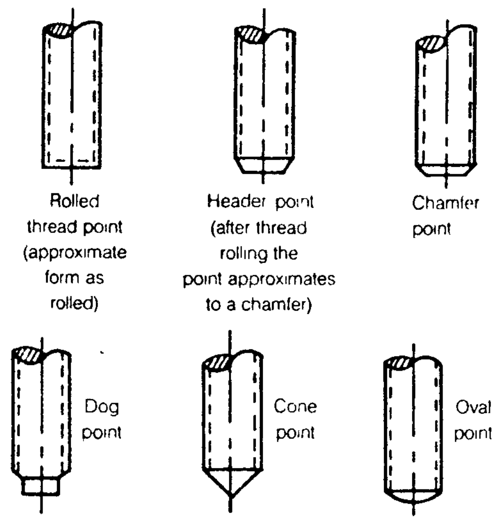
Figure: 13

researchers. The selection of the appropriate fastener should incorporate pre-installation attributes are those attributes considered before installation. These attributes include cost of the fastener, ease of parts feeding, and special material preparation.

Fasteners that are easier to feed may be symmetric, or may be channel fed. Tangle prone fasteners like open circlips should be avoided. Fastening techniques such as adhesive bonding, soldering, and brazing may require surface preparation prior to execution of the process. This adds additional cost and may also necessitate additional automation and the design of special tooling.

Installation attributes must also be considered. The method and direction of assembly must be analyzed. Simple fasteners requiring quick, one-step procedures and unidirectional installation are preferred. For example, split and pop rivets are much preferred to solid rivets, which require insertion and the constraint of the head from one direction while the rivet is deformed from the other side. Fastening methods meeting these criteria will require less installation time, less special tooling, and cost less to insert. In addition, those fastening methods which generate high contact forces or torques, or require special tooling, are candidates for replacement.

In general, threaded fasteners provide some difficulty for automatic assembly. Figure 14 illustrates several shapes for fastener points. Oval and cone points provide very good



Various Forms of Screw Point.

Figure: 14

location while dog and chamfer points provide only reasonable location. The header and rolled threaded pointsprovide poor location and are unable to centralize without positive control on the outside diameter of the screws.

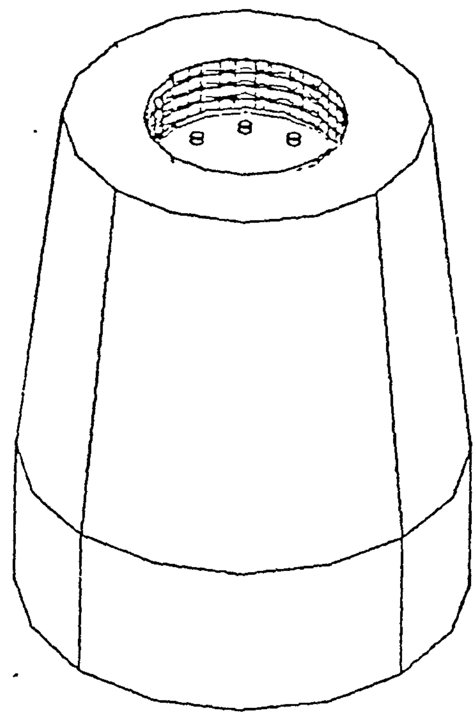
The various points made in this discussion of parts and product design for automatic assembly are summarized below in the form of simple rules for the designer.

4.5 Redesign of the Shower Head Assembly

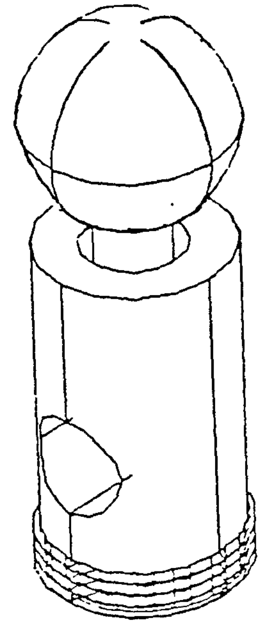
After discussing the various methods and principle for the design for automatic assembly, the design for the shower head assembly is done. The analysis of the assembly worksheet, figure 30, reveals two possible design changes in the assembly.

4.5.1 Shower Head and Sprinkler Plate

It is always advisable to eliminate parts when designing for the automatic assembly, especially when there is no relative motion between the part and the parts are made of same material. Considering the Sprinkler Plate and the Shower head it is seen that the two parts can be made into one part without affecting the functionality of the whole assembly. This unification of the parts can be done with new die cast or it may also be done by press fitting the sprinkler into the shower head from the bottom as there is a projection



(a) Shower Head and Sprinkler



(b) Directional Ball and Valve Holder

Figure: 15

from the inside where the sprinkler may rest. The redesigned part is shown in figure 15a.

With this design change it is observed that a very tedious and costly operation of the insertion of the sprinkler plate into the shower head is eliminated, further it is also seen that one work station is also removed which will result in saving of the downtime and the cost of the complete assembly process.

4.5.2 Valve Holder and Directional Ball

The second design change for the assembly is done between the Valve Holder and the Directional ball. The present dimension of the two parts is such that the faucet connector has to be placed inside the directional ball which has threads that turns into the valve holder. This configuration creates some assembly problems, because the directional ball needs to be hold down with the faucet connector to screw it into the valve holder in order to avoid the misalignment between the two parts.

This problem can be completely eliminated with as: by reducing the dimension of the valve holder from 22.0 m.m dia to 15.0 m.m. that is, the dia of the valve holder is made equal that of the threaded portion of the directional ball. Having done this, the ball part and the valve holder can be made as a single part. This results in eliminating the threaded operation between the two parts which is considered as a serious design problem for the assembly. The redesigned part is shown in figure 15b. With this design change the need for holding down the faucet connector is also removed, now the faucet connector can be directly placed on top of the shower head and the redesigned part can just be put on top of subassembly.

CHAPTER FIVE

COMPLETE AUTOMATED ASSEMBLY FOR THE SHOWER HEAD

5.1 TRANSFER SYSTEMS

In automatic assembly the various individual assembly operations are generally carried out at separate workstations. For this method of assembly, a system is required for transferring the partly completed assemblies from workstation to workstation, and a means must be provided for ensuring that no relative motion exists between the assembly and the work head while the operation is being carried out. As the assembly passes from station to station, it is necessary that it be maintained in the required aptitude. For this purpose, the assembly is usually built up on a base or work carrier and the machine is designed to transfer the work carrier from station to station.

Assembly machines are usually classified according to the system adopted for transferring the work carriers. Thus, an in-line assembly machine is one where the work carriers are transferred in-line along a straight slideway, and a rotary machine is one where the work carriers move in a circular path. In both types of machines, the transfer of work carriers may be continuous or intermittent.

In the case of shower head assembly, the work carriers are specifically designed to carry and hold the conical shape base part of the assembly. The work carriers are made exactly in the shape of the part, the dimensions of which are kept smaller so that the part can slide in the work carriers. The work carriers are made up of rubber so that it holds the part firm enough to execute the turning motion which will be encountered later. As for the transferring machine for the shower head assembly, a chain-driven Intermittent transfer work carrier transfer system is employed.

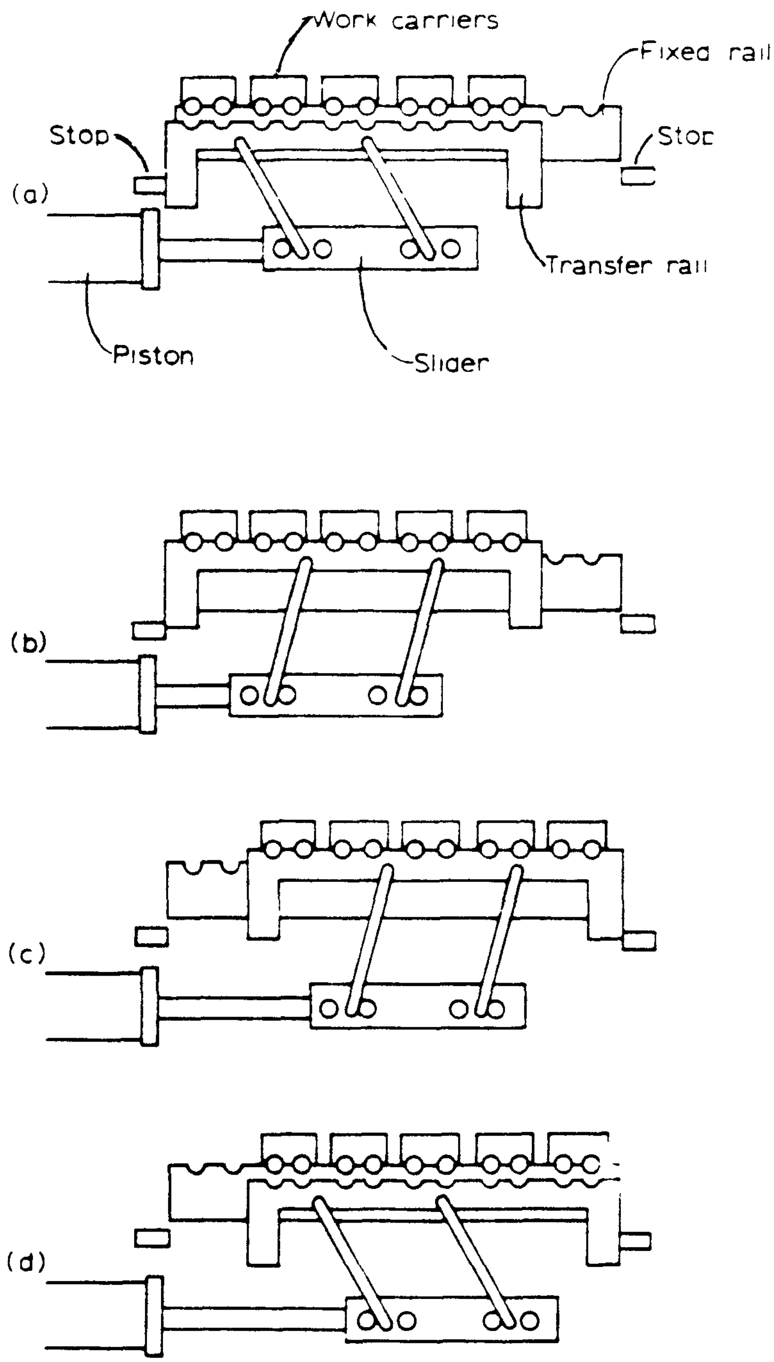
5.1.1 Intermittent Transfer

Basically, this machine uses an indexing mechanism that drives a chain to which are attached the work carriers. The work carriers are spaced to correspond to the distance between the work heads.

The intermittent transfer is more common system employed for both rotary and in-line machines. As the name implies, the work carriers are transferred intermittently and the work heads remain stationary. Usually, the transfer of all work carriers occurs simultaneously and the carriers then remain stationary to allow the time for the assembly operations.

5.2 Types of Transfer Mechanism

The transfer mechanism for the shower head assembly may be one of three types: the walking beam, the shunting work carrier, or the chain-driven work carrier.



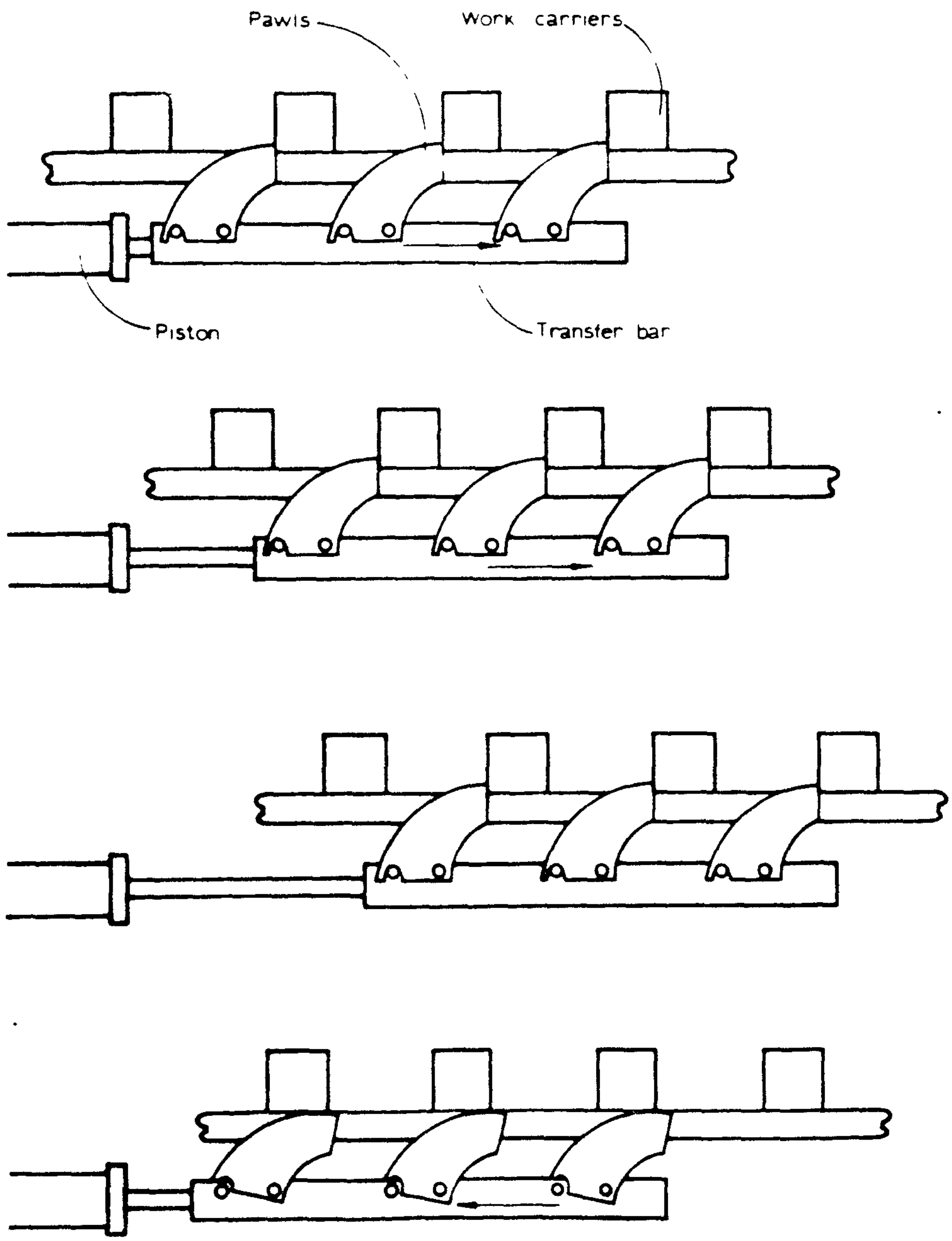
Walking Beam Transfer Mechanism

Figure: 16

5.2.1 Walking Beam Transfer System

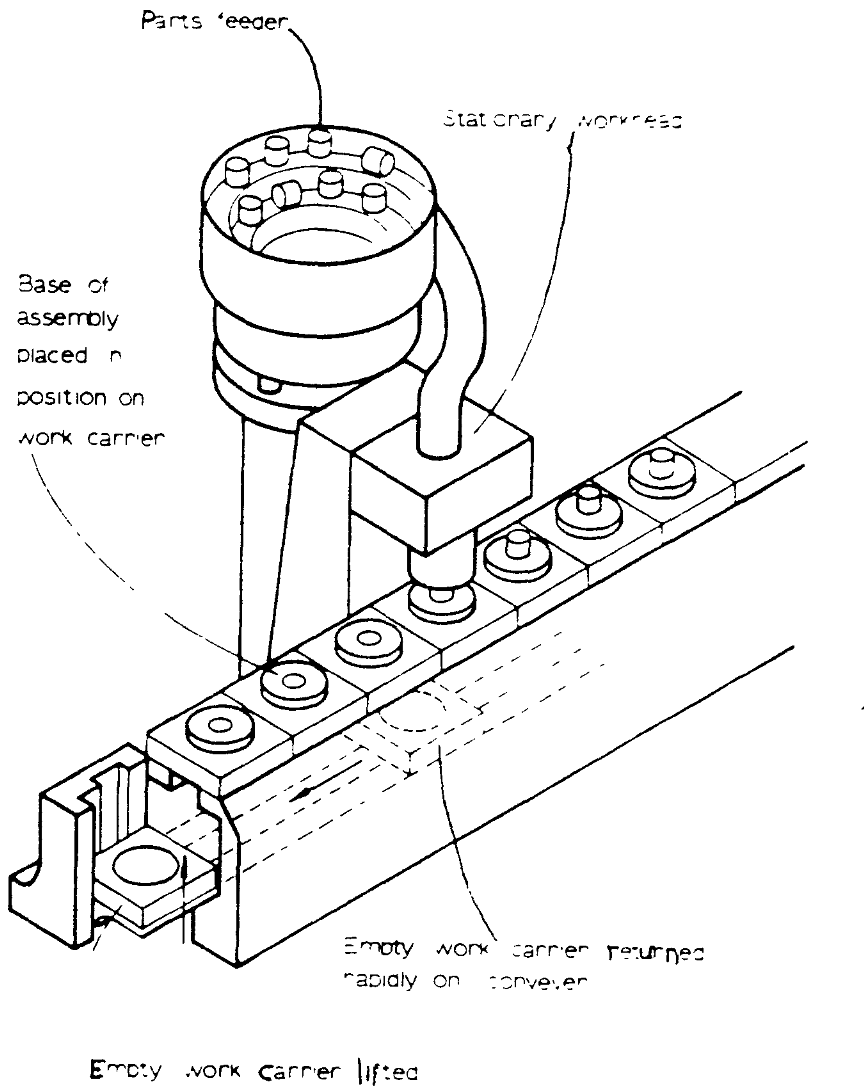
The various stages in the operation of the walking beam are illustrated in figure 16a. The mechanism consists of a fixed rail provided with grooves for location of the work carriers. A transfer rail is driven in such a way that it periodically picks up a series of work carriers and deposits them farther along the fixed rail. To accomplish this, the transfer rail is attached by linkage to a slider which is constrained to move horizontally and is activated by a piston. Figure 16a shows the start of the cycle where the work carriers are resting on the fixed rail and are awaiting the next index.

In figure 16b, it can be seen that as the slider moves to the left, the transfer rail lifts the work carriers from the fixed rail. At this point the supporting linkage has moved just past the vertical and is held in position by a stop. The piston now forces the slider to the right, and the transfer rail and work carriers move along over the fixed rail. In the position shown in figure 16c, further motion of the slider causes the linkage to rotate counterclockwise. The transfer rail falls downward and deposits the work carriers on the fixed rail in the next index position, as shown in figure 16d. The slider then moves to the left, which returns the transfer to its initial position.



Pawl Type Transfer System

Figure: 17



In-line Transfer machine with Shunting Work Carriers Returned in Vertical Plane.

Figure: 18

5.2.2 Pawl-Type Transfer System

Another transfer system, known as Pawl Transfer is shown in figure 17, where it can be seen that reciprocation of the transfer bar over a distance equal to the spacing of the work heads will cause the work carriers to index between the work heads.

5.2.3 Shunting Work Carrier Transfer System

In this system, shown in figure 18, the work carries have lengths equal to the distance moved during one index. Positions are available for work carriers at the beginning and end of the assembly line, where no assembly takes place. At the start of the cycle for operations, the work carrier position at the end of the line vacant. A mechanism pushes the line of work carriers up to a stop as the end of the line is removed. The empty work carrier from a previous cycle that has been delivered by the return conveyor is raised into position at the beginning of the assembly line.

5.3 Indexing Mechanism

While considering the indexing mechanism for the assembly following factors are taken into account.

1. The required life of the machine
2. The dynamic torque capacity required
3. The static torque capacity required
4. The power source required to drive the mechanism
5. The acceleration pattern required

6. The accuracy of positioning required from the indexing unit

The dynamic torque capacity Td, is the torque that must be supplied by the indexing unit during the index of a fully loaded machine. The Td is found by:

$$T_d = \{I+Fr\}*LF$$

where I = effects of the inertia

Fr= friction

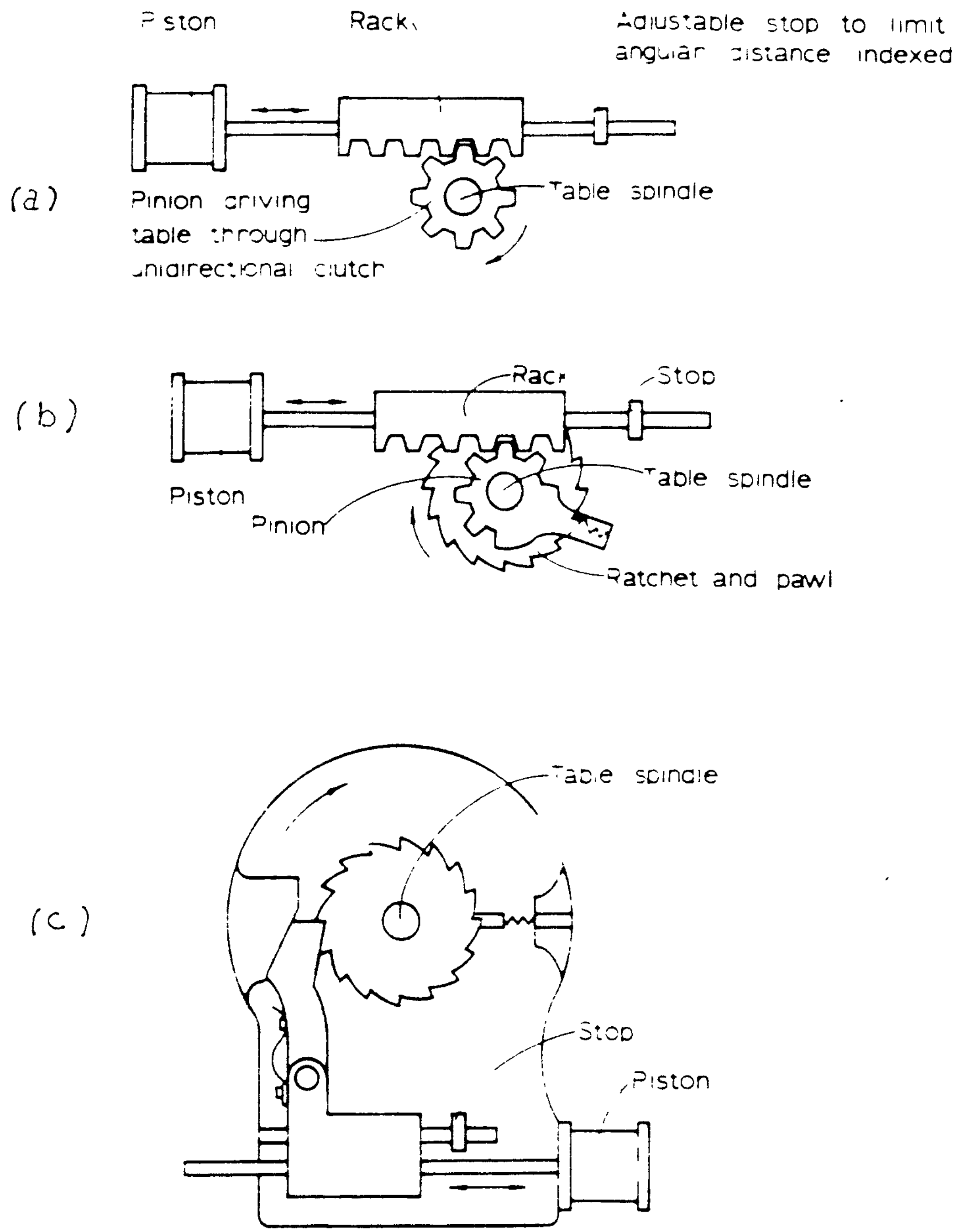
LF= life factor of the unit

the life factor being found from experience with the use of the indexing units.

The static torque Ts capacity is the sum of the torques produced at the unit by the operation of the work heads. The power required to drive an indexing unit will be obtained from the dynamic torque applied to the unit during the machine index.

5.4 Types of Indexing Mechanisms

Various types of indexing mechanisms are available for use on automatic assembly machines, and typical examples are given in figure 19a to figure 19c. These mechanisms fall into two principal categories: those that convert intermittent translational motion (usually provided by a piston) into angular motion by means of a rack and pinion or a ratchet and pawl (figure 19a), those that are continuously driven, such as Geneva mechanism (figure 19b) or the



Types of Indexing Mechanism

Figure: 19

crossover or scroll cam shown in figure 19c.

5.5 Magazine

An alternative means of delivering parts to an automatic assembly machine is from a magazine. With this method, parts are staked into a container or magazine which constrains the parts in the desired orientation. The magazine is then attached to the work head of the assembly machine. The magazines may be spring-loaded to facilitate delivery of the parts, or alternatively, the parts may be fed under gravity or assisted from the magazine by compressed air.

In the case of shower head assembly a rack stacked with the conical part is fed to the orienter, also a similar rack holds the stacked faucet connector on the other side of the assembly where it is fed again to a Rotating Agitator Parts Selector. The magazine is designed such that it is placed at an angle to allow the stacked part to travel under the action of gravity. A small gap according to the size of the part is left open and the part moves ahead one at a time when the gap coincides with the proper profile of the orienting part, as illustrated in figure 20.

Magazines have several advantages over conventional parts feeders and some of these are described below:

1. In some cases, magazines may be designed to accept only parts that would be accepted by the assembly machine work head and thus can act as inspection

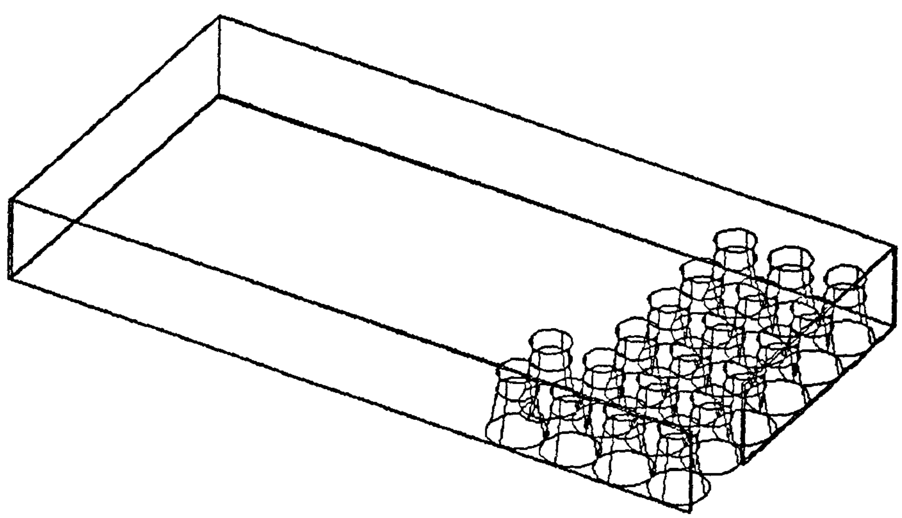


Figure: 20

devices. This can give a considerable reduction in the downtime on the assembly machine.

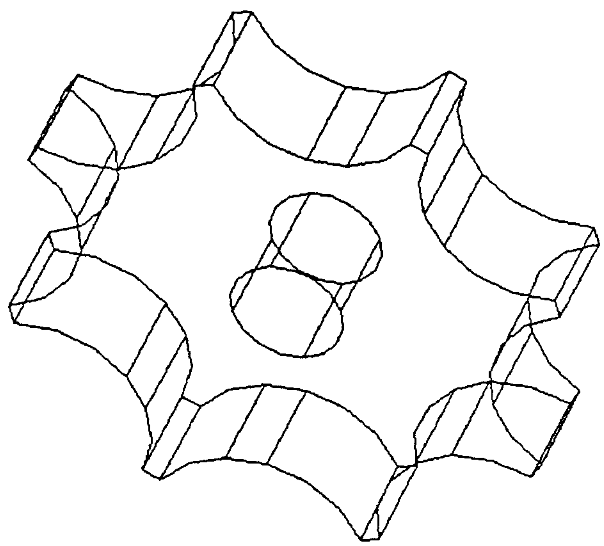
2. Magazines are usually very efficient feeding devices and assembly machine downtime due to feeder or feed track blockages can often be eliminated by their use.
3. Magazines can often replace not only the parts feeder but also the feed track.

Some benefits may be obtained if the magazines are loaded at the assembly factory. If a number of similar parts to be used in an assembly, it may be possible to use one hopper feeder to load all the required magazines. Further, if the magazine is designed to accept only good parts, or some method of inspecting the parts is incorporated into the parts feeder, downtime will occur on the magazine loader and not on the assembly machine.

5.6 Orienter

Part orienters are usually required when the part does not lend itself to any natural selection. If the part does not tend to fall or assume a predictable position with respect to the desired orientation, some external device, or orienter must be employed.

After studying the shape of the conical part of the shower head assembly, a part orienter is designed in the shape of the rotor, as shown in figure 21. The rack or bin type magazine feeder will release the conical part only if the



ORIENTER

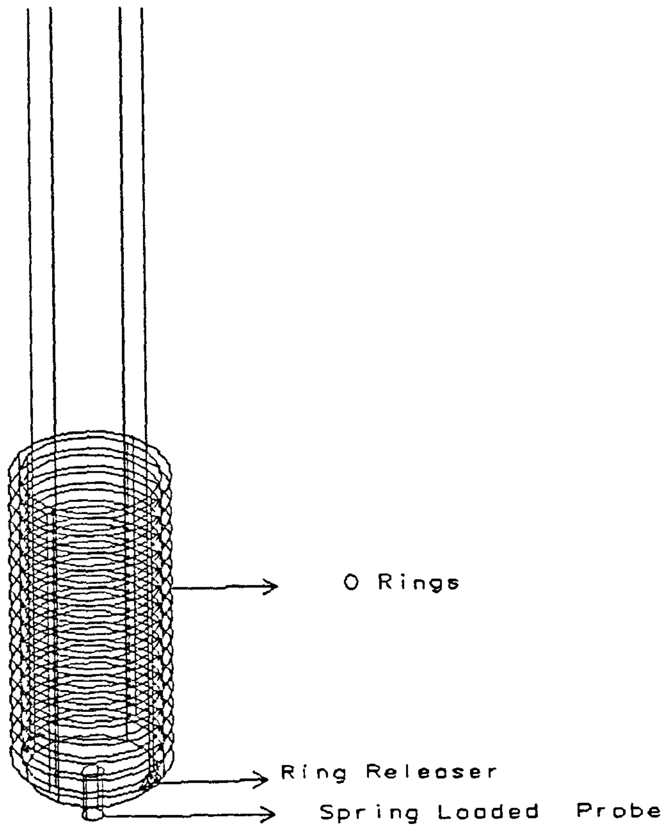
Figure: 21

the slot on the rotor matches the gap of the magazine. The slot of the rotor is designed such that as soon as the part comes in contact with the surface of the slot a spring loaded gripper will grip the part to be delivered on to the work carrier chain. The shape of the work carrier is specifically designed to grip the conical part, therefore when the work carrier on the chain fits inside the conical part, the slot of the rotor will release its grip.

5.7 O Ring Feeder

This device is again custom made to fit the specific need for the shower head assembly. As the O rings or washer is a flexible material it is very difficult to feed it to the required subassembly, therefore to feed the ring without distortion a cylindrical type of magazine is designed which will hold the ring on its outer surface. The rings are staked on the cylinder manually, as illustrated in figure 22.

Near the bottom of the cylinder, a half trapezoidal shape piece is fixed facing downward on both side of the cylinder. This piece restricts the rings to fall down, the trapezoidal piece is connected to a spring mechanism. There is also a probe like projection at the bottom of the cylinder. As the conical part comes directly on top of the cylinder, the intermittent transfer mechanism stops and the cylinder moves down so that the Probe touches the sprinkler resting inside the conical part. The touch activates the



O RING FEEDER

Figure: 22

spring mechanism which in turn depresses the trapezoidal piece and one ring is released on top of the sprinkler.

5.8 Rotating Drum Selecter

The rotating drum selector is designed around a bin having a stationary base and centerpost with a rotating side wall with profiles machined in its lower surface. As the drum rotates, paddles attached to its supporting web agitate the mass of parts to cause a continual realignment of part positions. This is shown in figure 23.

The Valve Holder will be fed manually into the rotating drum selector. The drum will have slots or selector profiles so that the valve holder may slip into. Parts properly oriented will slip into the profiles, or recesses in the drum and be carried upward about one quarter of a turn at which point they may discharge into a track or chute.

Headed parts which are to be fed head down will have a natural tendency to position themselves accordingly in this feeder. Caps, cups or other parts having sufficiently different shapes from face to face are readily oriented at high speeds in this feeder. A minimum of tumbling is possible since parts do not travel all the way upward in the drum rotation. Some parts are caught in the slots and carried around until, when each slot in turn reaches the highest position, it becomes aligned with a delivery chute down which the parts slide. A stationary circular plate at the center of the disk prevents the parts sliding out of the

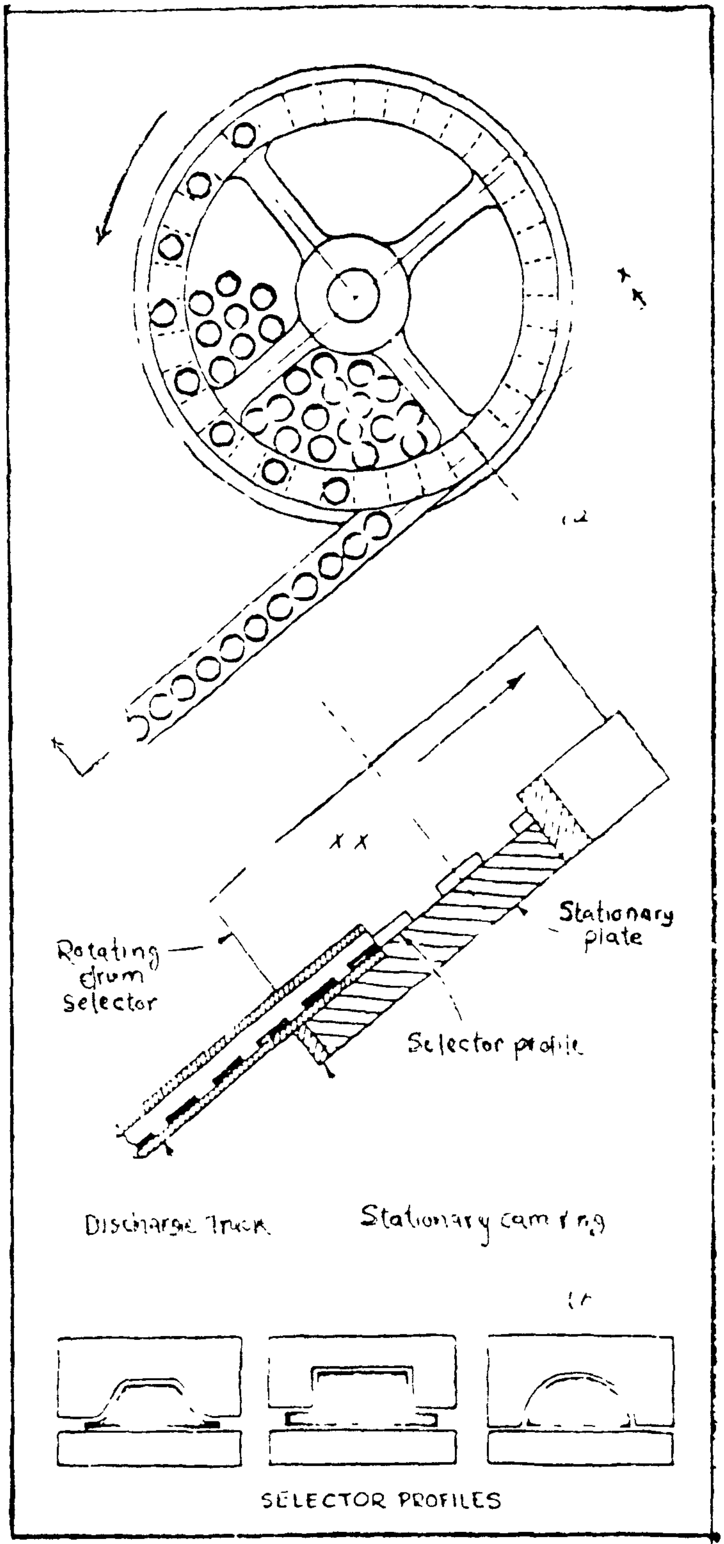

Rotating drum Selector
Stationary plate
Selector profile
Discharge Track
Stationary cam ring
SELECTOR PROFILES

Figure: 23

slots until they are aligned with the chute.

5.9 Indexing Rotary Disk Feeder

The time for index will be approximately equal to the dwell period. For the design illustrated in the figure 24, the time Ts required for all parts in one slot to slide into the delivery chute is given by:

$$Ts^2 = \frac{2l}{g(\sin O - u_d \cos O)}$$

where l = is the length of the slot

O = is the inclination of the delivery chute

ud= is the coefficient of dynamic friction between the part and the chute.

The total period of an indexing cycle Ti is therefore given by:

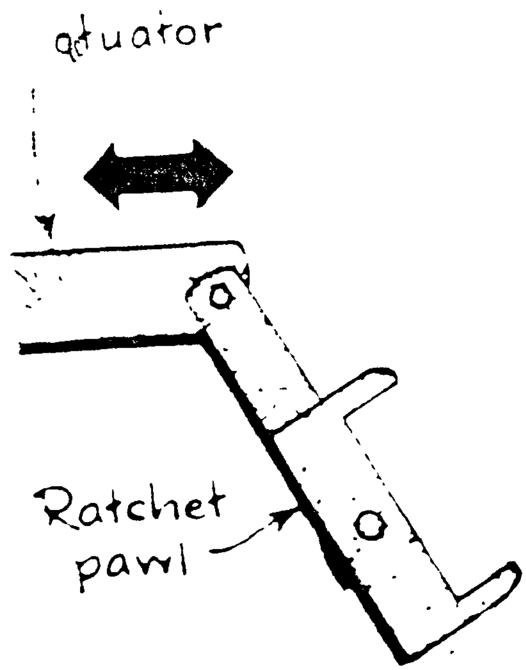
$$T_i = 2Ts = \frac{(8l)^{1/2}}{g\{\sin O - u_d \cos O\}^{1/2}}$$

If L is the length of a part, the maximum number that may be selected in a slot is l/L. However, in practice the average number selected will be less than this. If E is the efficiency of the feeder, the feed rate F will be given by

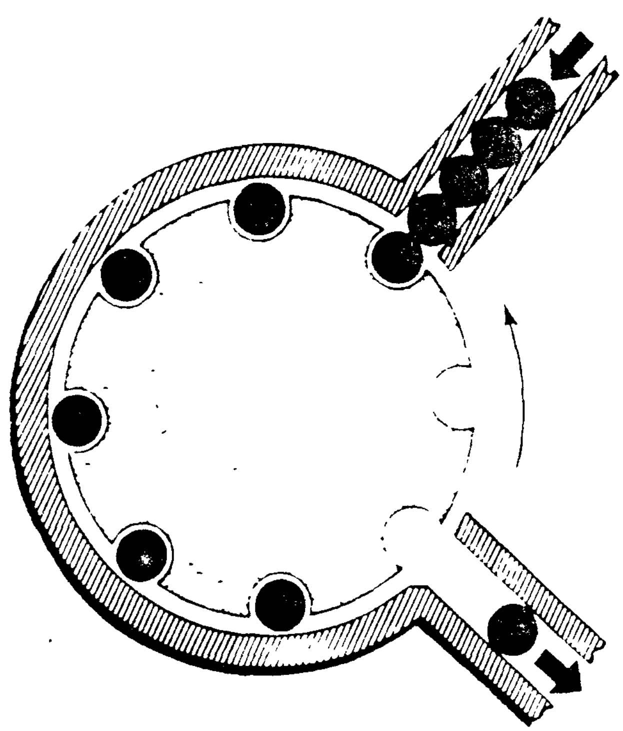
$$F = \frac{El}{LT_i} = \frac{E\{ lg(\sin O - u_d \cos O) \}^{1/2}}{8l^2}$$

It can be seen from the above equation that if E is assumed to remain constant:

1. The feed rate is independent of the number of slots



Ratchet Escapement



Drum Escapement

Figure: 24

in the disk.

2. For a given feeder the feed rate is inversely proportional to the length of the part.
3. For maximum feed rate with a given part, u_d should be as low as possible and both the delivery chute angle 0 and the slot length l should be as large as possible.

5.10 Escapements

Many types of escapement have been developed and quite often, for a given part, there are several different types available that will perform the required function. Some of the examples of different types of escapements are: Ratchet, Slide, Drum, Gate, Displacement and Jaw.

In the assembly of the shower head two different types of escapements have been used, one is the ratchet type and the other is the drum type.

5.10.1 Ratchet Escapements

This type of escapement is employed on the gravity chute. The valve holder coming down from the rotating drum selector are retained in the chute and allowed to pass one at a time by the escapement. A ratchet escapement is shown in figure 24. The pawl of the ratchet is designed so that as its front finger lifts clear of the line of the valve holder, its back finger retains either the next part, or a part further up the line. Ratchet escapements operating on several feed tracks can be activated from a single mechanism.

5.10.2 Drum Escapement

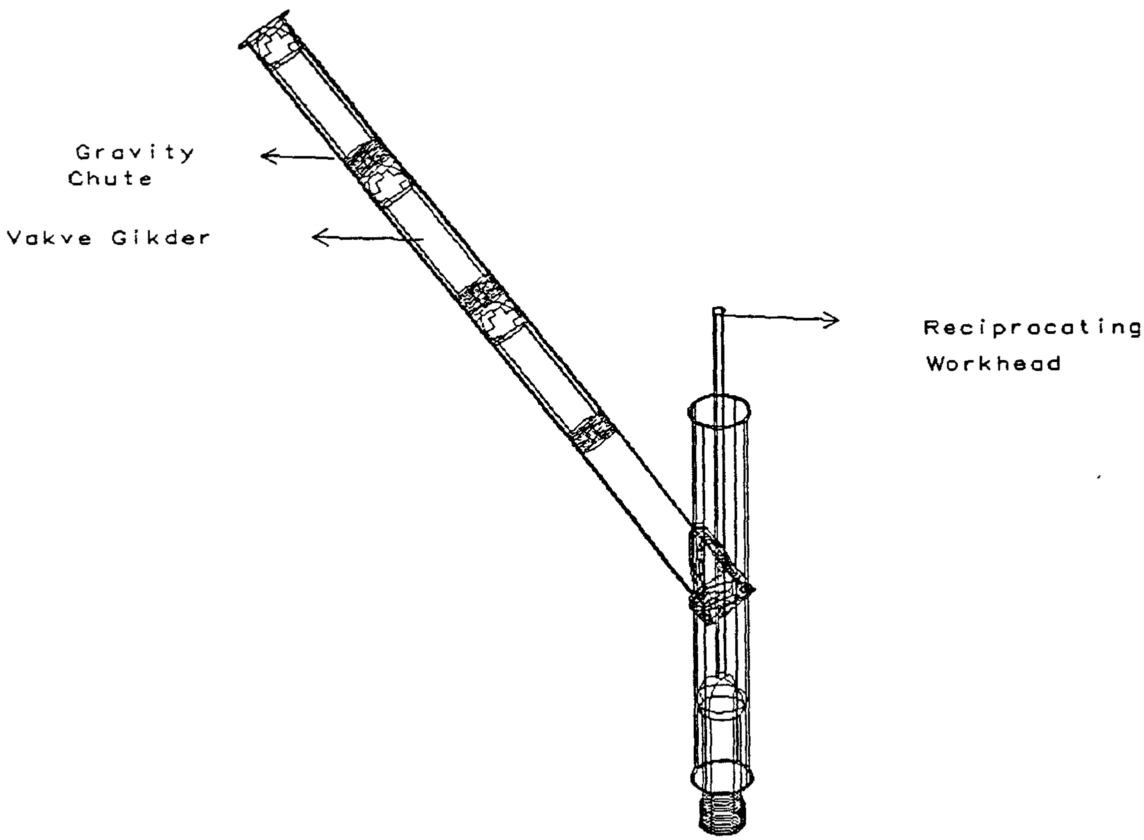
It is usually referred to as Drum-Spider escapement. The drum escapement is used to feed the mechanical arm with the faucet connector. The faucet connector is fed directly to the drum escapement by a similar bin or rack like feeder used for the feeding of the conical part to the rotor. The Drum escapement is shown in figure 24.

The drum is mounted vertically and the parts are either fed and delivered side by side or fed ind to end and delivered side by side. Other type of drum escapements are the star-wheel and worm.

5.11 Part Placing Mechanism

Two simple types of parts-placing mechanisms have already been described, that is the ratchet type and the rotating drum. These special applications, however, can only be used for a very limited range of parts and by far the most widely used parts-placing mechanism is a conventional gravity feed track working in conjunction with an escapement. This system of parts placing is probably the cheapest available but has certain limitations.

First, it may not be possible to place and fasten parts at the same position on the machine, because of interference between feed track and the work head. This would necessitate



Part Placing Mechanism

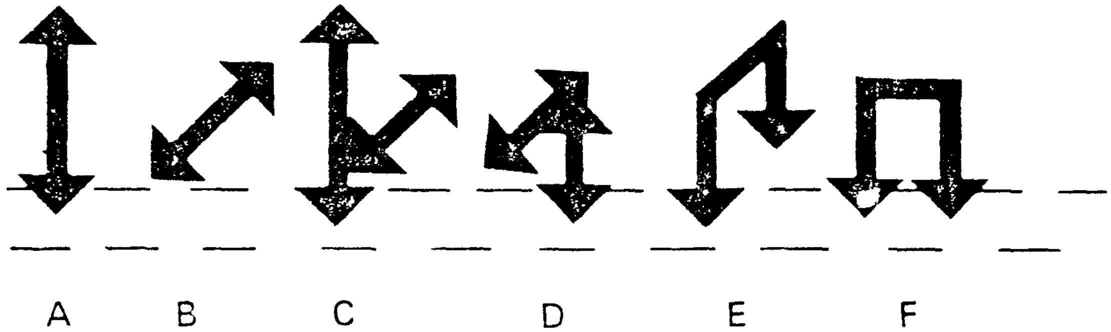
Figure: 25

a separate workstation for positioning the part, which would result in a an increase in the length of the machine. It then becomes necessary to retain the part in its correct orientation in the assembly during transfer.

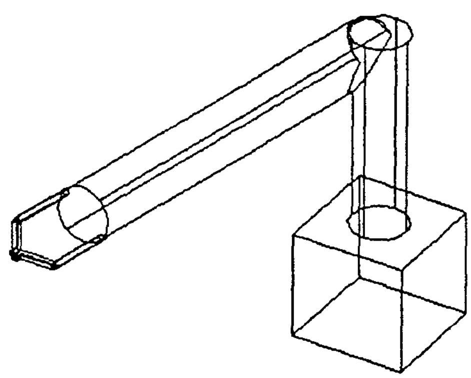
Second, if a close fit is required between the part and the assembly, the force due to gravity may not be sufficient to ensure that the part sits properly.

Third, if the part cannot be suitably chamfered, the gravity feed track may not give the precise location required. However, for placing of screws and rivets prior to fastening, which together form a large proportion of all parts-placing requirements, and where the tool activates the escapement and applies the required force to make assembly possible, the gravity feed track is invariably used.

Keeping these points in mind, a gravity feed track is designed to feed, place and screw the threads of the valve holder of the shower head assembly, illustrated in figure 25 The valve holder will drop down the gravity chute one at a time with the help of the ratchet escapement. The part that passes the ratchet will go in the other chute placed directly on top of the subassembly, the jaw escapement will position the valve holder while the reciprocating hexagonal shape work head will wound the threads of the part in the subassembly.



(a) Typical Standard Placement Device Motions



(b) Mechanical Arm

Figure: 26

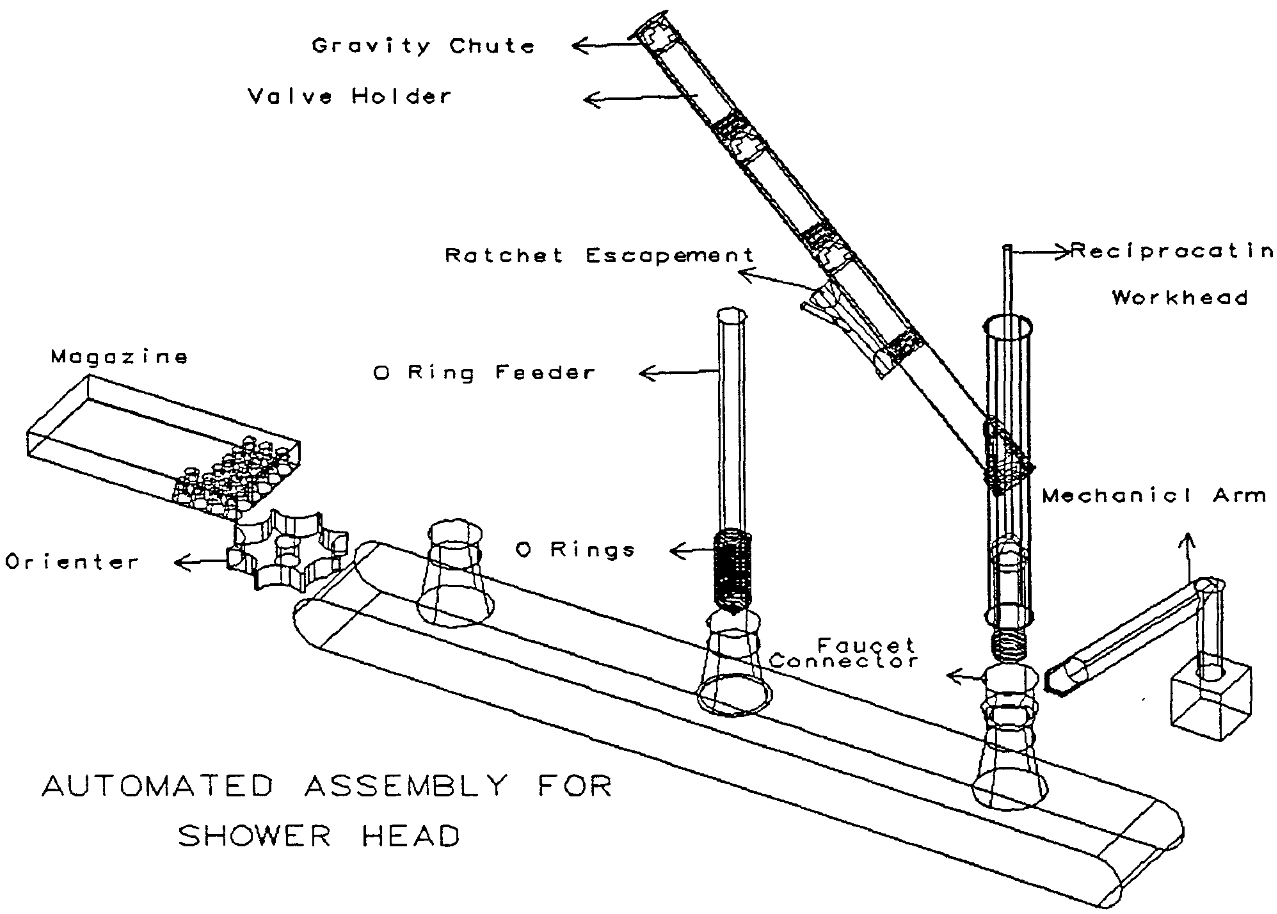
5.12 Mechanical Arm

For situations where the placing mechanism has to be displaced from the workstation location, the pick and place system is often used. The basic action of this system is shown in the figure 26a, where it can be seen that the device may follow one or combination of these paths.

A standard, off-the-shelf pick and place device available for use with electric motor, hydraulic or air motor drives is employed at the end of the assembly line, as illustrated in figure 26b. This device picks the faucet connector released one at a time by the drum escapement in a proper orientation and is placed on top of the conical part subassembly. The device holds the faucet connector in its place till the reciprocating work head starts to wound the thread on to the subassembled part.

After the selection of the fixtures, work heads, transfer devices, feeders, magazines and orienters, the final assembly sequence of the shower head assembly is shown in figure 27.

The conical part fed by the gravity rack or bin, is oriented on to the work carrier attached on top of the transfer device which is of the intermittent type. The part travels until it comes directly beneath the ring feeder, at this work station the O ring is dropped inside the conical part and rests on the projection of the said part. The subassembled part again travels until comes to the next workstation, the gravity chute. At this workstation three



Complete Shower Head Assembly

Figure: 27

separate operation is taking place, first, the mechanical arm picks the faucet connector released from the drum escapement and places it on top of the subassembled conical part. The ratchet releases only one valve holder which has been fed and oriented by the rotating drum selector, and the reciprocating hexagonal work head winds the thread of the valve holder on to the conical part, during the winding of the thread the work carrier being made of rubber grip the conical shape part and restricts its movement.

The automated assembly process of the shower head assembly terminates at the workstation two after which it drops into a collector bin under the action of the gravity. The part is then taken to a manual assembly station, where the valve pin is inserted inside the valve holder, with this process a complete shower head is ready to be dispatched to the packaging department.

CHAPTER SIX
ANALYSIS FOR THE AUTOMATED ASSEMBLY

The analyses for the automated shower head assembly is done using the principle described in the Handbook for Product Design for Assembly by Boothroyd and Dewhurst.

The techniques described in this handbook are concerned with minimizing the cost of assembly within the constraints imposed by the other design features of the product.

This chapter contains two different sections dealing with manual and automatic assembly analyses for the shower head, as well as a section to help determine which type of system is most practical for the product being considered, identify assembly difficulties and estimate assembly cost.

6.1 Feasibility Study

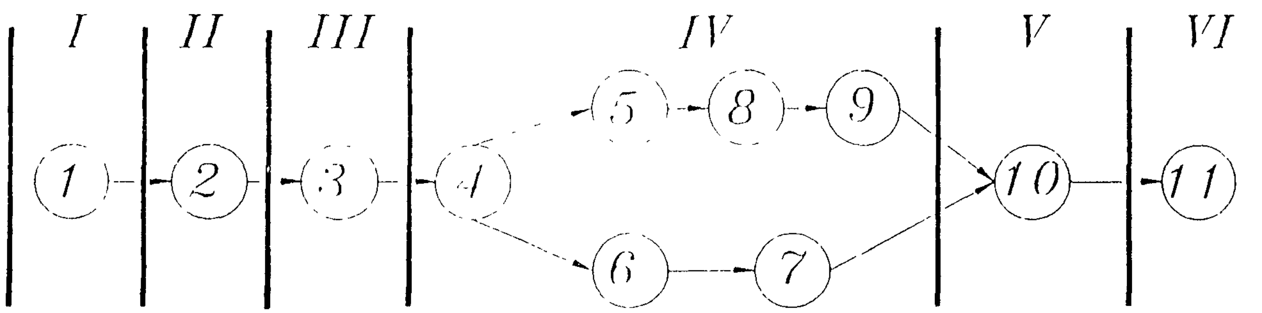
The decision to build or purchase an automatic assembly system is generally based on the results of a feasibility study. The object of this study is to predict the performance and economics of the proposed system. In automatic assembly these predictions are likely to be subject to greater errors than with most other types of production system. Mainly because the system is probably one of a kind and its performance will be very dependent on the qualities of the parts to be assembled. Also, similar systems will not generally be available for study. Nevertheless, a feasibility study must be made and all the knowledge and experience acquired in the part from automatic assembly projects must be applied to the problem in order to give predictions that are as accurate as possible.

Certain information is clearly required before a study can be made. For example, maximum and minimum production rates during probable life of the machine must be known. The range of variation in these figures are very important because a single assembly machine is very inflexible. The operators required on the machine must all be present when the machine is working, or if the machine is stopped due to a fall of demand for the product. they must be employed elsewhere. Thus, automatic assembly systems are generally suitable only when the volume of production is known to be steady. Other information required for the feasibility study are described below:

6.2 Precedence Diagrams

It is always useful when studying the assembly of a product to draw a diagram which shows clearly and simply the various ways in which the process may be carried out. In most assemblies there are alternatives in the order in which some of the parts may be assembled. There are also likely to be some parts where no flexibility in order id allowed. For example, in the shower head assembly as shown in figure 27, the O ring can only be inserted after the sprinkler is placed inside the conical part. Further, the directional ball can only be threaded to the valve holder after it is

PRECEDENCE DIAGRAM FOR SHOWER HEAD ASSEMBLY



1 *Shower Head fed into the rotor mechanism which in turn grips the part.*
2 *Shower Head is transferred on to work center*
3 *Ring feeder mechanism is activated*
4 *Rings are assembled on to the shower head.*
5 *Drum Agitator selects valve holder in right profile.*
6 *Drum escapement rleases on 'Faucet'connection.*
7 *Mechanical arm assembles and grips the 'Faucet' connection.*
8 *The ratchet escapement releases one V H from gravity chute on to the sub assembly.*
9 *The hexagonal work head activates and performs the turning operation.*
10 *Automatic shower head assembly is completed and dropped into the collector bin*
11 *Manual insulation of valve is performed.*

I through VI are the sets of mutually exclusive steps.

Figure: 28

placed inside the faucet connector.

The precedence diagram is designed to show all the possibilities in which the order of the assembly can take place. A precedence diagram for the s shower head assembly is shown in figure 28, where it can be seen that each individual operation has been assigned a number and is represented by an appropriate circle with number inscribed. The circles are connected by arrows showing the precedence relations.

In drawing the precedence diagram, all the operations that can be carried out first are placed in column 1. Usually, only one operation appears in this column: the placing of the base part on the work carrier. Similarly other column is drawn for different operation, these indicates that all the operation that must be completed before the operation under consideration can be performed.

6.3 Quality Level of Parts

If assembly of a completely new product is to be contemplated, the estimation of the quality levels of the parts may be extremely difficult, in not impossible. However, a large proportion of assembly machine feasibility studies are concerned with existing products, and in these cases experiments can be performed to determine the quality levels of the various parts.

6.4 Parts Feeding and Assembly

An estimate must now be made of the degree of difficulty with which the individual parts can be automatically fed and assembled. It should be noted here that for each operation, four possibilities exist:

1. Automatic feeding and assembly
2. Manual feeding and automatic assembly
3. Automatic feeding and manual assembly
4. Manual feeding and assembly

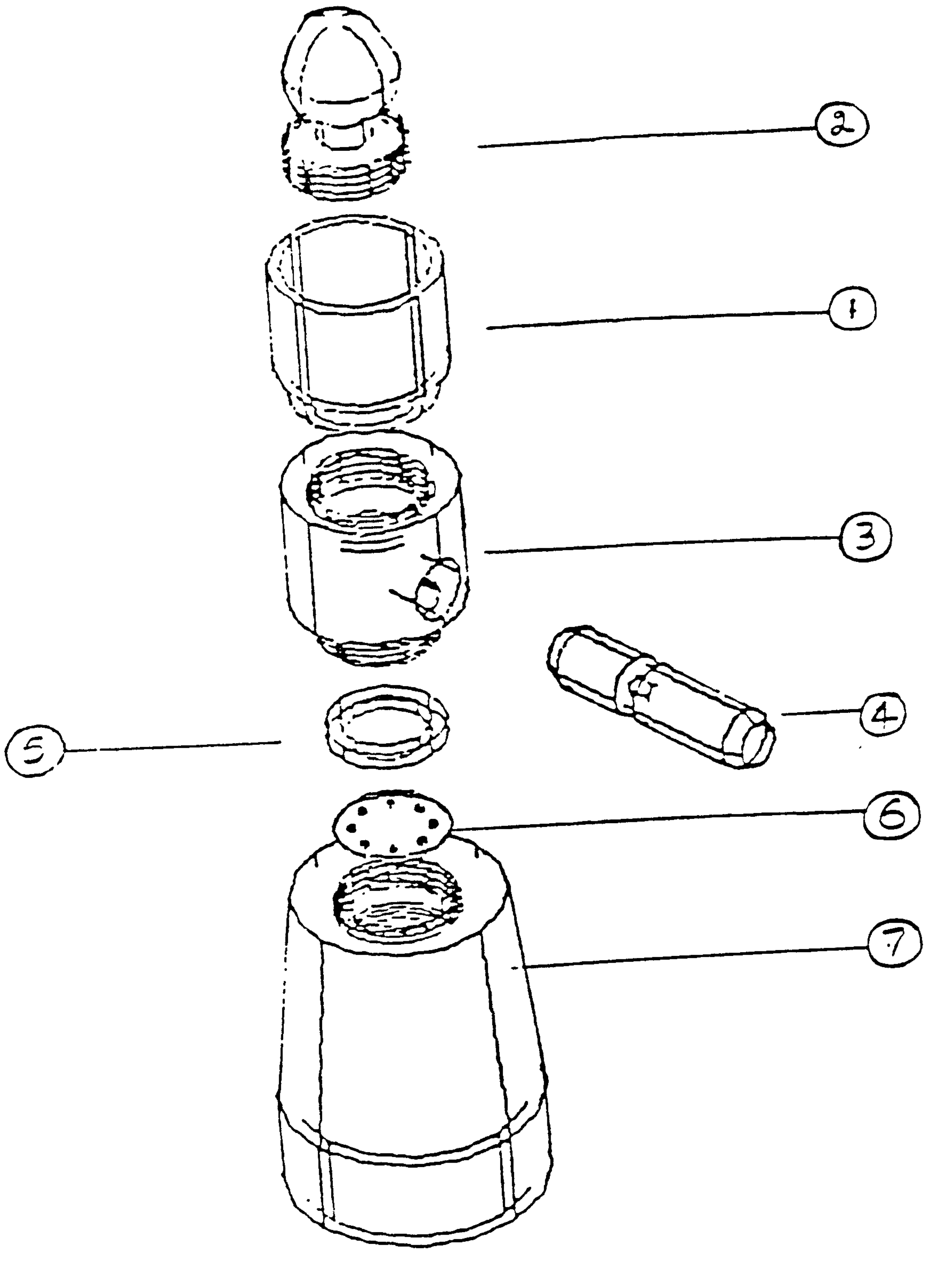
The technique for the design analysis of shower head assembly involves two important steps for each part in the assembly:

1. A decision as to whether the part can be considered a candidate for elimination or combination with other parts in the assembly;
2. An estimation of the time taken to grasp, manipulate and insert the part.

Having obtained this information it is then possible to obtain the total assembly time and to compare this figure with the assembly time for an ideal design.

6.5 Procedure for the Analysis of Shower Head for Manual Assembly

The method for analyzing the design, to identify those features resulting in high assembly costs, and then to



Exploded View of Shower Head Assembly
Figure: 29

calculate the design efficiency, is contained in the following steps.

STEP 1. Obtain the best information about the product or assembly. Useful items are:

* Engineering drawings
* Exploded three-dimensional views
* An existing version of the product
* A prototype

In figure 29, an exploded view of the shower head is shown.

STEP 2. Take the assembly apart (or imagine how this might be done). Assign an identification number to each item, as it is removed. In the figure 29 an identification numbers are shown on the exploded view. The base part of the assembly, that is, the conical part has been assigned number 1, where as the faucet connector is assigned number 7. If the assembly contains sub-assemblies treat these, at first, as parts and then analyze the sub-assemblies later. In this case there is no sub-assemblies involved.

STEP 3. Prepare a detail design for assembly worksheet for the shower head.

STEP 4. Begin to reassemble the product. First assemble the part with the highest identification number to the work fixture, then add the remaining parts one-by-one. To correctly use this analysis procedure, never assume that parts are grasped one in each hand and then assembled together before placing them in the partially-completed assembly.

Complete one row on the worksheet for each part.

Column 1. The identification number for the conical part is "7".

Column 2. The operation is carried out once, hence, "1" is entered.

Column 3. The two digit handling process code is generated from Chart 2-1, "Manual Handling-Estimated Times." For the conical part the code is "10".

Column 4. The handling time (1.5 seconds) is obtained from Chart 2-1 and corresponds to the two digit code.

Column 5. The insertion process code is a two digit number derived from Chart 2-2 "Manual Insertion-Estimated Time." For the conical part the code is "00".

Column 6. The insertion time (1.5 seconds) is obtained from Chart 2-2 and corresponds to the code.

Column 7. The total operation time in seconds is calculated by adding the handling and insertion times in column 4 and 6, and multiplying this sum by the number of repeated operation in column 2.

Column 8. The total operation cost in cents is obtained by multiplying column 7 by 0.4 where this later figure is typical manual assembly rate in cents per second.

second. However, different company may use different rates.

Column 9. It is in this column the figures are inserted which allow the theoretical minimum number of parts for the assembly to be determined. The estimation of this figure is a particularly important step in completing the analysis. As each part is added to the assembly and regardless of practical limitations, the designer must answer the following questions:

1. During operation of the product, does the part move relative to all other parts already assembled? Only gross motion should be considered-small motions that can be accommodated by elastic hinges, for example, are not sufficient for a positive answer.
2. Must the part be of a different material than or be isolated from all other parts already assembled? Only fundamental reasons concerned with material properties are acceptable.
3. Must the part be separate from all other parts already assembled because otherwise necessary assembly or disassembly of other separate parts would be impossible?

For the assembly of shower head the answer is yes, therefore "1" is entered in column 9. The complete worksheet for Design For Assembly is shown in figure 30.

STEP 5. When all rows have been completed the figures in Column 7 are all added to give total estimated manual assembly time. For the shower head assembly this figure comes out to be 37.52 seconds/part. Also, Column 8 are added to give the cost of manual assembly for the shower head, which comes out to be 15.0 cents per part.

DESIGN FOR MANUAL ASSEMBLY WORKSHEET

1	2	3	4	5	6	7	8	9	Name of Assembly
part I.D. No.	number of times the operation is carried out consecutively	two-digit manual handling code	manual handling time per part	two-digit manual insertion code	manual insertion time per part	operation time, seconds (2)x[(4)+(6)]	operation cost, cents 0.4x(7)	figures for estimation of theoretical minimum parts	
7	1	10	1·5	00	1.5	3·0	1.2	1	SHOWER HEAD
6	1	03	1·69	03	3.5	5.19	2.076	0	SPRAYING PLATE/SPRINKLER
5	1	03	1.69	01	2.5	4.19	1.676	1	O RING
4	1	00	1·13	3.0	2.0	3.13	1.252	1	VALVE
3	1	10	1·5	38	6.0	7.5	3.0	0	VALVE HOLDER.
2	1	10	1.5	06	5.5	7.0	2·8	1	FAUCET CONNECTOR
1	1	10	1·5	38	6·0	7.5	3.0	1	DIRECTIONAL BALL
						37.51	15.00	5	design efficiency = 3xNM/TM = 39.9%
						TM	CM	NM	

Figure: 30

STEP 6. Finally, the manual assembly design efficiency is obtained by entering the figures generated from the worksheet into the equation:

$$EM = 3 * NM/TM$$

Where EM = manual design efficiency

NM = theoretical minimum number of parts

TM = total manual assembly time

This equation compares the estimated assembly time for an assembly containing the theoretical minimum of parts each of which can be assembled in the ideal time of 3 seconds. This time is obtained by assuming that each part is easy to handle and insert. Also, about one-third of the parts are secured immediately on insertion with well-designed snap-fit elements.

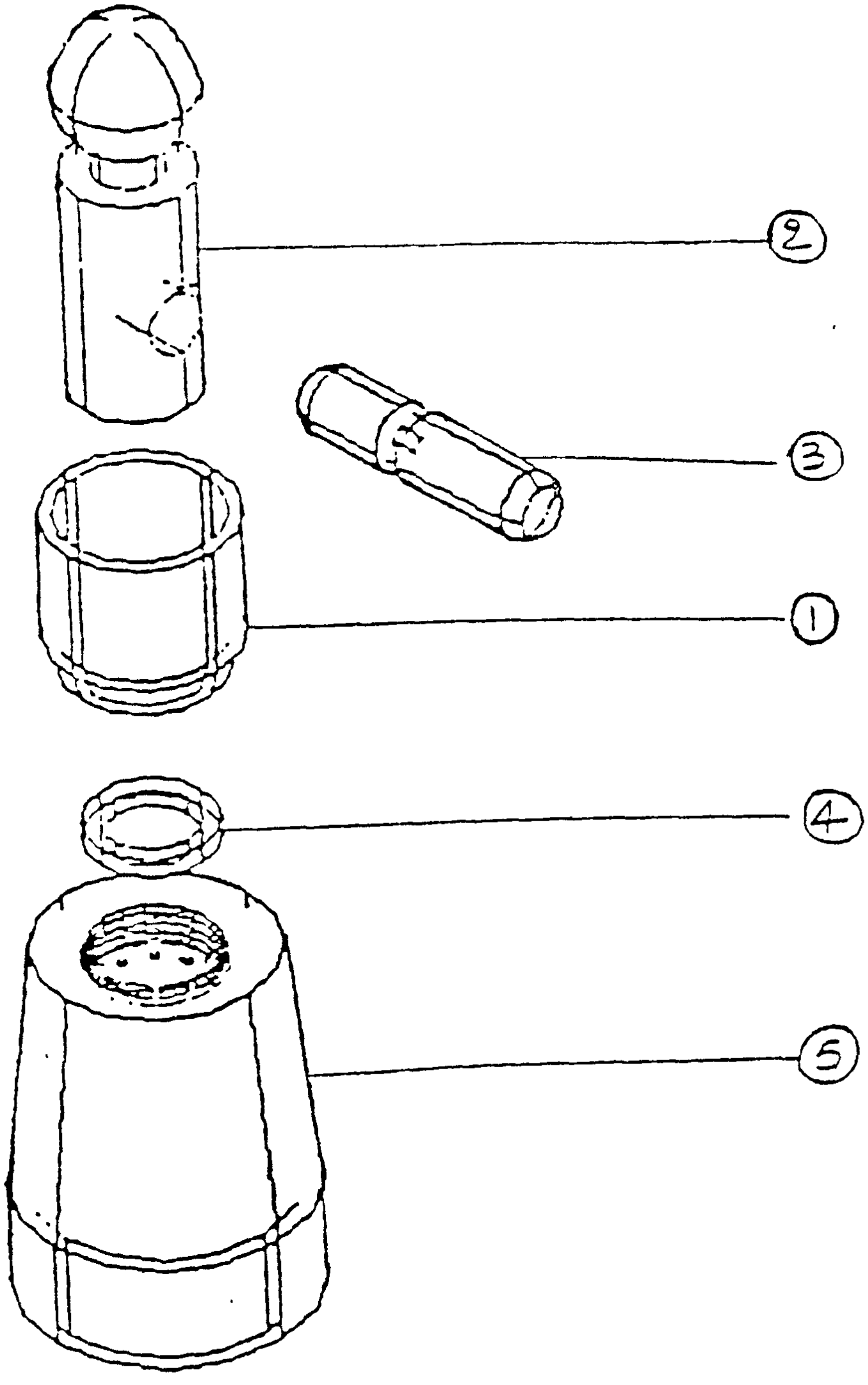
Thus, the estimated design efficiency for shower head comes out to be:

$$\frac{3 * 5}{37.52}$$

$$EM = 39.97 \text{ percent}$$

6.6 Procedure for the Analysis of Shower Head for Automated Assembly

The technique used involves a systematic classification of the features of the design in order to estimate the full cost of automation. The technique also identifies areas for



Exploded View for Shower Head Assembly
Automatic Assembly

Figure: 31

possible improvement through re-design. The re-design for the shower head for the automated assembly is already done in the previous chapter. With the re-designed shower head the production rate is assumed to be 20 parts per minute. The worksheet is completed in seven steps.

STEP 1. Obtain the best information about the product or assembly. Useful items are:

* Engineering drawings
* Exploded three-dimensional views
* Existing versions of the product
* A Prototype

Figure 31 shows an exploded view for the redesigned shower head assembly.

STEP 2. Take the assembly apart. Assign an identification number to each item.

STEP 3. Refer to the design for automatic assembly worksheet in figure 32.

STEP 4. Begin to re-assemble the product, beginning with the highest identification number. Complete the first row of the worksheet for the Shower Head as:

Column 1. The I.D. number for the conical part is entered as "5".

Column 2. The operation is carried out once, hence "1" is entered.

Column 3. The part feeding and orienting code is determined for the part using Chart 4-1 to 4-4. The conical part is assigned code number "13000". This determines the data to be entered in Column 4 and Column 5.

Column 4. OE = 0.7

Column 5. CR = 3.0

Column 6. The size of the conical part is 37.5 m.m and so the maximum feed rate FM, from a standard feeder is given by FM = 1500 * .7/37.5 = 28.0 parts/m.

Column 7. The required assembly rate is 20 parts per minute that is, FR = 20. Since this required rate is less than FM, the difficulty rating for automatic handling is given by:

$$DF = CR * 60/Fr$$

$$DF = 3$$

Column 8. The cost for feeding and orienting each unit of Conical part is:

$$CF = 0.03 * DF$$

$$= .09 \text{ cents}$$

Column 9. The conical parts are inserted into the work carrier, which has been designed to allow easy alignment and positioning from vertically above. The two digit code obtained from Chart 4-5 is "00".

Column 10. The relative workhead cost from Chart 4-5

WC = 1

Column 11. FR = 20 and so the difficulty rating for

DESIGN FOR AUTOMATIC ASSEMBLY WORKSHEET

1	2	3	4	5	6	7	8	9	10	11	12	13	14	required rate of assembly FR (per minute) 20
part I D No	number of times operation is carried out simultaneously	five-digit automatic handling code	orienting efficiency OE	relative feeder cost CR = FC + DC	maximum basic feed rate FM	difficulty rating for automatic handling DF	cost of automatic handling per part CF = 0.03 x DF	two-digit automatic insertion code	relative workhead cost WC	difficulty rating for automatic insertion DI	cost of automatic insertion per part, CI = 0.06 x DI	operation cost cents (2) x [(8) + (12)]	figures for estimation of theoretical minimum parts	Name of Assembly
5	1	10000	·7	1	28	3	·09	00	1	3	·18	·27	1	REDESIGNED SHOWER HEAD
4	1	00012	·7	5	70	12	·36	01	15	45	·27	·63	1	O RING
3	1	24000	MANUAL ASSEMBLY REQUIRED									125	1	VALVE
2	1	2300	·85	1	2771	3	·09	38	·8	2·4	144	·234	1	REDESIGNED. VALVEHOLDER + DIRECTIONAL BALL.
1	1	03000	·5	1	3947	3	·09	08	2	60	·36	·45	1	FAUCET CONNECTOR
												2834 CA	5 NM	Efficiency = $\frac{0.09 \times NM}{CA} \times \frac{60}{FR}$ = 47.7

Figure: 32

automatic insertion is:

$$DI = (60/FR)*WC = 3$$

Column 12. The cost of insertion for each unit is

$$CI = 0.06*DI = 0.18 \text{ cents per part.}$$

Column 13. The total operation cost for feeding, orienting and inserting the part is the sum of Column 8 and Column 12 multiplied by the numbers of simultaneous operations.

Column 14. The correct number for entry in Column 14 is obtained by applying the three criteria in turn to each of the conical part. The appropriate number in Column 14 is "1". The complete work sheet of Design For Automatic Assembly is shown in figure 32.

STEP 5. Continue to enter the data for each part in the assembly into successive rows in the worksheet, until the final operation has been performed.

STEP 6. Obtain the total cost of automatic handling and insertion, CA, and the theoretical minimum number of parts, NM, by adding the numbers in Column 13 and Column 14 respectively. For the present example,

$$CA = 2.052$$

$$NM = 5$$

STEP 7. Finally, the automatic assembly design efficiency is obtained by entering the figures generated from the worksheet into the equation:

$$EA = 0.09*NM * 60/FR$$

Where EA = automatic assembly design efficiency

NM = theoretical minimum number of parts

FR = required assembly rate

By putting the figures in the above formula the design efficiency comes out to be

EA = 47.77 percent

6.7 Results

Redesigning the shower head for automatic assembly reduces the theoretical minimum number of parts from 7 to 5. The reduction and simplification of the part res savings from 15.0 cents per part to 2.834 cents per part. Further, the assembly design efficiency increased from 39.97 percent to 47.77 percent.

CHAPTER SEVEN
CONCLUSIONS AND RECOMENDATIONS

There is no such thing as a standard assembly process. Each system is a custom operation. Using a combination of mechanized handling equipment and automatic feeding and orientation of parts a complete assembly process is developed for the Shower Head.

While developing an automated assembly, one of the basic consideration is the Design for Assembly of the part. Good Design For Assembly practice requires that the parts should be added in layer fashion from the base part and should either be self-locating or secured immediately. The Shower Head equipment has been redesigned keeping this in mind Initially the assembly consisted of seven part. After using the design principles for the automatic assembly the number of parts are reduced to five, that is, the base part and the spraying plate is joined together, the valve holder and directional ball are made as one unit. Further application of the principles resulted in the part simplification and ease of assembly, that is, a complex and costly assembly operation of threading the two part is totally eliminated.

The next step is the analysis of the assembly on the basis of design changes of the Shower Head. For this, Boothroyd and Dewhurst handbook on Product Design for Assembly is used. A comparison of Manual versus Automatic assembly operation is done to see whether it is feasible to assemble the shower head automatically. The results indicate that the assembly design efficiency increased from 39.9 percent to 47.7 percent. The results also show that the cost of assembling is reduced from 15.00 cents per part to 2.834 cents per part when the shower head is assembled automatically. Further, the production rate is increased from 2 assemblies per minute to 20 assembly per minute which is one of the basic reasons to have automation in any area.

The complete automation of the Shower head assembly is done by designing the equipments used at each workstation including:

* Magazine to feed the base part
* Orienter for the base part
* Workcarrier to hold and transfer the base part
* O Ring Feeder
* Rotating Drum selector for the valve holder
* Gravity Chute for the valve holder
* Ratchet Escapement for the valve holder
* Drum Escapement for the faucet connector
* Workhead for fastening threads.
* Mechanical Arm to place and hold the faucet connector

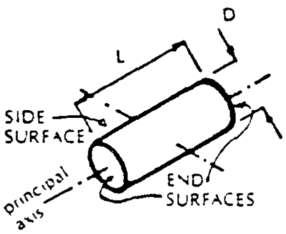
The complete assembly process and individual workstation is explained with the help of "IDEAS" software developed drawings.

APPENDIX

AUTOMATIC HANDLING-DATA FOR ROTATIONAL PARTS
(first digit 0, 1 or 2)

KEY

first digit		OE	FC
	0 ▷	0 3	1
	1 ▷	0 15	1 5
	2 ▷	0 45	1 5



		part is symmetrical about its principal axis (BETA symmetric) (see note 2)	part is not BETA symmetric (code the main feature or features requiring orientation about the principal axis)						
			BETA asymmetric projections steps or chamfers (can be seen in silhouette)			BETA asymmetric grooves or flats (can be seen in silhouette)			slightly asymmetric or small features less than D 10 and L 10 OR holes or recesses which cannot be seen in outer shape of silhouette
			on side surface only	on end surface(s) only	on both side and end surface(s)	through groove or flat can be seen in end view	through groove can be seen in side view: on end surface	through groove can be seen in side view: on side surface	
		0	2	3	4	5	6	7	8
part is ALPHA symmetric (see note 1)	0	0 7 1 0 7 1 0 9 1	0 3 1 0 15 1 0 45 1	0 5 1 0 2 1 0 9 2	0 3 1 0 15 1 0 45 1	0 35 1 0 2 1 0 9 1	0 2 1 0 2 1 0 9 2	0 5 1 0 2 1 0 9 2	
part is not ALPHA symmetric (code the main feature or features requiring end to end orientation) (see note 1): part can be fed in a slot supported by large end or protruding flange with center of mass below supporting surfaces	1	0 4 1 0 3 1 0 9 1	0 2 1 0 1 1 0 45 1	0 25 1 0 1 1 0 9 2	0 2 1 0 1 1 0 45 1	0 2 1 0 1 1 0 9 1	0 1 1 0 1 1 0 9 2	0 25 1 0 1 1 0 9 2	
BETA symmetric steps or chamfers on external surfaces (see note 3)	2	0 4 1 0 3 1 0 75 1	0 15 1 0 1 1 5 0 37 1 5	0 25 1 0 1 1 5 0 25 3	0 15 1 0 1 1 5 0 37 1 5	0 35 1 0 2 1 5 0 5 1	0 1 1 0 05 1 5 0 5 3	0 25 1 0 1 1 5 0 5 2	
BETA symmetric grooves holes or recesses (see note 3): on both side and end surface(s)	3	0 5 1 0 2 1 0 85 1	0 15 1 0 1 1 5 0 43 1 5	0 25 1 0 1 1 5 0 25 2	0 15 1 0 1 1 5 0 43 1 5	0 2 1 0 1 1 5 0 5 1	0 1 1 0 05 1 5 0 5 2	0 25 1 0 1 1 5 0 5 2	—MANUAL HANDLING REQUIRED—
BETA symmetric grooves holes or recesses (see note 3): on side surface only	4	0 5 1 0 1 1 0 85 1	0 15 1 0 1 1 5 0 43 1 5	0 25 1 0 1 1 5 0 25 2	0 15 1 0 1 1 5 0 43 1 5	0 2 1 0 1 1 5 0 5 1	0 1 1 0 05 1 5 0 5 2	0 25 1 0 1 1 5 0 5 2	
BETA symmetric grooves holes or recesses (see note 3): on end surface(s) only	5	0 5 1 0 2 1 0 6 1	0 15 1 0 1 1 5 0 27 1 5	0 25 1 0 1 1.5 0 25 2	0 15 1 0 1 1 5 0 27 1 5	0 2 1 0 1 1 5 0 45 1	0 1 1 0 05 1 5 0 45 2	0 25 1 0 1 1 5 0 45 2	
BETA symmetric hidden features with no corresponding exposed features (see note 4)	6	0 6 1	0 27 1 5	0 25 2	0 27 1 5	0 45 1	0 45 2	0 45 2	
BETA asymmetric features on side or end surface(s)	7		0 27 2	0 25 1 0 1 1 5 0 25 3	0 1 1 0 05 1 5 0 27 2	0 1 3	0 1 1 0 05 1 5 0 5 3	0 25 1 0 1 1 5 0 5 3	
slightly asymmetric or small features amount of asymmetry or feature size less than D 10 and L 10	8	—MANUAL HANDLING REQUIRED—							

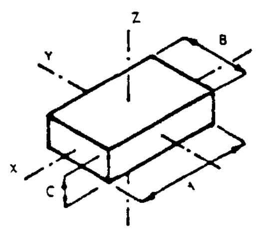
CHART 4-2

AUTOMATIC HANDLING-DATA FOR NON—ROTATIONAL PARTS
(first digit 6, 7 or 8)

Key

first digit		OE	FC
6	▷	0 7	1
7	▷	0 45	1 5
8	▷	0 3	2

		A > 1 1B and B > 1 1C	A ≤ 1 1B or B ≤ 1 1C (code the main feature or features which distinguish the adjacent surfaces having similar dimensions)							
			steps or chamfers (2) parallel to —			through grooves (2) parallel to —			holes or recesses > 0 1B (cannot be seen in silhouette)	other including slight asymmetry (3) features too small etc
			X axis and > 0 1C	Y axis and > 0 1C	Z axis and > 0 1B	X axis and > 0 1C	Y axis and > 0 1C	Z axis and > 0 1B		
		0	1	2	3	4	5	6	7	8
part has 180° symmetry about all three axes (1)	0	0 8 1 0 9 1 0 6 1	0 8 1 0 9 1 0 5 1	0 2 1 0 5 2 0 15 2	0 5 1 0 5 1 5 0 15 1 5	0 75 1 0 5 1 0 5 1	0 25 1 0 5 1 5 0 15 1	0 5 1 5 0 6 1 0 15 1 5	0 25 2 0 5 1 0 15 2	MANUAL HANDLING REQUIRED



			code the main feature or if orientation is defined by more than one feature then code the feature that gives the largest third digit							
			steps or chamfers (2) parallel to			through grooves (2) parallel to			holes or recesses > 0 1B (cannot be seen in silhouette)	other - including slight asymmetry (3) features too small etc
			X axis and > 0 1C	Y axis and > 0 1C	Z axis and > 0 1B	X axis and > 0 1C	Y axis and > 0 1C	Z axis and > 0 1B		
			0	1	2	3	4	5	6	7
part has 180° symmetry about one axis only (1)	about X axis	1	0 4 1 0 5 1 0 4 1	0 6 1 0 15 1 0 6 1	0 4 1 5 0 25 2 0 4 2	0 4 1 0 5 1 0 2 1	0 3 1 0 25 1 0 3 1	0 7 1 0 25 1 5 0 15 1	0 4 2 0 25 3 0 1 2	
	about Y axis	2	0 4 1 0 4 1 0 5 1	0 3 1 0 2 1 0 15 1	0 4 1 5 0 25 2 0 5 2	0 5 1 0 4 1 0 2 1	0 3 1 0 25 1 0 15 1	0 4 1 0 25 1 0 15 2	0 4 2 0 25 2 0 15 2	
	about Z axis	3	0 4 1 0 3 1 0 4 1	0 3 1 0 2 1 0 2 1	0 4 1 5 0 25 2 0 4 2	0 4 1 0 3 1 0 2 1	0 3 1 0 25 1 0 15 1	0 4 1 5 0 25 2 0 15 2	0 4 2 0 25 2 0 15 2	MANUAL HANDLING REQUIRED
part has no symmetry (code the main feature(s) that define the orientation) (4)	orientation defined by one main feature	4	0 25 1 0 25 1 0 15 1	0 15 1 0 1 1 5 0 14 1	0 15 1 5 0 24 2 0 15 1	0 1 1 0 2 1 0 1 1	0 15 1 0 1 1 5 0 05 1	0 1 1 5 0 15 2 0 1 1 5	0 1 2 0 15 3 0 08 2	
	orientation defined by two main features and one is a step chamfer or groove	6	0 2 2 0 1 3 0 05 2	0 15 2 0 1 3 5 0 05 2	0 1 2 5 0 1 4 0 05 2 5	0 1 2 0 1 3 0 05 2	0 15 2 0 1 3 5 0 05 2	0 1 2 5 0 1 4 0 05 2 5	0 1 3 0 1 5 0 05 3	
	other including slight asymmetry (3) etc	9	MANUAL HANDLING REQUIRED							

CHART 4-3

AUTOMATIC INSERTION-RELATIVE WORKHEAD COST, WC

Key

PART ADDED but NOT SECURED

			after assembly no holding down required to maintain orientation and location (5)				holding down required during subsequent process(es) to maintain orientation and location (5)			
			easy to align and position (6)		not easy to align or position (no features provided for the purpose)		easy to align and position (6)		not easy to align or position (no features provided for the purpose)	
			no resistance to insertion	resistance to insertion (7)	no resistance to insertion	resistance to insertion (7)	no resistance to insertion	resistance to insertion (7)	no resistance to insertion	resistance to insertion (7)
			0	1	2	3	6	7	8	9
addition of any part (1) where no final securing is taking place (2)	straight line insertion	from vertically above								
		0	1	1 5	1.5	2 3	1.3	2	2	3
		1	1 2	1 6	1.6	2 5	1.6	2 1	2 1	3 3
	not from vertically above (3)									
	insertion not straight line motion (4)	2	2	3	3	4.6	2.7	4	4	6 1

PART SECURED IMMEDIATELY

			no screwing operation or plastic deformation immediately after insertion (snap or press fits etc.)		plastic deformation immediately after insertion							screwing immediately after insertion	
					plastic bending			rivetting or similar plastic deformation					
						not easy to align or position (no features provided for the purpose)			not easy to align or position (no features provided for the purpose)				
			easy to align and position (6) no resistance to insertion	not easy to align or position and/or resistance to insertion	easy to align and position (6)	no resistance to insertion	resistance to insertion (7)	easy to align and position (6)	no resistance to insertion	resistance to insertion (7)	easy to align and position (6) no resistance to screwing	not easy to align or position and/or resistance to screwing (7)
			0	1	2	3	4	5	6	7	8	9
addition of any part (1) where final securing is taking place	straight line insertion	from vertically above										
		3	1 2	1 9	1 6	2.4	3 6	0 9	1.4	2 1	0 8	1 8
		not from vertically above (3)										
		4	1 3	2 1	2.1	3.2	4 8	1	1 5	2 3	1.3	2
	insertion not straight line motion (4)	5	2 4	3 8	3.2	4.8	7.2	1.8	2 8	4 2	1 6	3 6

SEPARATE OPERATION

		mechanical fastening processes (parts already in place)				non-mechanical fastening processes (parts already in place)				non-fastening processes	
		none or localized plastic deformation				metallurgical processes					
							additional material required				
		bending or similar processes	rivetting or similar processes	screwing or other processes	Snap fit, snap clip, press fit, etc	no addition of material (friction or resistance welding, etc.)	soldering processes	welding or brazing	chemical processes (adhesive bonding etc.)	manipulation of parts or sub-assembly (orienting fitting adjustment etc.)	other processes (liquid insertion etc.)
		0	1	2	3	4	5	6	7	8	9
assembly process where all solid parts are in place or non-solids added or parts are manipulated	9	1 6	0 9	0 8	1.6	1 2	1.1	1 1	0 8	1 5	

CHART 4-5

AUTOMATIC INSERTION-RELATIVE WORKHEAD COST, WC

Key

PART ADDED but NOT SECURED

				after assembly no holding down required to maintain orientation and location (5)				holding down required during subsequent process(es) to maintain orientation and location (5)			
				easy to align and position (6)		not easy to align or position (no features provided for the purpose)		easy to align and position (6)		not easy to align or position (no features provided for the purpose)	
				no resistance to insertion	resistance to insertion (7)	no resistance to insertion	resistance to insertion (7)	no resistance to insertion	resistance to insertion (7)	no resistance to insertion	resistance to insertion (7)
				0	1	2	3	6	7	8	9
addition of any part (1) where no final securing is taking place (2)	straight line insertion	from vertically above	0	1	1 5	1.5	2 3	1.3	2	2	3
		not from vertically above (3)	1	1 2	1 6	1.6	2 5	1.6	2 1	2 1	3 3
	insertion not straight line motion (4)		2	2	3	3	4 6	2 7	4	4	6 1

PART SECURED IMMEDIATELY

				no screwing operation or plastic deformation immediately after insertion (snap or press fits etc.)		plastic deformation immediately after insertion						screwing immediately after insertion	
						plastic bending			rivetting or similar plastic deformation				
							not easy to align or position (no features provided for the purpose)			not easy to align or position (no features provided for the purpose)			
				easy to align and position (6) no resistance to insertion	not easy to align or position and/or resistance to insertion	easy to align and position (6)	no resistance to insertion	resistance to insertion (7)	easy to align and position (6)	no resistance to insertion	resistance to insertion (7)	easy to align and position (6) no resistance to screwing	not easy to align or position and/or resistance to screwing (7)
				0	1	2	3	4	5	6	7	8	. 9
addition of any part (1) where final securing is taking place	straight line insertion	from vertically above	3	1 2	1 9	1 6	2.4	3 6	0 9	1 4	2 1	0 8	1 8
		not from vertically above (3)	4	1 3	2.1	2.1	3 2	4 8	1	1.5	2 3	1.3	2
	insertion not straight line motion (4)		5	2.4	3 8	3.2	4.8	7.2	1.8	2 8	4 2	1 6	3 6

SEPARATE OPERATION

		mechanical fastening processes (parts already in place)				non-mechanical fastening processes (parts already in place)				non-fastening processes	
		none or localized plastic deformation				metallurgical processes					
							additional material required				
		bending or similar processes	rivetting or similar processes	screwing or other processes	Snap fit, snap clip, press fit, etc	no addition of material (friction or resistance welding, etc.)	soldering processes	welding or brazing	chemical processes (adhesive bonding etc.)	manipulation of parts or sub-assembly (orienting, fitting, adjustment etc.)	other processes (liquid insertion etc.)
		0	1	2	3	4	5	6	7	8	9
assembly process where all solid parts are in place or non-solids added or parts are manipulated	9	1 6	0 9	0 8	1.6	1 2	1 1	1 1	0 8	1 5	

CHART 4-5

BIBLIOGRAPHY

1. Andreasen, M.M., S. Kahler, and T Lund. "Design for Assembly." U.K.: IFS Publications Ltd., 1983

2. Behjuniak, J. A. "Product design-The First Step in Assembly Automation." Proceedings 15th CIRP International Seminar on Manufacturing Sustems. University of Massachusetts, 1983.

3. Boothroyd, G. and P. Dewhurst "Computer-Aided Design for Automatic or Manual Assembly." SME Technical Paper AD82-151 (1982).

4. Boothroyd, G., C. Poli, and L. Murch "Automatic Assembly." New York: Marcel Decker, inc., 1982.

5. Bracken, F.L "Design of Electro-Mechanical Products for Flexible Manufacturing Line." Proceedings 15th Cirp International Seminar on Manufacturing Systems. University of Massachusetts, 1983.

6. Dean, J.W. and G.I. Susman. "Organizing for Manufacturable Design." Harvard Business Review 67:1 (1989) 28-37.

7. Hoyle, P. "The State of the Art of Automatic Fastener Feeding and Installation." Techincal Report. SPS Laboratories, Eecember 1987.

8. Iredale, R. "Automatic Assembly-Components and Products." Metalworking Production (April 8, 1964).

9. Poli, C. "A Design for Assembly Analysis of a Floppy Disk Drive." CIRP International Seminar on Manufacturing Systems. University of Massachusetts, 1983.

10. Riley, F.J. "The look of Automatic Assembly." Manufacturing Engineering 89 (August 1982) 79-82.

11. Wood, B.O.,P.H. Cohen, D.J. Medeiros, and J.G. Goodrich. "Design for Robotic Assembly." Robotics and Manufacturing Automation ASME PED-Vol. 15 (1985): 259-268.

12. Zorowski, C. "PDM-A Product Assemblability Merit Analysis Tool." ASME paper 86- DET- 124.

13. Cleland, I.David, Bidanda, Bopaya "The Automated Factory" Handbook, Technology and Management.

14. Goodrich, J.L., and G.P. Maul, "Programmable Parts Feeders." Industrial Engineering, May 1983, pp28-33

15. Treer, Kenneth R. "Automated Assembly." Society of Manufacturing Engineers, 1979.

16. Maekzka, W.J., "Feeding the Assembly Systems," Assembly Engineering, April 1985 pp:32-34.

17. Ahmadi, Reza H., Tang, Christopher S., "An Operation Partitioning Problem for Automted Assembly System Design." Manufacturing Engineering, pp:104

18. Nesbitt, Charles B. "Using AI in Automated Assembly." Automtion, pp:46-49.

19. Weimer, George. "Automatic Assembly: The way it All Comes Together." Automation, pp:48-50.