Redesign of parts and Simulation of Flexible Assembly Cell for safety water shower assembly

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ABSTRACT

A Design for Assembly (DSA) method is used to analyze the safety water shower assembly and to redesign the components with emphasis on meeting the criteria of allowing for flexible Assembly Cell (FAS). An Expert System is developed to select the right Assembly using VP-Expert. This thesis contrasts the old and new safety water shower assembly designs and describes the design of a final Flexible Assembly Cell. A PUMA 550 robot was investigated for use in the cell design. The flexible Assembly cell is simulated on silion grahics using the IGRIP software. The economics of each part presentation method is considered. Flexible assembly cell has the advantage of high reliability, faster cycle time, low operating cost in the long run relative to the manual assembly process.

REDESIGN OF PARTS AND SIMULATION OF FLEXIBLE ASSEMBLY CELL FOR SAFETY WATER SHOWER ASSEMBLY

By

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CHAPTER 1

INTRODUCTION

1.1 HISTORY

A Flexible Assembly System is normally associated with automatic or robotic assembly of products, supported by automated material handling systems.

The FAS will realize a revolutionary concept, but it should not, in general, contain individual elements of unproven design. The concept is one of a small (2,800 square meter floor area) unit on two or three floors, employing approximately 250 persons. The unit should be capable of producing two to three times the added value per head that could be achieved in a conventional factory making the same products.

The FAS will produce electric / electro-mechanical devices of less than fifteen kilograms in weight, and generally less than 0.03 cubic meters in volume. The final product, in most cases, will be constructed from sub-assemblies, also made within the system, each typically constituting 10-30 percent of the final product size.

The process technologies will be many and varied, and the FAS will be needed to be flexible enough to accept new ones with relative ease. It is important that the areas of technological growth for the next decade be identified, so that the FAS's fabric can be designed for easy incorporation.

The intention is to produce 200,000 to 300,000 units of any kind per year with individual product types having volumes less than 100,000 and greater than 1,000. It will be necessary to run different products concurrently, and the minimum lead time from order to delivery will be between a week and four weeks in general practice, assuming adequate documentation and availability of materials. It will also be possible to switch from one product to another in an unusually short time (one to two hours) thus combining the efficiencies of flow production with the flexibility of batch production.

The target is a FAS that will cost no more than a conventional factory, of the same output. The intention is to achieve this target by developing a flexible integrated materials handling, storage, information and control system which feeds multiproduct work areas. The work areas will be dedicated to specific processes and will have extensive computer assistance. Where feasible and appropriate the work areas will be robotic in nature, yet at the same time utilizing general purpose, or where necessary, dedicated automated equipment.

The heart of the FAS is the conversion sector, or work center, where the raw materials and purchased components are transformed into the value added goods.

1.2 DIFFERENCE BETWEEN FAS and FMS

A Flexible Manufacturing System can be defined as a automated manufacturing system consisting of numerically controlled machines capable of performing multiple functions. These machines are linked together by material handling systems, all controlled by a computer system. An FMS is characterized by versatile machines and material handling equipment, as well as minimal set-up time for operation(task) changes. The aim of an FMS is to achieve the efficiency of automated high-volume means production with retaining the flexibility of low-volume job shop production.

Flexible Assembly System(FAS), in which operations are confined to assembly and joining process, represent a large and important subset of FMS. FAS have received little attention in the research literature. Most of the research work on FMS has been focused on Flexible Machining Systems (FMS), which mainly perform metal-cutting operations.

Several researchers have compared the FAS and FMS. Hall and Stacke [1986]point out that FASs have a more complex workstation design, greater production requirements for a smaller number of product types, more dedicated transporters, looser tooling constraints and more complex material handling for component delivery. Owen[1984] says that the fundamental difference between the two systems are that an FMS is a computer-controlled automated machining system for converting raw materials into components of a known and desired geometric quality, while an FAS is a computer-controlled automated assembly system for converting raw material and purchased components into products of a known and desired functional quality.

An FAS consists of a set of assembly and a loading/unloading (L/UL) station connected by conveyors or automated vehicle (AGV) paths. A base part of assembly, for a printed circuit board (PCB), is loaded on a pallet (work carrier) and enters the FAS at U/UL station. As the pallet is carried by conveyors or AGVs through the assembly stations,components are assembled with the base part. when all the required components are assembled with the base part, it is carried back to the UL/L station and leaves the FAS.

The FAS under study has four characteristics. The first characteristic is that the FAS is a flow system with a series of assembly stations, each of which may have multiple(identical) assembly machines in parallel. In a flow system, a part may bypass some stations without being processed but does not revisit any station. High volume and short task times in FAS necessitate the efficiency of a flow system. A base part enters the flow system and is processed by a cluster of stations containing flexible machines of type1, followed by a cluster of stations containing flexible machines of type2, containing in this manner to completion. The machines of each types are typically of a particular types of machines. All tasks requiring this technology must to be uniquely defined, as assumption which is either true or not unreasonably restrictive for many products planned for specific technologies. Often there will be just one type of machine(root).

1.3 FLEXIBLE ASSEMBLY IN INDUSTRIES

The following examples illustrates the advantages of implementing the flexible assembly in the industries like APPLE, IBM, Sun Micro-Systems.

1.3.1 How Apple achieves Assembly flexibility

Apple started as an R & D project [3] but quickly turned into a fast-track production program. The highly automated $6.5 million system are two modular conveyor systems, five horizontal, rotary rack carousals and an integrated control systems. The modular conveyors form a materials highway between the carousals, assembly stations and final packing operation. Two of the carousals staged raw materials while the other three perform final burn in testing for up to 900 computers at a time. The control network manages the shop floor schedule while tracking and routing materials and work in process. Herrick's team of apple computers determine that automated but flexible material handling would be central to success. They emphasized on automated assembly flow and material routing rather than an automation of the assembly process. Other requirements included inventory tracking and scheduling and random access to staged materials and assemblies.

How the system works:

From the receiving dock to finished product packaging, all material and assemblies travel on dedicated pallets along two, independent conveyors. [3]All pallets carry bar codes, which are read at strategy locations by fixed position scanners for identification. Using this information, computers route materials and assemblies through out the system only when work stations are ready for them. From receiving, raw materials travel in their boxes along one of those conveyors either of two carousals with a total of 900 storage locations. Typically, material remains in the carousal for less than four hours before a personal computer calls it out to replenish one of the assembly work stations.

After the operator removes the material from its box at the work station, the empty box back travels by conveyor to the dunnage removal station. The empty pallet is done return by conveyor to the receiving area for reuse.

Partially assembled computers travel along that same closed loop conveyor between work stations on their own special, dedicated pallets. The work station that completes a computer assembly sends it to one of three rotary racks upto 19hrs of burn in testing.

As do the two materials carousals, each burn in carousal has five independently rotating levels. The 60 storage bins per level add up to a total of 900 positions for loads measuring 24 inch by 24 inch by 24 inch.

Putaway and retrieval for each carousal is by an automatic insert/extract mechanism that travels along a vertical runway servicing each level. To optimize throughput a personal computer directs the insert/extract mechanism to a storage position on one level at the same time that the rotary rack prepositions the next carousal bin for the mechanism.

When released from the carousal, burned in assemblies travel by a second conveyor to inspection station. Fully inspected computers ready for shipment then are routed to pack out stations for final packing.

1.3.2 How Flexible Assembly System Eliminated Kitting in IBM

Kitting to collect and consolidate parts is usually required for computer assembly. However, at the IBM corporation plant[5], in Boca Raton, Florida, a carefully planned handling system means kitting has no role in assembling the personal system/2 line. This new assembly system is supported by highly flexible packaging system that can accommodate all present and future computer models. Pallets have bar code labels attached in the receiving area and are placed in computer-assigned locations in the flow rack, which was the key to eliminating kitting. Hot pallets , plastic trays that can be plugged into test equipment for testing and burn in , are one reason that IBM has been successful at designing handling systems to accommodate new products before they are designed. Extensive safety features also had been build into the system including 1. Extensive diagnostics in the programmable controllers, 2. Video cameras to monitor the system and 3. A storage and retrieval machine.

How IBM does Flexible Assembly:

The IBM's objective was to build a handling system able to accommodate all present and future computer models. The company met its objective. [5]Upto 8 different models of the PS/2 can be built in any of the nineteen new assembly stations, although only 6 models are currently produced in Boca Raton.

In receiving area, parts arrive on the pallets and are staged on the floor for verification and checking. Checking pallet loads are stretch wrapped issued a bar code label, placed on a slave pallet, and put are on a conveyor where their size and weight are checked. Transportation to storage is overhead. Following sizing and weighting, pallets of parts travel to an overhead chain driven, live roller conveyor via a continuous strand, vertical conveyor. The pallets are staged on the overhead roller conveyor until a slug of 15 pallets is built up. Then, the slug is released to storage.

The slug moves into the assembly area, where pallets accumulate on a zoned CDLR conveyor from which the pallets can be released individually for storage in an automated storage and retrieval system.

The automated storage system includes Flow rack, and that feature is one key to the elimination of kitting. A completely retrofitted storage retrieval machine picks up the pallets that arrive by conveyor and places them into computer assisted locations in the flow rack. The assignment is based on the reading of the bar codes on the pallets. The pallets, then, flow to another aisle serviced by a second retrofitted S/R machine.

Based on requirements at assembly stations, a second machine picks up pallets of parts guided by computer, the machine deposits the pallets of parts in the right location in static racks on the other side of aisle. Two special transfer cars equipped with S/R shuttles, pick up the pallets from the other side of the static rack. Programmable controllers guide the man-aboardcars while on-board computer instruct operators aboard part requirements in the assembly stations. Based on these requirements, transfer car operators depalletize the parts and feed cartons to gravity roller conveyors which flow directly into the assembly stations.

A frame prep area is the other source of materials for the assembly stations. In frame prep stations, computer frames are matted with hot pallets plastic trays that can be plugged directly into text equipment for testing and burn in. In the workstations conveyors deliver the pallatized, coded frames. The flow lines from the transfer cars provide parts. The screens provide with detailed directions for assembly. As parts are pulled from cartons on the flow line, the assembler scans the bar code on each part before installing the part. Empty cartons are simply tossed on to the trash conveyor running past the assembly station area.

1.3.3 How Flexibility helped company cope with rapid growth

Sun microsystems Inc[6] is relatively a new company, founded in 1982, with a unit demand that doubles annually.

On top of all that, a constantly changing product mix with many custom variations made a flexible plant a necessity for the Sun microsystems plant.

The new facility tackles all these issues head on. Design goals included:

- Flexibility to meet product changes with simple routing commands.
- Quality improvement through better materials handling and process flow.

- Ability to track control materials through a computerized shop floor control systems.
- Improved employee morale through a more pleasant working environment.

1.3.4 How Automated handling boosted flexible Assembly Safety

When IBM [8]wanted to upgrade their materials handling system used to manufacture large, multi-layered printed circuit boards, the company's main goal was to eliminate manual lifting and other handling operations that might lead to personal injury. The large (24in. by 27 in.) boards, which can weigh up to 90 lb when completed, must be delivered and transferred to production tools, work stations and testing equipment on two separate floor space in IBM's huge manufacturing complex in Poughkeepsie, N.Y.

The company installed a flexible assembly system, centered around a "spine" layout, that uses a car on track conveyor network to automatically deliver in process boards to robotic and manual work stations. A computer control system tracks and routes boards to the appropriate assembly, test, and repair stations as needed.

Since operation began, the system has resulted in:

- Improved manufacturing yields,
- Improved manufacturing cycle time,

conveyer system. A computer control system oversees board transport and assembly, routing boards to specific stations as needed. After all assembly and testing steps are completed, the boards move to IBM's facility in Kingston, N.Y., where they're installed into 3080 or 3090 series mainframe computers.

Prior to installing the automated handling system, IBM used totally manual materials handling methods. The boards were lifted and placed on wheeled carts, which were then pushed to various work stations throughout the system. Transfers of boards from the carts to assembly and test stations were totally manual. Now, lifting has been virtually eliminated, and has been replaced by automatic or mechanically assisted devices.

1.4 OUTLINE OF THE THESIS

The objective of thesis is to redesign the components of the safety water shower assembly, development of and expert system for the right assembly selection and simulation of the flexible assembly cell using the IGRIP.

Chapter two describes the requirements of Flexible Assembly Systems. The basic elements which are to be studied, Assembly tasks, Workstation Design are described in detail.

Chapter three describes the safety water shower assembly. The assembly is subdivided into the part and each part's is physical description and it's functions are discussed in detail. Figures of each part are shown.

Chapter four describes the selection of assembly method. How the company's are to select which[1] assembly system best suits for their company. The whole philosophy is coded in an Expert-System using VP-Expert. This chapter also describes the Expert Systems, Menu-driven software development.

Chapter five describes the redesign principles for easy assembly [18] and easy manufacturing. On that principles how the safety water shower is redesigned and reduced the number of parts is discussed in detail.

Chapter Six describes the analysis of the assembly Systems. The procedures for analyzing the manual assembly and flexible Assembly are discussed in detail and compared the advantages and disadvantages.

Chapter Seven describes the Simulation of Manufacturing Systems, Advantages of Simulation, Simulation softwares and it's usage, Simulation languages are discussed in detail.

This chapter describes the Simulation of Workcell design for the water shower assembly, and it's components. The simulation procedures and code are also presented with color printouts.

CHAPTER 2

REQUIREMENTS OF FLEXIBLE ASSEMBLY SYSTEMS

Assembly work includes parts supply, assembly, inspection and transfer as shown in figure 1. [13]Screws and nuts which are, in many cases are arranged on a pallet, are supplied by a unit based on vibrations, such as the ball feeder. Relatively large parts are supplied by using a mobile conveyor feeder, etc.

The supplied parts undergo press fit, fitting, screwing caulking, bonding etc. These operations are conducted by an assembly cell comprising the assembly robot and assembly machine components such as a press, special screwing machine, caulking machine, etc. depending on the time and force required. The assembly cell is of course provided with sensors or the like for purpose of inspection.

There is a concept that the robots should be provided with every necessary implement and conduct the total assembly. However, we do not employ this concept. Instead, we employ the assembly cell and allocate jobs to the assembly robot as shown in fig 2. We determine whether the assembly robot should insert screws, etc. according to the time required for that work.

The Flexible Assembly Cell has the following features and is shown in fig 3.

1 Unmanned Operation.

2 Not only one work process but all the processes can be automated by using one assembly cell capable of performing several

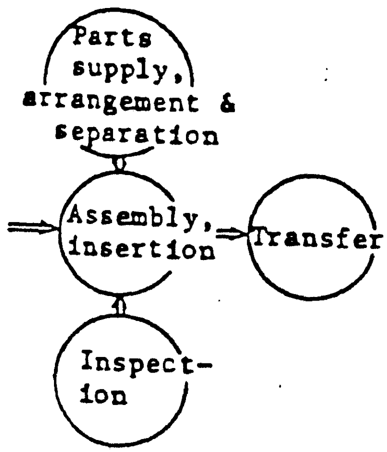


fig.1 Assembly work

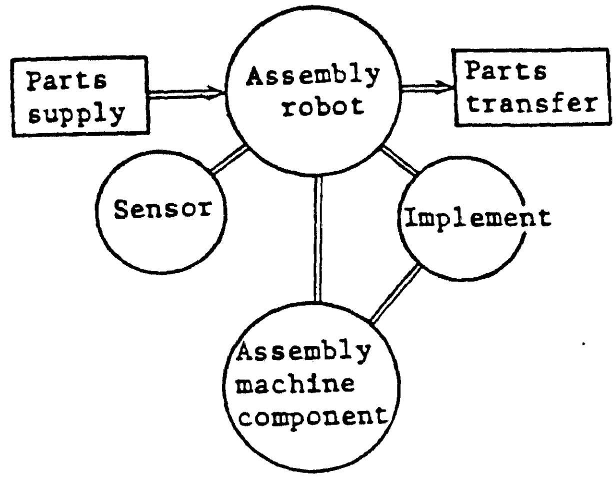


fig.2 Composition of Assembly **Cell**

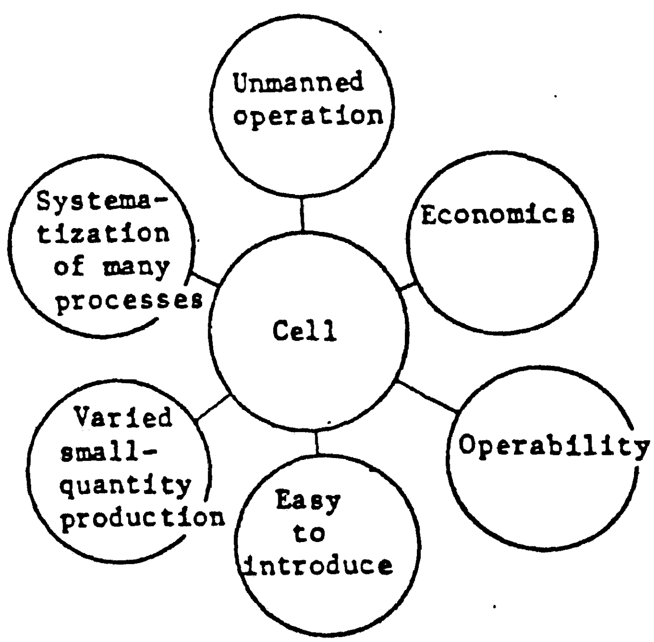


fig.3 Features and purpose of cell

assembly processes, or by combining several assembly cells.

3 The assembly cell is highly flexible and can cope with a varied, small quantity parts production, and the setup work is simple.

4 It is easy to operate, and the setup work is simple.

5 The assembly cell is easy to introduce, and is also very inexpensive to operate.

The assembly cell can automatically assemble various, small-quantity parts, which could not be economically assembled with the conventional assembly machine. It is particularly suitable for economically assembling several hundreds thousands parts per month.

2.1 ELEMENTS OF FLEXIBLE ASSEMBLY SYSTEMS

The main elements of Flexible Assembly System [14],[15] are

1 Assembly Stations

2 Load and Unload Station

3 Workpiece transport equipment

4 Part presentation and orientation

5 Pallets

6 Fixtures

7 Robots

8 Buffer

9 Other storage facilities

10 Human Operators

11 Control Computer

2.1.1) Assembly Stations

The Assembly Stations vary according to the type of part being assembled. Usually Robots, Screwing Machines, Inserting Machines, Presses are used.

2.1.2) Load and Unload Stations

Parts have to be introduced into the system at some point and there are usually load unload stations, where parts are placed on pallets, usually by human operators. In some cases parts may be supplied by an orienting device and loaded by robot. Unloading is done usually at the same stations, but may be separate unload stations. In some systems load-unload stations are dedicated to one type of sub-assemblies while in others they may be any type of sub-assemblies.

2.1.3) Sub-Assembly Transport Equipment

Workpieces must be transported from the load positions to the productive equipment and back for unloading. Three types of equipment are in common use, namely conveyers, assemblystation and some form of addressing system to direct workpieces to the correct station. Conveyor systems seem to be less popular. There are several types of vehicle. Railcars, which run on rails connecting the work stations, usually follow linear tracks and are therefore to be found in the smaller type of FAS. Automated Guided Vehicles (AGV) follow track layouts. Some vehicles can carry only one load at a time, while others have two load positions. Some, more specialized, vehicles can handle several loads simultaneously for workpiece transport. However, overhead gantry-mounted robots are popular for both workpiece and tool handling.

2.1.4) Part presentation and orientation

Components can be presented to a workstation in 5 basic ways.

1 They may be placed in a bin or pile that the (manual) operator can take from as necessary.

2 They may be presented one at a time from a bulk holder to a pickup point.

3 They may be supplied on a reeled tape or strip for automatic or manual removal.

4 They may be manufactured as desired at the work station.

5 they may be presented singly from a gravity magazine, feeder, or tray.

2.1.4.1) Bulk feeders: This group of parts feeders present the components in a jumbled heap, and it is then up to the operator to select individual components from the heap as demand requires. One of the major problems with this kind of feeding is that the components can become tangled and jumbled together so that separation into individual parts can be problematic.

2.1.4.2) Orientating feeders: The function of these types of components feeders is to regiment a mass of jumbled, randomly oriented components in the desired attitude and orientation for direct assembly or transfer into an assembly or transfer into an assembly device. There are five basic types of these feeders.

1 Vibratory bowl feeders.

2 In-line vibratory feeders.

3 Rotary feeders.

4 Oscillating feeders.

5 Centrifugal feeders.

2.1.4.3) Reel feeders: These feeding devices are used for very fragile "metal" parts and electronic components that are manufactured in a progressive press tool, for example pins for electrical connectors. The processed components are kept in the strip form, which is rolled up into a reel for presentation. The ribbon is then fed to the assembly equipment where each part is shared from the "ribbon" as desired and assembled. The second type of reel feeder or bandolier is used for dispensing discrete electronic components into, say, an automatic board populator. In this technique, individual electronic components are mounted on continuous strips of adhesive tape, in a form where they are centered across the tape and are at standard pitches along it. The tape consists of either just one type of component arranged in the sequence that they are to be placed into the assemblies. It is important that the individual components are not damaged or distorted in any way since this would prelude assembly from the tape into the printed circuit board

2.1.4.4) Gravity magazines and stacks: It is not always economical to feed and/or orient components automatically. However, assembly related cost savings can be achieved through the use of manually packed dispenses in which components have been pre-oriented and are offered individually to the assembly station by gravity.

2.1.4.5) Ancillary feeding equipment: There are two major ancillary equipments.

1 Escapement devices

2 Sensors.

2.1.5) Pallets

Sub-Assemblies are normally held in pallets of some sort for transport and locating on machine tables. Two types are common. One type of pallet serves just as a carrier for a batch of small parts, to facilitate and reduce the frequency of movements. They serve as trays into which the parts may be placed at the load stations, and from which they may be lifted and placed into the machines, perhaps by a robot. The second type of pallet is one in which one or more parts are accurately located and which is itself moved on to the machine table and held in position while Assembling operations are performed on the parts.

2.1.6) Fixtures

Fixtures are used to locate parts precisely on pallets. They are usually specific to one type of part, so that each part requires a different fixture. In some cases however, several types of part may be sufficiently similar to make use of the same fixture. The fixtures may be permanently bolted on the pallets, or they may be removed from the pallet when a part requiring a different fixture is to be introduced into the system and placed on the pallet. If the parts are small, several parts, either all of the same type or of different types, may be held on a pallet.

2.1.7) Robots

Robots may be either stationary or mobile. There are several types of mobile Robot, principally mounted either on rails on the floor or on over-head gantries. In some systems robots are mounted on AGVs which carry pallets to the machines; Robots may also be used to perform the processes themselves, such as insertion and process screwing. The grippers on the robot may have to be changed between handling one type of part and another. Obviously, this reduces the flexibility of the robot and the whole-system, imposing batch operation.

2.1.8) Buffer Storage at Assembly Stations

Most systems include form of storage at Assembly Stations. This permits Sub-Assemblies to be brought to an Assembly machine while it is operating on the previous part, and the machine to work on the next part while the previous one is waiting to be transported away. There are several types of buffer storage. Often it takes the form of two pallet stands in front of the machine. One provides a queuing position for work waiting to be taken away from it. In another type the machine has a rotary pallet shuttle, with one queuing position and one working position. Some systems provide an automatic work changer, or chain of pallets, giving six or eight positions for queuing.

2.1.9) Other Storage Facilities

In addition to buffer storage at Sub-Assemblies many systems have storage facilities for work-in-progress, pallets, fixtures. There are many different arrange ments. Work-in-progress buffer storage points may be distributed throughout the system to smooth out any surges in Assembly flow. In most systems there are storage positions for the pallets. There may be a home position for every pallet, or there may just be sufficient to cater for those pallets not currently at an Assembly Station load-unload station. In some systems the load-unload stations also serve as the home location. Some systems have a central storage facility, which might be used to hold a build-up of work prior to an unmanned shift. Others include an automatic storage and retrieval system (AS/RS) for Sub-Assemblies, which may serve the factory as a whole and not just the FAS.

2.1.10) Human Operators

Despite the advances towards unmanned factories most, if not all FAS require human operators for a variety of tasks, although many systems operate unmanned for one shift, or part of a shift, per day. Operators may be required for loading and unloading parts, fixing the magazines, clearing faults, or faulty location of sub-assemblies, and system monitoring to cope with other exception conditions, and for generally managing the system.

2.1.11) Control Computer

The tasks of the "executive" computer are many and varied. The basic functions are to give instructions to the Assembly machines and transport devices so that this can be done is a vital function. Most executive computers also give instructions to the operators at the magazine filter areas and load-unload stations, and make scheduling decisions. In order to schedule the work, the computer must be supplied with production requirements and components availability data. This may be achieved through a link to the main factory production control system computer. The computer will also provide management reports on the work done, system productivity, diagnostics and so on. Programmable logic controllers may be used to control small systems or sections of systems. There will normally be a separate controller for the AGVs in systems with several vehicles.

Perhaps surprisingly, the control computer seldom features in a simulation model of an FMS. Instead the decision rules which it employs are built into the logic of the control the system is in doubt would it be part of the model. In that case the model would probably be a special one to model the communications network.

2.2 ASSEMBLY TASKS

Every assembly task [14] is simplistically a pick and place motion, where one part is collected and taken to a second to which it is filled, with in this simple action, there are however seven distinct and different actions involved.

1 position

2 grip

3 pick

4 move

5 place

6 fit

2.3 WORK STATION DESIGN

The major requirement of a work station is that it should be totally flexible in operation, physical layout, and technology. One aspect of the technological level of the work stations would be capable of the following.

- immediate practical application
- reliable in-production usage
- readily repairable by staff who were adequately trained but not necessarily highly qualified.

There are four different basic types of work station. The first is a hard automation unit that performs a specific task. It may be fitted with removable and adjustable tooling that permits the task to be performed on differently sized or different shaped components. Its use within the FAS is limited to the performance of tasks that analysis shows are economically viable, even though the use is limited to one task on one product. Flexible and automation are the identifiable features of the second type of work station. These consists of robotic or other adjustable systems that can quickly be reconfigured by hardware changes to suit various product tasks. All tasks performed by these units are performed automatically. The third choice is that of the semiautomatic work station, such as those marked by lano and ISM, which make use of automatic modular handling and processing equipment to enable a human to perform the various assembly tasks. The last style is that of manual work station, where the components are collected from bins or trays and the assembly is performed entirely by hand, although automatic hand tools such as auto screw drivers may be used.

Except for the hard automation work station, for which there may be no other option, the choice of work station depends upon the philosophy adopted by the FAS management. It may be decided that all stations should be semiautomatic or manual at the set up stage of the FAS, and that after the production problem has been sorted out, a gradual upgrading to robotic and semi-automatic work stations will occur as a technological aspects and the liability of the higher status work stations are proven.

While the concept and the allocation of the work station to either manual or robotic operation can be undertaken by considering only the assembly operation being conducted in a specific time period, the design of a specific work station requires that the working area, ergonomic requirements, and environmental and psychological requirements also be considered.

CHAPTER 3

PART DESCRIPTION

This safety water shower is used to extinguish the fire in case of any fire accidents. It is mainly used in building of offices, schools, apartments, factories and many other similar areas.

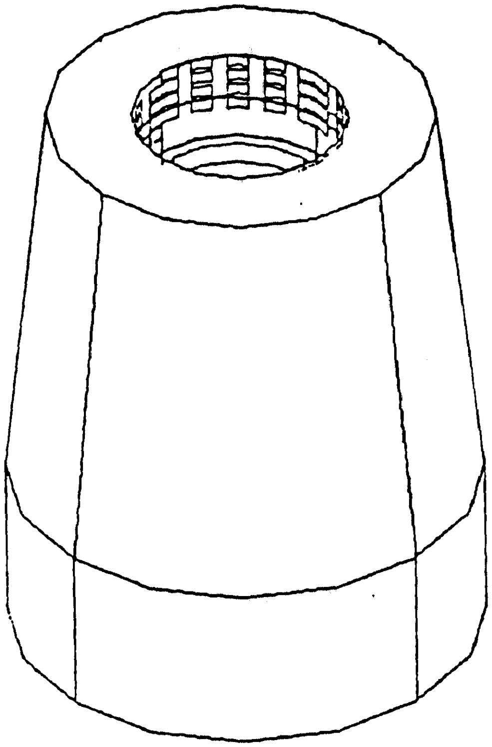
The crossrod inside the device is first assembled such that it blocks the spray of water. In case of fire, if somebody pulls the chain which is attached to the cross rod, It will be displaced from it's original place, and the gap on this part allows the water to flow through the device, and sprinkles the water around the person standing under it. Thus it gives the protection from the fire.

The safety water shower has 7 parts and are shown in figure 4 & figure 5

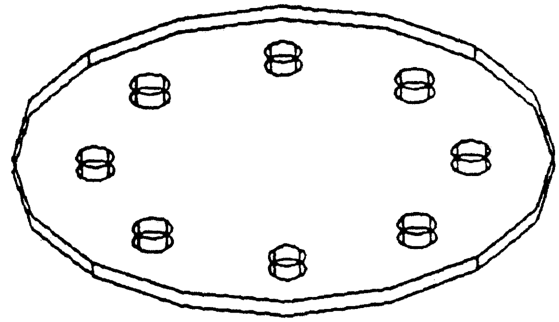
1. Conical part
2. Plate with holes (Sprinkler)
3. Rubber part
4. Cylindrical part
5. Cap
6. Ball Part
7. Cross rod

3.1 Conical part

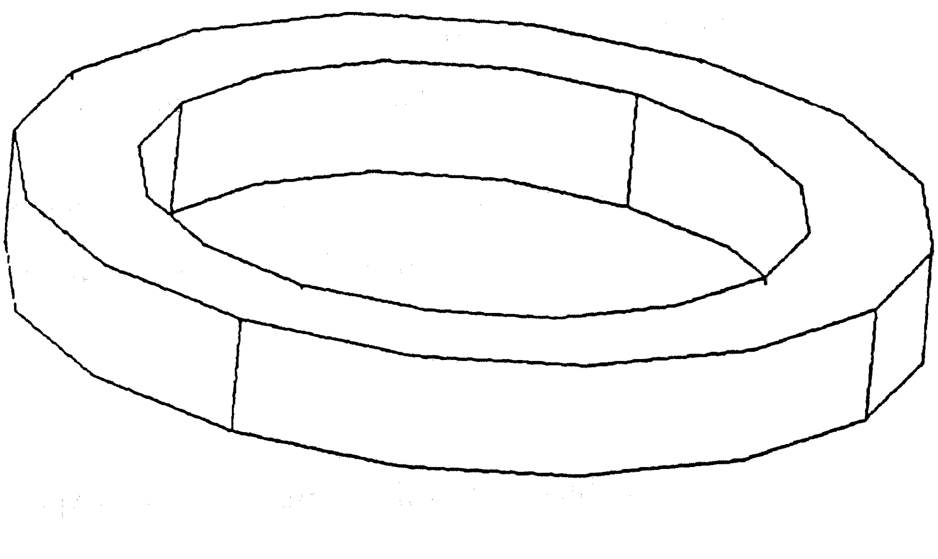
It is of the conical shape. The final water splashes comes out this part. It is the base part for our assembly. This part is of conical shape of



Conical part



Sprinkler



Rubber part

fig 4. Components of Safety water shower

diameter 26.85 m.m at the top and is gradually increasing to 33 m.m. It has a 6 m.m thickness . There is a opening with 15 m.m. diameter, 7.5 m.m. depth with the lower diameter end and it has projection at top of the opening to hold the plate and the rubber part. This opening is tapped inside so that it can be threaded with cylindrical part. The bottom of the cone is cylindrical shape with diameter 33 mm and height 12.17 mm.

3.2 Plate with holes (Sprinkler):

It is used to block the water flow and lets the water to flow through the small holes so that water will be sprinkled around.

It is 14.5 m.m diameter and has a thickness of 0.46 mm. The distance between the holes and the edge of the plate is 2.24 m.m. It rest on the projections in the conical part.

3.3 Rubber Part:

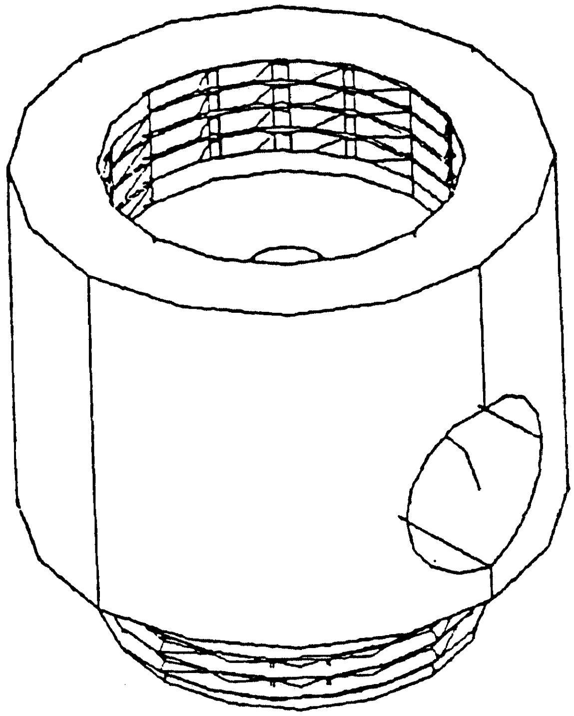
The rubber part is used as a sealing between the filter and the round part. It rests on the filter in the conical part.

It is made of rubber with inner diameter 10.84 mm, outer diameter of 14.84 mm, and has the thickness of 2.00 mm.

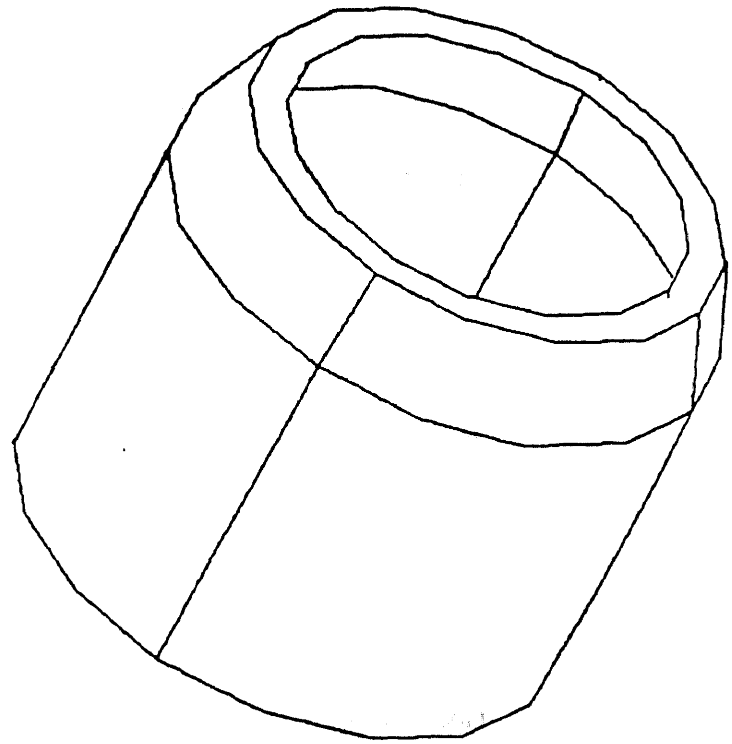
3.4 Cylindrical Part:

It acts as a support for ball part, conical part, and cross-rod.

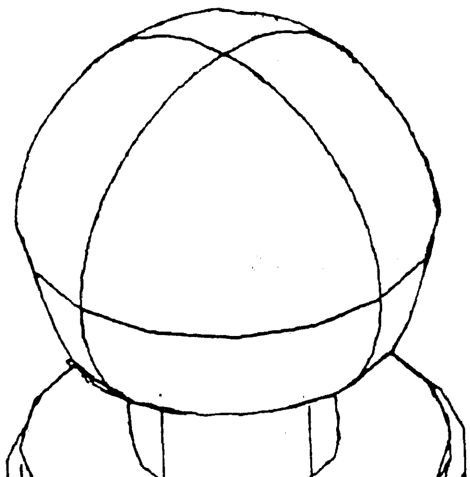
It has a cylindrical shape of diameter 22.07 mm and height 16.9 mm. The bottom of the cylinder is a small cylinder with diameter 15 mm and



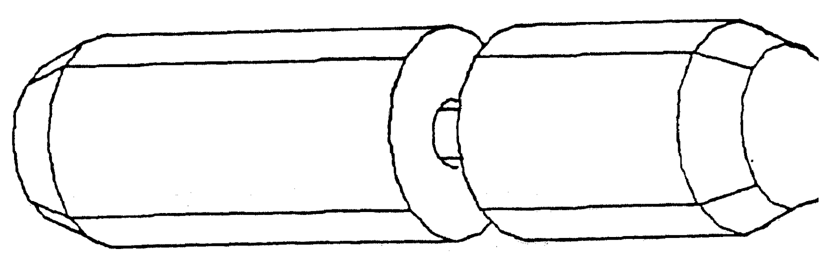
Cylindrical part



Cap



Ball part



Cross rod

fig 5. Components of Safety water shower

height 5.52 mm. The bottom cylinder has threads on it to go into the conical part. The top cylinder has a hole with diameter of 22.07 mm and it has threads to fit with the ball part. There is a hole with diameter 8 mm to fit the cross rod. This hole is 7.26 mm away from the top edge of the part and is perpendicular to the axis of insertion. It has a hole of diameter 3.7 mm along the axis of insertion throughout the part so that water can pass through the part.

3.5 Cap:

This cap helps in fitting the water shower to the wall and it gives 360 degrees free rotation to the assembled part around the plane of insertion.

The cap has a outer diameter of 21.6 mm, inner diameter of 18.6 mm and height 15.02 mm. The cap on its bottom has a conical shape and the diameter is gradually reduced to 18.71 outer diameter and 15.71 inner diameter. The height of the conical shape is 4 mm.

3.6 Ball Part:

This part gives the free movement to the assembled part. It rests in the cap.

The ball part has a diameter of 17.34 mm. The bottom of the ball has a small cylindrical block with diameter of 7.00 mm and height 17.2 mm. There is one more cylindrical block of diameter 14.84 mm and height 4.72 mm and has threads on it so that it can fit in the cylindrical part.

3.7 Cross rod:

This cross rod acts as a valve to let the water flow through the device. Initially it blocks the water to flow through the device and when some one pulls then chain the this cross rod moves and lets the water to flow through the device.

It is 31.76 mm long and 7.12 mm in diameter. At a distance of 9.44 mm from one side of the cross rod the diameter is reduced to 2.5 mm. This reduced diameter portion is of 3.06 mm length. One end of the cross rod has a button like thing. It acts as a lock, so that the cross rod will not come out of the devise, when it is pulled, but it will move its position.

CHAPTER 4

SELECTION OF ASSEMBLY METHOD USING EXPERT SYSTEM.

It is important to decide at an early stage in design which type of Assembly method is likely to be adopted, based on the method yielding the lowest costs. This section allows the designer to decide, from the values of basic product and company parameters (Production volume, Number of parts, e.t.c) which Assembly method is likely to be most economic.

For example, a product or Assembly where only 1,000 units per year are required would obviously be assembled manually. For a product where several millions per year are required, the purchase of special purpose automation equipment (High speed automatic Assembly) would almost certainly provide excellent return on investment. Somewhere between these extremes is a range of annual production volumes for which robot assembly might be the best economic choice if the assembly were appropriately designed.

The manual assembly differs widely from Automatic Flexible Assembly due to the difference in ability between human operators and any mechanical method of Assembly. An operation that is easy for an assembly worker to perform might be impossible for a robot of special purpose workhead.

According to the Mr.Geoffery Boothroyd the following methods are divided[1] as follows:

1 Automated Assembly using special purpose indexing machines, work heads, and automatic feeders. Designated by "AI".

2 Automatic Assembly using special purpose free-transfer machines, workheads, and Automatic feeders. Designated by "AF".

3 Automatic Assembly using manually loaded part magazine and a free-transfer machine with programmable workheads capable of performing several assembly tasks. Designated by "AP".

4 Automatic assembly using manually loaded part magazines and a sophisticated two arm robot with a special purpose gripper that can handle all the parts for one assembly.

5 Manual Assembly on a multistation assembly line. The transfer device is free- transfer machine. Designated by "MA".

6 Manual assembly with mechanical assistance. This system is the same as the above, but feeders or other device are provided and the assembly time per part therefore reduced.

4.1 SELECTION PROCESS:

This method [16] for assessing the available processes is summarized in the chart. This chart is based on an analysis of mathematical models of the various assembly process. Using the chart requires that six basic facts be known:

- Production volume per shift.
- Number of parts in an assembly.
- Single product vs variety of products.
- Number of parts required for different styles of the product.
- Number of major design changes expected during product life.
- Company policy on investment in labour-saving machinery.

The production volume per shift and number of parts in an assembly determine the correct row in the chart. The other factors determine the correct column. The intersection of row and column describes the most economical assembly process.

4.2 EXPERT SYSTEM TO SELECT THE RIGHT ASSEMBLY:

The above mentioned selection process involves lot of time to go through the chart, and one should know the assembly terminology. He must have through knowledge to follow the step by step procedure of the chart. So we developed an expert system for the assembly selection process. The selection process is converted into the rule based knowledge system. That means the expert's knowledge is kept in the rules of the vp-Expert system. It will just asks you the simple questions and will make the decisions. Now to use this Expert system one doesn't necessary to know about the Assembly.

4.3 FEW WORDS ABOUT EXPERT SYSTEM

For years AI has been a research area carried out mostly by a few major universities and research labs. However, in recent months, AI and Expert Systems have received tremendous publicity. The decline of hardware costs and the availability of reliable and supported software tools have enabled AI to emerge as a realistic and practical technique that offers a large variety of useful applications in manufacturing and engineering areas.

Expert systems produce [17] intelligent behavior by operating on the knowledge of a human expert in a well-defined application domain. The ability to operate on this knowledge gives the expert system the capability to perform its task at a skill level usually associated with the expert.

Because knwoledge is the key ingredient in an expert system, such systems are often called knwoledge-based systems.

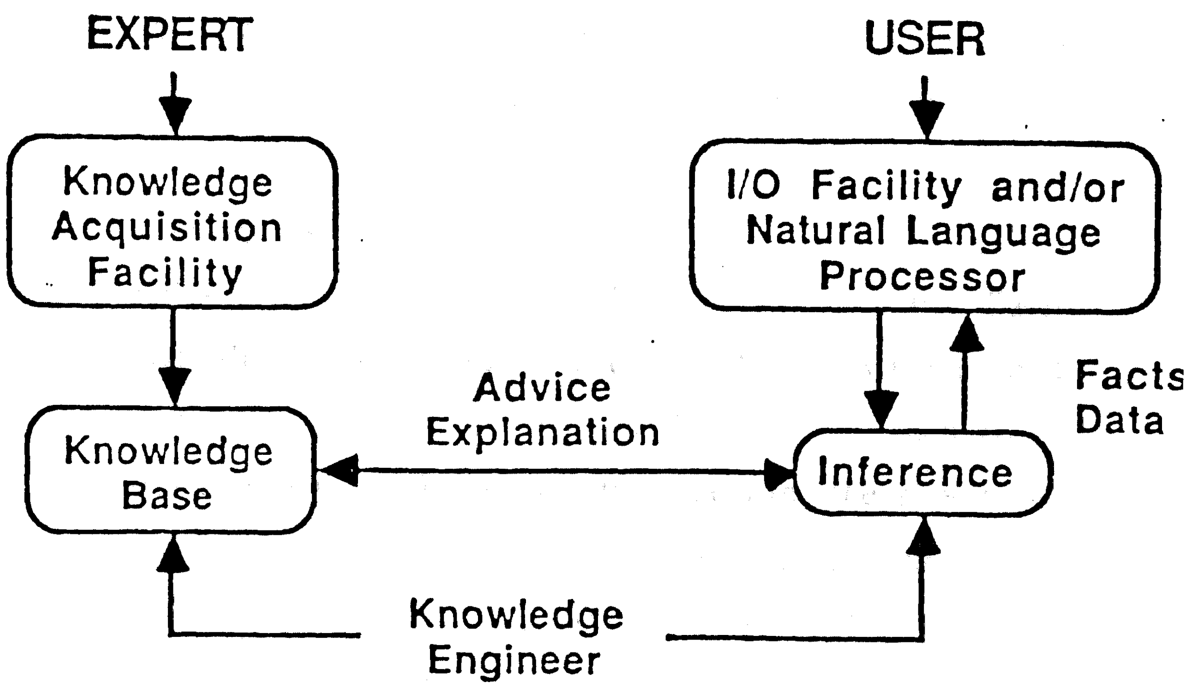


fig 6. Structure of an Expert System

The Structure of an expert system is shown in fig 6. These systems include a knowledge base containing facts, rules, heuritics, and situation patterns, and an inference system that makes decisions within a domain. Recent applications of expert systems have demonstrated the potential to achieve a high level of human performance while preserving knowledge that otherwise might be lost by attrition, retirement, or death.

These systems also have demonstrated the ability to improve upon the performance of average individuals by providing them access to the encoded knowledge of the scarce experts.

The components include:

1 **Input/Output** facilities, that allow the user to communicate (sometimes referred to as Natural Language Interface) with the system and to create and use a data base for the specific case at hand.

2 **Inference Engine**, that incorporates resoning methods, which in turn act upon input data (i.e., rule interpreter) and knowledge from the knowledge base, to both solve the stated problem and produce an explanation for the solution.

3 **Knowledge Base**, and (perhaps) a Knowledge Acquisition Facility, which allows the system to acquire further knowledge about the domain from experts and/or from libraries and data bases. The inference engine acts as executive that runs the expert system. It fires rules according to a built-in reasoning protocol, and by so doing performs actions that lead to solution of the problem. At the same time, the inference engine may change the knowledge base by adding new knowledge to it. The knowledge base contains the domain-specific knowledge which provides the context for the specific applications of the expert system.

4.4 VP-Expert:

Expert System technology, the field we are concerned with, involves the creation of computer software that emulates the way people solve problems. Like a human expert, an expert system gives advice by drawing upon its own store of knowledge and by requesting information specific to the problem at hand. The knowledge is stored in IF - THEN rules. The specific information is provided by the person seeking advice.

VP Expert is an "Expert system developing tool". VP Expert provides the inference engine, the user interface, the commands - indeed , everything needed to create a working expert system. The only thing you have to do is encode knowledge on a particular subject into a knowledge base.

4.5 Why VP Expert:

There are a number of expert system tools on the market, but VP-expert offers a combination of powerful features that make it the clear state of the art choice for developing microcomputer-based expert systems-even over tools costing thousand of dollars. It is a serious expert system tool, it lets the uses are by no means restricted to expert systems. Special features include:

- The ability to exchange data with VP-Info or dBASE database files, VP-Planner, VP-Planner Plus, 1-2-3, or Symphony worksheet files, and ASCII text files.
- Rapid execution of knowledge base.
- Simple English like rule construction.
- Knowledge base "chaining", which lets you create knowledge bases that would otherwise be too large to fit in memory.
- Commands that allow VP-Expert to explain its actions during a consultation.

the Expert System program for our problem is as follows:

```
ACTIONS
        DISPLAY " This expert system is developed by Balraj Y.Gardilla on
the guide lines of Dr.Raj S. Sodhi, Director of Manufacturing Engineering.
Press any key to begin the consultation. ~ "
        CLS
        DISPLAY "This expert system advices you on which Assembly System
best suits to your company.
Press any key to begin consultation.~ "
        CLS
        FIND Assembly_System
        WOPEN 1,2,6,10,60,7
        ACTIVE 1
        DISPLAY "The best Assembly System for your company is {#Assembly_Syst
Press any key to conclude the consultation .~ ";
RULE 1
IF      vs > 0.65
AND       total >= 16
THEN      row = 0;

RULE 2
IF      vs > 0.65
AND       total <= 15
AND       total >= 7
THEN      row = 1;

RULE 3
IF      vs > 0.65
AND       total <= 6
THEN      row = 2;

RULE 4
IF      vs <= 0.65
AND       vs > 0.4
AND       total >= 16
THEN      row = 3;

RULE 5
IF      vs <= 0.65
AND       vs > 0.4
AND       total <= 15
AND       total >= 7
THEN      row =4;

RULE 6
IF      vs <= 0.65
AND       vs > 0.4
AND       total <= 6
THEN      row = 5;

RULE 7
IF      vs <= 0.4
AND       vs > 0.2
AND       total >= 16
THEN      row = 6;
```

```
RULE 8
IF      vs <= 0.4
AND        vs > 0.2
AND        total <= 15
AND        total >= 7
THEN       row = 7;

RULE 9
IF      vs <= 0.4
AND        vs > 0.2
AND        total <= 6
THEN       row = 8;

RULE 10
IF      vs <= 0.2
THEN       row = 9;

RULE 11
IF      extra < (1.5 * total)
AND        effect < (0.5 * total)
AND        ri >= 5
THEN       column = 0;

RULE 12
IF      extra < (1.5 * total)
AND        effect < (0.5 * total)
AND        ri < 5
AND        ri > 2
THEN       column = 1;

RULE 13
IF      extra < (1.5 * total)
AND        effect < (0.5 * total)
AND        ri <= 2
AND        ri >= 1
THEN       column = 2;

RULE 14
IF      extra < (1.5 * total)
AND        effect < (0.5 * total)
AND        ri  < 1
THEN       column = 3;

RULE 15
IF      extra >= (1.5 * total)
OR        effect >= (0.5 * total)
AND        ri  >= 5
THEN       column = 4;

RULE 16
IF      extra >= (1.5 * total)
OR        effect >= (0.5 * total)
AND        ri < 5
AND        ri > 2
```

```
THEN     column = 5;

RULE 17
IF       extra >= (1.5 * total)
OR        effect >= (0.5 * total)
AND        ri <= 2
AND        ri >= 1
THEN      column = 6;

RULE 18
IF       extra >= (1.5 * total)
OR        effect >= (0.5 * total)
AND        ri <  1
THEN      column = 7;

RULE 19
IF       row = 0
AND        column = 0
THEN      Assembly_System = AF;

RULE 20
IF       row = 0
AND        column = 1
THEN      Assembly_System = AF;

RULE 21
IF       row = 0
AND        column = 2
THEN      Assembly_System = AF;

RULE 22
IF       row = 0
AND        column = 3
THEN      Assembly_System = MM&AF;

RULE 23
IF       row = 0
AND        column = 4
THEN      Assembly_System = AP;

RULE 24
IF       row = 0
AND        column = 5
THEN      Assembly_System = AP;

RULE 25
IF       row = 0
AND        column = 6
THEN      Assembly_System = AP&MM;

RULE 26
IF       row = 0
AND        column = 7
THEN      Assembly_System = MM;
```

```
RULE 27
IF      row = 1
AND       column = 0
THEN      Assembly_System = AF;

RULE 28
IF      row = 1
AND       column = 1
THEN      Assembly_System = AF&AP;

RULE 29
IF      row = 1
AND       column = 2
THEN      Assembly_System = AI&AF;

RULE 29
IF      row = 1
AND       column = 3
THEN      Assembly_System = MM&AI;

RULE 30
IF      row = 1
AND       column = 4
THEN      Assembly_System = AP;

RULE 31
IF      row = 1
AND       column = 5
THEN      Assembly_System = AP;

RULE 32
IF      row = 1
AND       column = 6
THEN      Assembly_System = MM&AP;

RULE 33
IF      row = 1
AND       column = 7
THEN      Assembly_System = MM;

RULE 34
IF      row = 2
AND       column = 0
THEN      Assembly_System = AI;

RULE 35
IF      row = 2
AND       column = 1
THEN      Assembly_System = AI;

RULE 36
IF      row = 2
AND       column = 2
THEN      Assembly_System = AI;
```

RULE 37
IF row = 2
AND column = 3
THEN assembly_System = AI;

RULE 38
IF row = 2
AND column = 4
THEN Assembly_System = AI;

RULE 39
IF row = 2
AND column = 5
THEN Assembly_System = AI&AP;

RULE 40
IF row = 2
AND column = 6
THEN Assembly_System = MM;

RULE 41
IF row = 2
AND column = 7
THEN Assembly_System = MM;

RULE 42
IF row = 3
AND column = 0
THEN Assembly_System = AP;

RULE 43
IF row = 3
AND column = 1
THEN Assembly_System = AP;

RULE 44
IF row = 3
AND column = 2
THEN Assembly_System = MM&AP;

RULE 45
IF row = 3
AND column = 3
THEN Assembly_System = MM;

RULE 46
IF row = 3
AND column = 4
THEN Assembly_System = AP;

RULE 47
IF row = 3
AND column = 5
THEN Assembly_System = AP;

RULE 48
IF row = 3
AND column = 6
THEN Assembly_System = AP;

RULE 49
IF row = 3
AND column = 7
THEN Assembly_System = MA&MM;

RULE 50
IF row = 4
AND column = 0
THEN Assembly_System = AI;

RULE 51
IF row = 4
AND column = 1
THEN Assembly_System = AI;

RULE 52
IF row = 4
AND column = 2
THEN Assembly_System = AI;

RULE 53
IF row = 4
AND column = 3
THEN Assembly_System = MM;

RULE 54
IF row = 4
AND column = 4
THEN Assembly_System = AP;

RULE 55
IF row = 4
AND column = 5
THEN Assembly_System = AP;

RULE 56
IF row = 4
AND column = 6
THEN Assembly_System = MM&AP;

RULE 57
IF row = 4
AND column = 7
THEN Assembly_System = MA&MM;

RULE 58
IF row = 5
AND column = 0
THEN Assembly_System = AI;

```
RULE 59
IF      row = 5
AND       column = 1
THEN      Assembly_System = AI;

RULE 60
IF      row = 5
AND       column = 2
THEN      Assembly_System = MM&AI;

RULE 61
IF      row = 5
AND       column = 3
THEN      Assembly_System = MM;

RULE 62
IF      row = 5
AND       column = 4
THEN      Assembly_System = AI&MM;

RULE 63
IF      row = 5
AND       column = 5
THEN      Assembly_System = MM;

RULE 64
IF      row = 5
AND       column = 6
THEN      Assembly_System = MM;

RULE 65
IF      row = 5
AND       column = 7
THEN      Assembly_System = MA&MM;

RULE 66
IF      row = 6
AND       column = 0
THEN      Assembly_System = AP;

RULE 67
IF      row = 6
AND       column = 1
THEN      Assembly_System = AP;

RULE 68
IF      row = 6
AND       column = 2
THEN      Assembly_System = MM;

RULE 69
IF      row = 6
AND       column = 3
THEN      Assembly_System = MM;
```

```
RULE 70
IF      row = 6
AND     column = 4
THEN    Assembly_System = AP;

RULE 71
IF      row = 6
AND     column = 5
THEN    Assembly_System = AP;

RULE 72
IF      row = 6
AND     column = 6
THEN    Assembly_System = AP;

RULE 73
IF      row = 6
AND     column = 7
THEN    Assembly_System = MA;

RULE 74
IF      row = 7
AND     column = 0
THEN    Assembly_System = AI&MM;

RULE 75
IF      row = 7
AND     column = 1
THEN    Assembly_System = MM;

RULE 76
IF      row = 7
AND     column = 2
THEN    Assembly_System = MM;

RULE 77
IF      row = 7
AND     column = 3
THEN    Assembly_System = MM;

RULE 78
IF      row = 7
AND     column = 4
THEN    Assembly_System = AP;

RULE 79
IF      row = 7
AND     column = 5
THEN    Assembly_System = MM;

RULE 80
IF      row = 7
AND     column = 6
THEN    Assembly_System = MA&MM;
```

RULE 81
IF row = 7
AND column = 7
THEN Assembly_System = MA;

RULE 82
IF row = 8
AND column = 0
THEN Assembly_System = MM;

RULE 83
IF row = 8
AND column = 1
THEN Assembly_System = MM;

RULE 84
IF row = 8
AND column = 2
THEN Assembly_System = MM;

RULE 85
IF row = 8
AND column = 3
THEN Assembly_System = MM;

RULE 86
IF row = 8
AND column = 4
THEN Assembly_System = MM;

RULE 87
IF row = 8
AND column = 5
THEN Assembly_System = MM;

RULE 88
IF row = 8
AND column = 6
THEN Assembly_System = MA&MM;

RULE 89
IF row = 8
AND column = 7
THEN Assembly_System = MA;

RULE 90
IF row = 9
AND column = 0
THEN Assembly_System = MM;

RULE 91
IF row = 9
AND column = 1
THEN Assembly_System = MM;

```
RULE 92
IF      row = 9
AND     column = 2
THEN    Assembly_System = MM&MA;

RULE 93
IF      row = 9
AND     column = 3
THEN    Assembly_System = MA;

RULE 94
IF      row = 9
AND     column = 4
THEN    Assembly_System = MM;

RULE 95
IF      row = 9
AND     column = 5
THEN    Assembly_System = MA;

RULE 96
IF      row = 9
AND     column = 6
THEN    Assembly_System = MA;

RULE 97
IF      row = 9

AND     column = 7
THEN    Assembly_System = MA;

ASK total : "How many total number of parts you have?";

ASK ri : "What is the value of ri? (ri= (number of shifts * expenditure to
replace one operator on one shift)/Annual cost of one assembly operator)";

ASK extra: "How many extra parts you are needed ?";

ASK effect: "How many parts are effected ?";

ASK vs : " What is your annual production volume in millions ? ( enter like .65)";
```

4.7 OUT PUT OF THE EXPERT SYSTEM FOR OUR PROBLEM:

What is your annual production volume in millions ? (enter like .65)

0.7 (entered)

How many total number of parts you have?

7 (entered)

How many extra parts you are needed?

0 (entered)

How many parts are effected ?

2 (entered)

what is the value of ri? (ri= (number of shifts * expenditure to replace one operator on one shift)/Annual cost of one assembly operator)

3 (entered)

The best Assembly System for your company is AI&AP

So we can go for a Flexible assembly cell, which may consists of special purpose indexing machines, workheads, automatic feeders, manually loaded part magazines, and free-transfer machine with programmable workheads capable of performing several assembly tasks.

Finally we can conclude that we can leave the existing manual assembly and we can go for automation.

CHAPTER 5

REDESIGN FOR FLEXIBLE ASSEMBLY

Automated equipment[18], whether flexible or dedicated, requires an orderly environment. Therefore, before automated-assembly techniques can be implemented, the product must be properly designed and the plant layout should be such that part flow through the factory is orderly and efficient.

5.1 Proper Product Design

Within the last few years it has become increasingly important that products are designed for ease of assembly. This is true even if a factory is not automated, for any design characteristic that enables a product to be assembled automatically also increases the efficiency with which that product can be assembled manually. A product that is properly designed for automation is easy to assemble and contains parts that can be easily fed and oriented.

5.2 Ease of Assembling Parts

Before a product can be automatically assembled, its structure must incorporate several design features, including the following:

1 Product should have a base part on which assemblies can be built. The shape of this base should be such that it is easy to orient and stable enough to allow parts to be assembled on or within it without becoming dislocated.

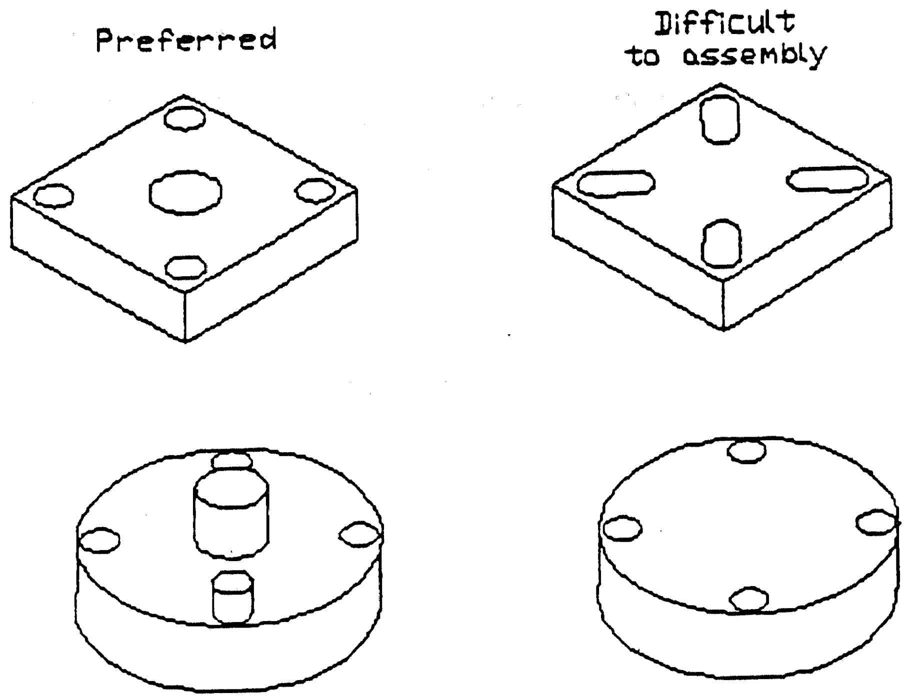


fig 7. Usage of Guide pins

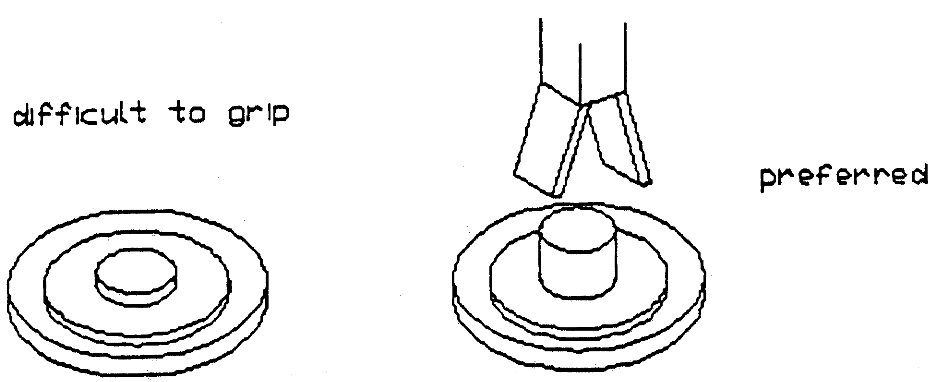


fig 8. Part design for easy handling(grasping)

2 Where possible, parts should be incorporated into subassemblies which can then be put together to form a final product.

3 Parts should be capable of being inserted from an above position. If possible, parts should be able to be added to an assembly or subassembly in layer fashion.

4 Wherever required, guide pins should be used to increase the ease of layering parts as shown in fig 7.

5 Parts should be able to be inserted with straight-line motion.

6 Parts to be assembled should be kept to a minimum.

7 Number of assembly operations should be kept to a minimum.

8 Parts should be able to be easily gripped and manipulated as shown in fig 8.

9 Assemblies and subassemblies should be designed so that any tool required for insertion or tightening can easily reach the required location and perform the required task. Products should be designed to provide unobstructed access to all parts and in such a way that parts can be assembled with one-step single-handle d adjustments.

10 If possible, all parts that go into the same assembly should be able to be handled by a single gripper or tool. If this is not possible, the concept of multiple-device tooling should be explored.

11 Parts should be designed in such a way that, once inserted, they cannot be dislocated. It should not be necessary to hold a part down in order to maintain orientation or location. (If possible, parts should be pressed rather than slipped into place.)

12 Bolt-and-nut assemblage should not be used.

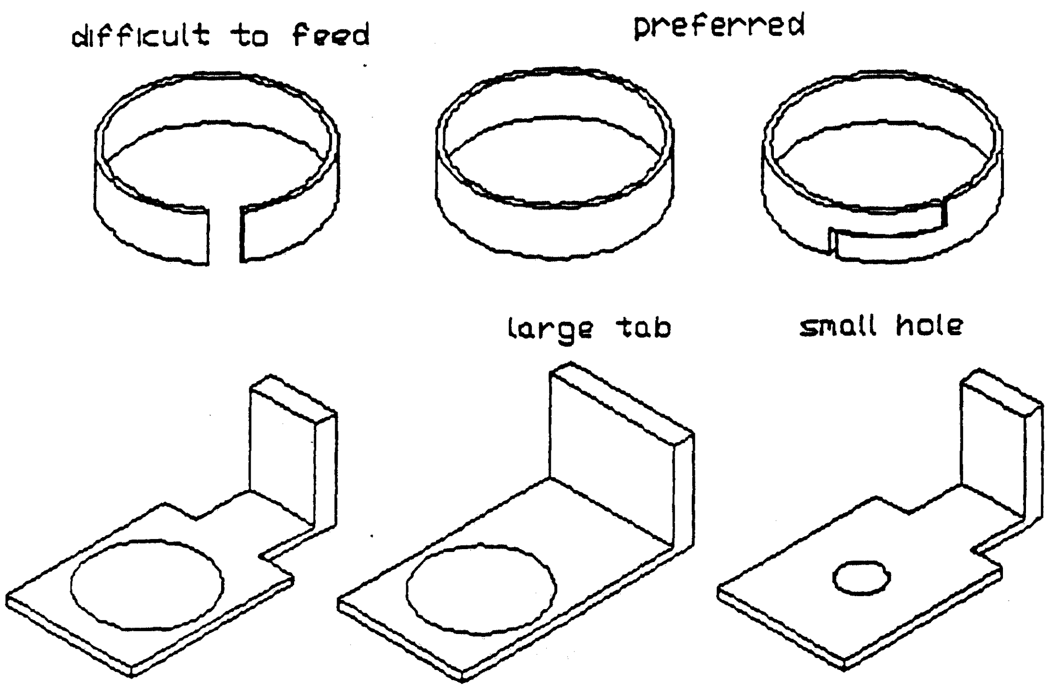


fig 9. parts with tabs

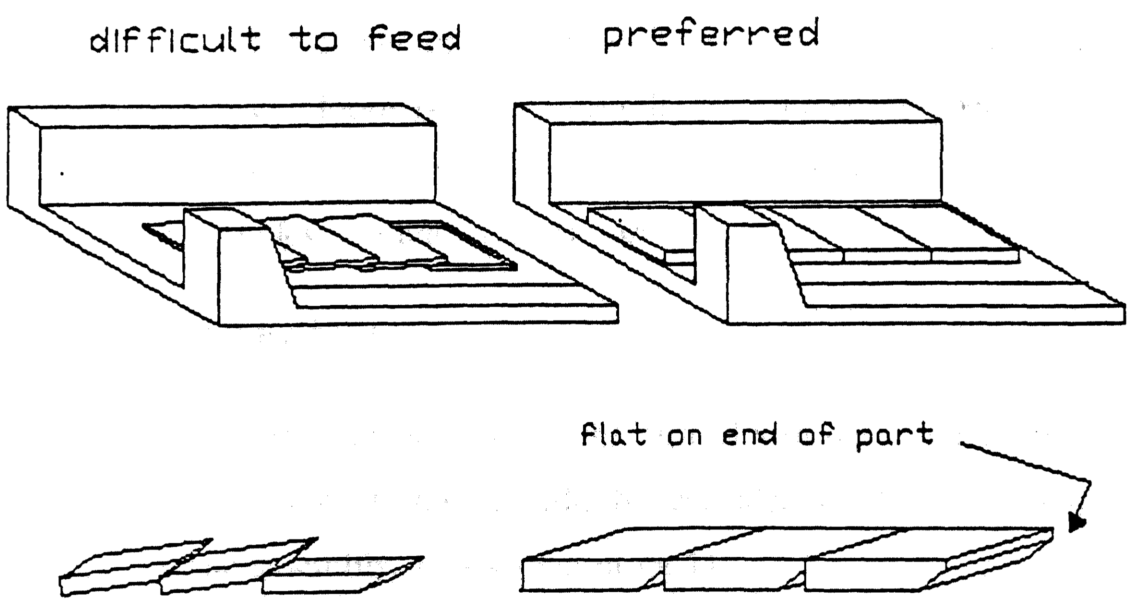


fig 10. parts with flat ends

13 Where possible, parts should be able to be pushed or snapped together rather than screwed together.

14 If screws are required, they should all be of the same size.

15 Parts should be compliant and self aligning. This requires the use of chamfered and tapered parts. Screws, if used, should have cone or oval points.

5.3 Ease of Feeding Parts

Parts that tend to tangle, overlap, or wedge cannot be easily fed through parts-presentation devices. When parts are being designed, therefore, several factors should be considered as shown in fig 9 & fig 10.

1 Parts should include ribs or tabs to prevent them from nesting.

2 Parts should have flat ends to prevent them from overlapping or wedging against one another.

3 Parts that tend to become entangled during presentation should be avoided. These include ope-ended springs, springs in which the space between loops is greater than the wire thickness, open loops or lock washers that can chain, and parts with tabs that can get caught in holes of same or other parts.

5.4 Ease of Orienting Parts

Parts that must be oriented increase the difficulty of the assembly process. Therefore, several factors should be considered when designing parts for automatic assembly. It is shown in fig 11

1 Keep the number of possible orientations of a part to a minimum. Symmetrical parts have few orientation requirements.

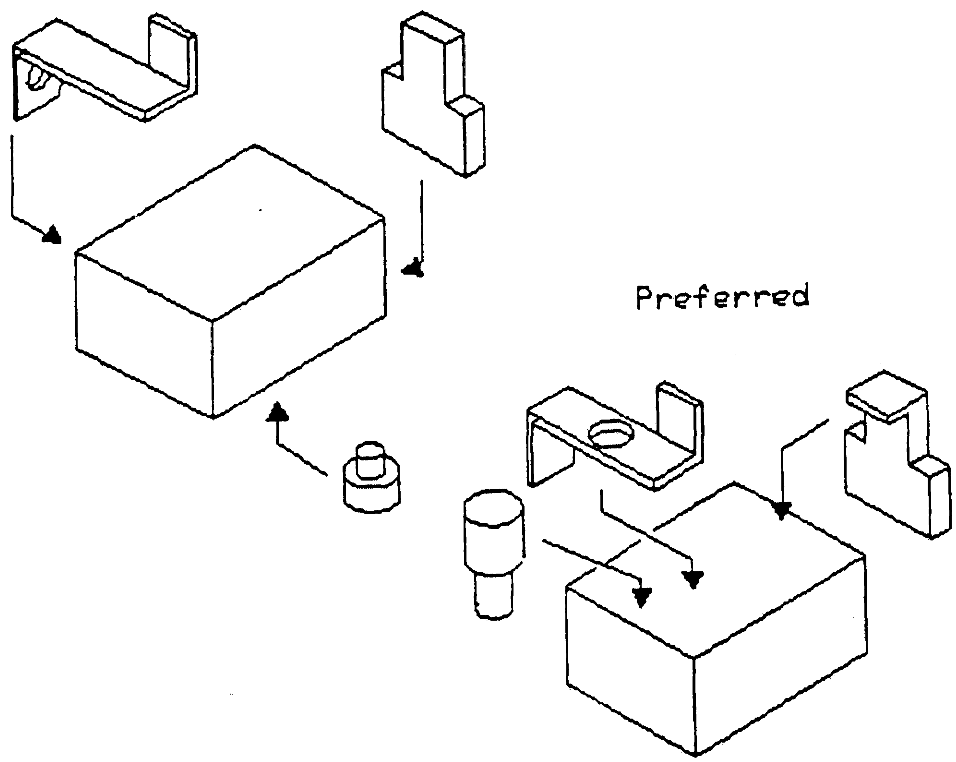


fig 11. Minimize directions

2 Asymmetrical parts, which have several orientation possibilities, should have such polar properties as an offset center of gravity or a marked asymmetry that enables the part to be oriented with automatic part-presentation equipment.

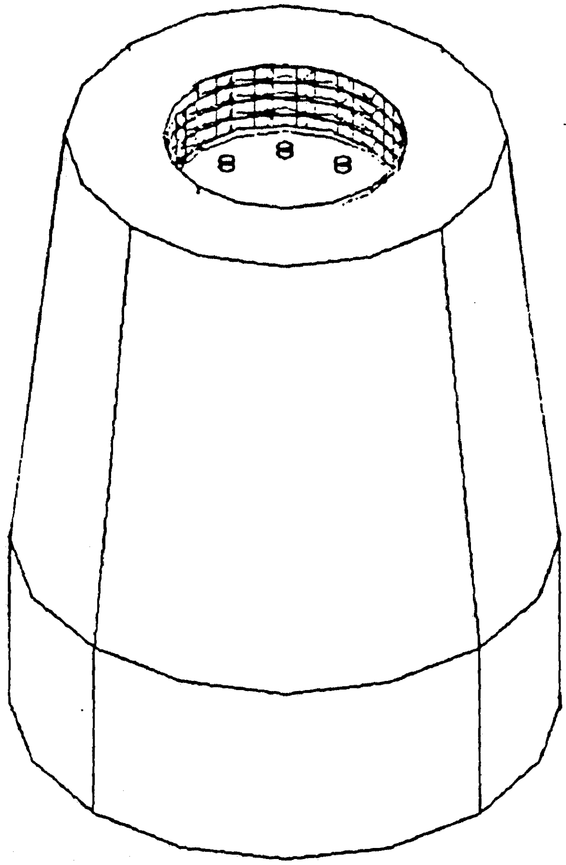
5.5 The Safety water shower device components are redesigned as follows: (fig.12)

5.5.1 Sprinkler and Cone Part

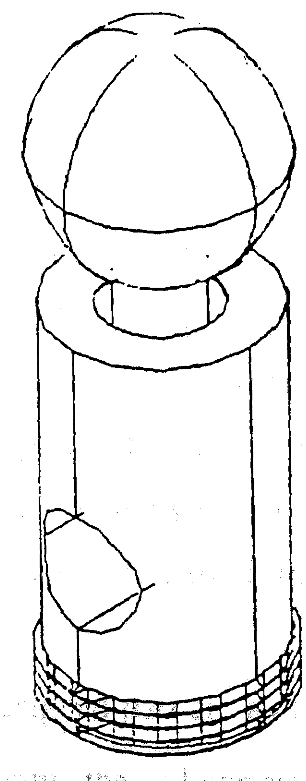
There is no relative motion between the sprinkler and the cone part, so we can join the two parts. These two parts are made with same material. Therefor there will not be any problem. According to the design rules it is always advisable to join the two parts, which are of the same material and there is no relative motion between the two parts. Thus two parts can be joined to one part, by reducing one assembly operation. By joining the sprinkler to the cone part, there will not be any problem in manufacturing the redesigned part. It can be easily casted or it can be manufactured by any other means. Now the newly redesigned part becomes the base part for our assembly.

If these two parts were not joined, the insertion of the sprinkler would have been very difficult. The sprinkler insertion would have been needed some grasping aids to hold and to insert into the cone part. This operation would have been also needed blower to keep the sprinkler into the position.

So it is very advisable to redesign the part and eliminate unnecessary assembly operation, according to the above mentioned design principles.



Redesigned part 1



Redesigned part 2

fig 12. Redesigned components of Safety Water Shower

Now the redesign part is able to easily gripped, oriented and manipulated.

5.5.2 Cylindrical Part and Ball Part

We can eliminate one complex screwing operation by subjecting the two parts (Cylindrical Part, Ball Part) to serious redesign principles.

From the present design we know that the ball part has a cylindrical block of diameter 14.84mm and has threads on it. This cylindrical block goes into the 15 mm hole of cylindrical part. There is a screwing operation between cylindrical part and the ball part. It is a very expensive operation. Robots for screwing operation costs very much. According to design principles, we have to try to avoid this kind of operations with some easy operations like snap fit, etc., or redesign the part for easy assembly.

By keen observation with the design principles, We can conclude that, this can be redesigned from two parts to one part, with some design changes without affecting the functions of the two parts, which are subjected to redesign.

The ball parts and the cylindrical parts are joined by eliminating the screwing operation. The cylindrical part diameter is reduced from 22.07mm to 14.80mm. The cylindrical part bottom cylinder also coincides with the top cylinder. The cross rod hole and its position are not at all affected, the diameter of cylindrical part is reduced to the ball part bottom cylindrical block diameter, because the whole part can easily pass through the cap, except the ball. The bottom of the part is threaded as it is and can go with the cone part.

The final dimensions of the redesigned part are as follows:-

The ball has a diameter of 15mm, the cylindrical block of diameter

14.80mm and height 45.64mm and is attached to the ball part with small diameter cylindrical block of diameter 7mm, height 3.5mm. There is a hole of diameter 8mm and is 11.98mm from the top of the cylindrical block of diameter 14.80mm. There are threads from the bottom of the part up to 3.88mm height. There is a hole of diameter 3.7mm along the axis of the cylinder throughout the part.

CHAPTER 6

ANALYSIS OF ASSEMBLY SYSTEMS

The Assembly System Analysis is done on the basis of Mr.Geoffery Boothroyd and Peter Dewhert principles which are taken from the product design for assembly hand book published by Boothroyd Dewhert, Inc.

Here we are comparing both manual assembly and flexible assembly systems.

The technique involves [1] two important steps, for each part in the assembly.

1 A decision as to whether 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 a part.

Having obtained this information it is then possible to compare the total assembly time and assembly cost for both the assembly systems.

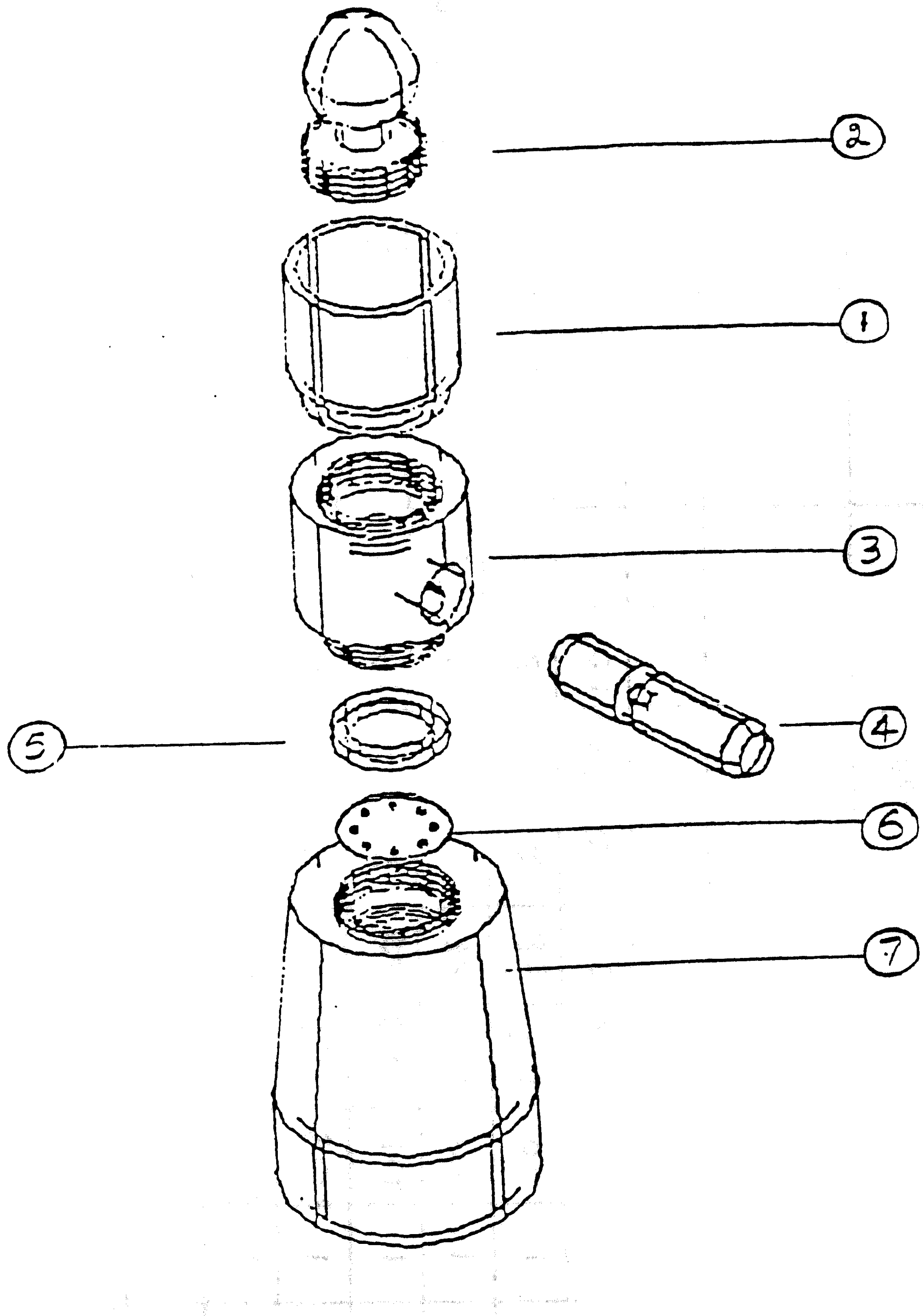
6.1 Procedure for the Analysis of Manual Assembly

To analyze, we have to follow the following steps

Step 1: Obtain the best information about the product and assembly.

The useful items are :

- Engineering Drawings
- Exploded three dimensional views
- An existing version of the product



Exploded view for the Manual Assembly

fig 13.

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 handing time per part	two-digit manual insertion code	manual insertion time per part	operation time, seconds (2) x [(4) + (6)]	operation cost, cents 0.4 x (7)	figures for estimation of theoretical minimum parts	
7	1	10	1.5	38	6	7.5	3	1	CONICAL PART
6	1	03	1.69	00	1.5	3.19	1.276	0	SPRINKLER
5	1	03	1.69	00	1.5	3.19	1.276	1	RUBBER PART
4	1	01	1.43	30	2	3.43	1.372	1	CROSS ROD
3	1	10	1.5	38	6	7.5	3	0	CYLINDRICAL PART
2	1	10	1.5	38	6	7.5	3	1	BALL JOINT
1	1	00	1.13	00	1.5	2.63	1.052	1	CAP.
						34.94	13.97	5	design efficiency = $\frac{3 \times NM}{TM}$ = 42%
						TM	CM	NM	

fig 14. Manual Assembly work sheet

- A proto type

In figure 13 we have exploded the view.

Step 2: Take the assembly part (or imagine how this might be done). Assign an identification number to each item, as it is removed.

In figure 13 the numbers are shown on the exploded view. If the assembly contains sub-assemblies treat this at first, as "Parts" and then analyze the sub-assemblies later.

Step 3: Prepare the assembly worksheet as shown in figure 14.

Step 4: Begin re-assembling the product. First assemble the part with the highest identification number to the work picture, 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.

Complete one row on the worksheet for each part.

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

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

Column 3: The two digit handling process code is generated from Chart 2-1, "manual handling estimated time". This is coded "10".

Column 4: The handling time (1.5 seconds) is obtained from chart 2-1 and corresponds to a two digit code of "10".

Column 5: The insertion process code is a two digit number derived from chart 2-2 "Manual Insertion-Estimated times." This is coded "38".

Column 6: The insertion time (6 seconds) is obtained from chart 2-2 and corresponds to the two digit code of "38".

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

Column 8: The total operation cost in cents is obtained by multiplying the operation time in column 7 by 0.4 where its later figure is a typical manual assembly rate in cents per second. However the user is expected to employ a figure which is appropriate for the particular company.

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

1 During the 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?

If the answer to any of these questions is yes then a "1" is placed in Column(9) except where multiple identical operations are indicated in Column(2), in which case the number of parts that must be separate is placed in Column(9).

In our case it is yes. So "1" is entered in column9

Step 5: When all rows have been completed (re-assembly is complete) the figures in Column(7) are all added to give the total estimated manual assembly time. The figures in Column(8) are added to give the total manual assembly cost and the figures in Column(9) added to give the theoretical minimum number of parts for the complete assembly.

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 is the manual design efficiency, NM is the theoretical minimum number of parts and TM is the 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 ideal time is obtained by assuming that each part is easy to handle and insert. Also, about on-third of the parts are secured immediately on insertion with well-designed snap-fit elements.

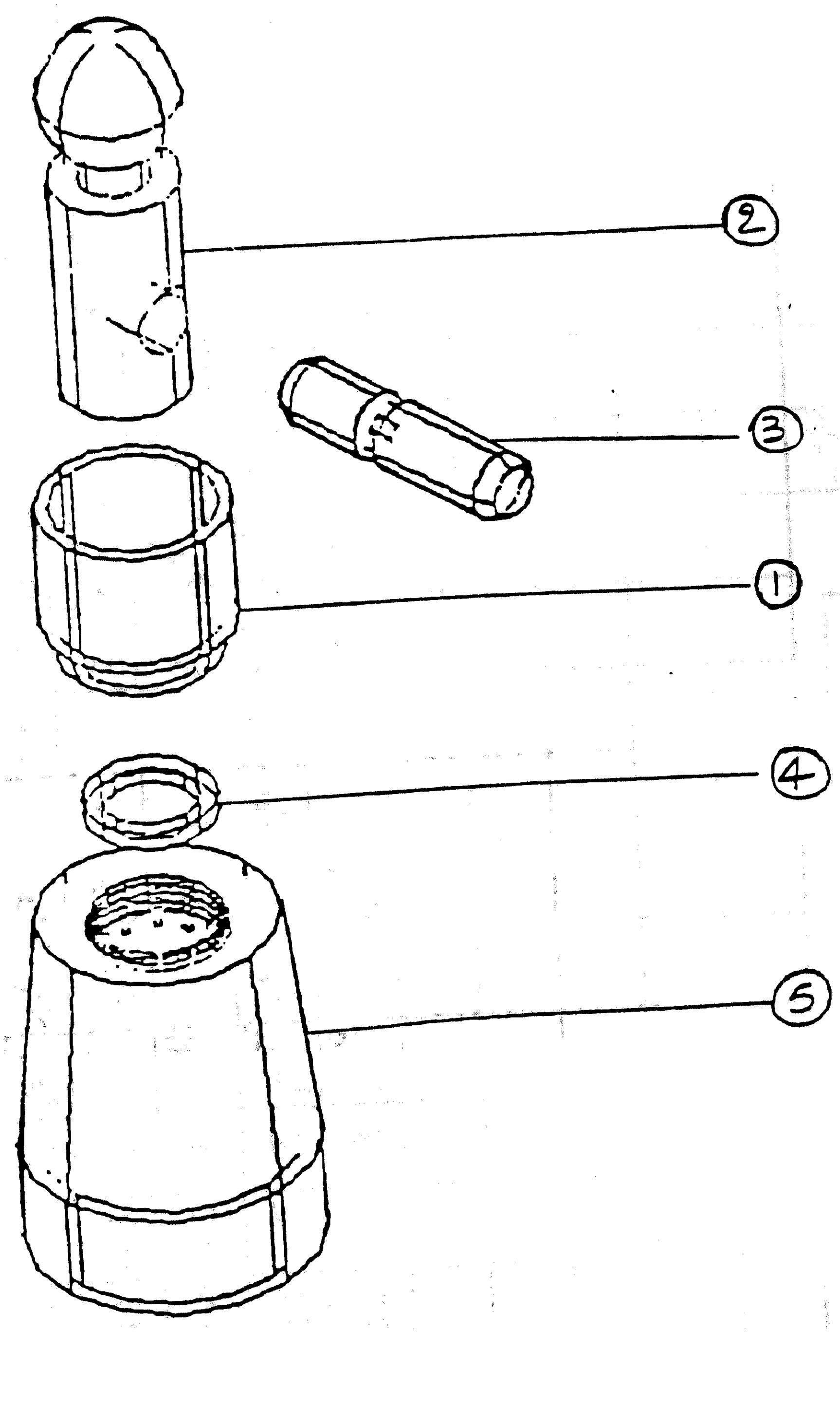
In our example

$$EM = 3 * 5/34.94 = 0.42 \text{ (42 percent)}$$

Thus, the estimated design efficiency for water shower assembly is 42%.

6.2 Procedure for the Analysis of Flexible Assembly

The completion of the "Assembly Worksheet" is presented in a similar manner to that of the previous one. Assuming the annual production of 10,000 units/year, The required production rate is 30 assemblies per



Exploded view for the Flexible Assembly

fig 15.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	required rate of assembly FR (per minute)
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	10040	0.7	3	25.24	7.31	0.21	30	1.2	2.4	0.144	0.3514	1	CONICAL PART
4	1	03012	0.5	5	50.5	10	0.3	01	1.5	3.0	0.16	0.46	1	RUBBER PART
3	1	24002	0.5	3	23.61	7.6	0.22	41	2.1	4.2	0.252	0.472	1	CROSS ROD
2	1	20002	0.7	3	23.00	7.8	0.23	39	1.8	3.6	0.216	0.446	1	REDESIGNED PART
1	1	13002	0.2	3	15.78	11.40	0.34	08	2	4	0.24	0.56	1	CAP
												2.30	5	
												CA	NM	

Column 6: $FM = 1500 \times \frac{OE}{Y}$, Y = part 'size'

Column 7: $DF = \frac{60}{FR} \times CR$ if $FR < FM$; $DF = \frac{60}{FM} \times CR$ if $FR \geq FM$

Column 11: $DI = \frac{60}{FR} \times WC$ if $FR < 60$; $DI = WC$ if $FR \geq 60$

fig 16. Flexible Assembly work sheet

minute.

The completion of the Automatic Assembly Worksheet will be examined is 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 15 shows an exploded view of the redesigned Safety water shower Assembly.

Step 2: Take the assembly apart (or imagine how this might be done). Assign an identification number to each item. In the example the parts and I.D.numbers are listed in Figure 15. The parts are numbered in the order of disassembly, starting with the Cap which are assigned the I.D. number "1". If the assembly contains sub-assemblies treat these, at first, as "parts" and then analyze the sub-assemblies later.

Step 3: Refer to the Assembly worksheet in Figure 16

Step 4: Begin to re-assemble the product, beginning with the part with the highest identification number. Complete the first row of the worksheet. The first row of the worksheet for the Water shower Assembly is completed in the following way:

Column 1: The I.D. number of the parts; for the Conical Part this is "5".

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

Column 3: The part feeding the orienting code is determined for the part using Charts 4-1 to 4-2. The Conical Part is assigned code number "10040". This determines the data to be entered in Columns (4) and (5).

Column 4: OE = 0.7

Column 5: CR = 3

Column 6: The size of the conical part is 33mm and so the maximum feed rate from a standard feeder is given by FM = 1500 * 0.7/41.6 = 25.24 parts per min.

Column 7: The required assembly rate is 30 per minute, i.e., FR = 30. Since this required rate is greater than FM, the difficulty rating for automatic handling is given by DF = CR * 60/25.24 = 7.131. It should be noted that when several identical parts are assembled at a single workstation then the feeder will be required to operate at a higher rate than the assembly rate in the calculation of DF as above will result in an estimated handling cost appropriate to the cost of engineering the feeder for transfer of the part to several delivery tracks.

Column 8: The cost for feeding and orienting each Conical Part is, CF = 0.03 * DF = 0.21 cents.

Column 9: The Conical Parts are inserted into the workcarrier which will have been designed to allow easy alignment and positioning from vertically above. The appropriate two-digit code obtained from Chart 4-5 is thus "30".

Column 10: The relative workhead cost from Chart 4-5 is WC = 1.2

Column 11: FR = 30 and so the difficulty rating for automatic insertion is, DI = (60/FR) * WC = 2.4.

Column 12: The cost of insertion for each Conical part is, CI = 0.06 * DI = 0.144 cents.

Column 13: The total operation cost for feeding, orienting and inserting the Conical Part is obtained by equation:[Columns(8) and (12) multiplied by the number of simultaneous operations[Column(2)], i.e. (2) * [(8) + (12)] where the number in parentheses refer to the data in those columns. So, the total cost of 0.35 cents is obtained.

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 thus "1".

Step 5: Continue to enter the data for each part in the assembly into successive rows in the worksheet, until the final assembly 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 Columns(13) and (14) respectively. This gives CA = 2.30 cents and NM = 5.

6.3 Result:

From the above analysis, we can see that the theoretical number of parts are reduced from 7 to 5, operating cost per part is reduced from the 13 cents to 2 cents, the operation time is reduced from the 34 seconds to 2 seconds. This drastic changes are achieved when we went from the manual to flexible assembly. When ever there is high production rate, it is advisable to go for automation.

MANUAL HANDLING—ESTIMATED TIMES (seconds)

Key:

ONE HAND

		parts are easy to grasp and manipulate					parts present handling difficulties (1)				
		thickness > 2 mm			thickness ≤ 2 mm		thickness > 2 mm			thickness ≤ 2 mm	
		size >15 mm	6 mm ≤ size ≤15 mm	size <6 mm	size >6 mm	size ≤6 mm	size >15 mm	6 mm ≤ size ≤15 mm	size <6 mm	size >6 mm	size ≤6 mm
		0	1	2	3	4	5	6	7	8	9
parts can be grasped and manipulated by one hand without the aid of grasping tools	0 — (α+β) < 360°	1.13	1.43	1.88	1.69	2.18	1.84	2.17	2.65	2.45	2.98
	1 — 360° ≤ (α+β) < 540°	1.5	1.8	2.25	2.06	2.55	2.25	2.57	3.06	3	3.38
	2 — 540° ≤ (α+β) < 720°	1.8	2.1	2.55	2.36	2.85	2.57	2.9	3.38	3.18	3.7
	3 — (α+β) = 720°	1.95	2.25	2.7	2.51	3	2.73	3.06	3.55	3.34	4

ONE HAND with GRASPING AIDS

			parts need tweezers for grasping and manipulation							parts need standard tools other than tweezers	parts need special tools for grasping and manipulation
			parts can be manipulated without optical magnification				parts require optical magnification for manipulation				
			parts are easy to grasp and manipulate		parts present handling difficulties (1)		parts are easy to grasp and manipulate		parts present handling difficulties (1)		
			thickness > 0.25 mm	thickness ≤ 0.25 mm	thickness > 0.25 mm	thickness ≤ 0.25 mm	thickness > 0.25 mm	thickness ≤ 0.25 mm	thickness > 0.25 mm	thickness ≤ 0.25 mm		
			0	1	2	3	4	5	6	7	8	9
parts can be grasped and manipulated by one hand but only with the use of grasping tools	α ≤ 180°	4 — 0 ≤ β ≤ 180°	3.6	6.85	4.35	7.6	5.6	8.35	6.35	8.6	7	7
		5 — β = 360°	4	7.25	4.75	8	6	8.75	6.75	9	8	8
	α = 360°	6 — 0 ≤ β ≤ 180°	4.8	8.05	5.55	8.8	6.8	9.55	7.55	9.8	8	9
		7 — β = 360°	5.1	8.35	5.85	9.1	7.1	9.55	7.85	10.1	9	10

TWO HANDS for MANIPULATION

	parts present no additional handling difficulties					parts present additional handling difficulties (e.g. sticky, delicate, slippery, etc.) (1)				
	α ≤ 180°			α = 360°		α ≤ 180°			α = 360°	
	size > 15 mm	6 mm ≤ size ≤ 15 mm	size < 6 mm	size > 6 mm	size ≤ 6 mm	size > 15 mm	6 mm ≤ size ≤ 15 mm	size < 6 mm	size > 6 mm	size ≤ 6 mm
	0	1	2	3	4	5	6	7	8	9
8 — parts severely nest or tangle or are flexible but can be grasped and lifted by one hand (with the use of grasping tools if necessary) (2)	4.1	4.5	5.1	5.6	6.75	5	5.25	5.85	6.35	7

TWO HANDS required for LARGE SIZE

	parts can be handled by one person without mechanical assistance									parts need special tools for grasping and manipulation
	parts do not severely nest or tangle and are not flexible								parts severely nest or tangle or are flexible (2)	
	part weight < 10 lb				parts are heavy (> 10 lb)					
	parts are easy to grasp and manipulate		parts present other handling difficulties (1)		parts are easy to grasp and manipulate		parts present other handling difficulties (1)			
	α ≤ 180°	α = 360°	α ≤ 180°	α = 360°	α ≤ 180°	α = 360°	α ≤ 180°	α = 360°		
	0	1	2	3	4	5	6	7	8	9
9 — two hands required for grasping and transporting parts	2	3	2	3	3	4	4	5	7	9

CHART 2-1

MANUAL INSERTION—ESTIMATED TIMES (seconds)

Key:

- PART ADDED but NOT SECURED
- PART SECURED IMMEDIATELY
- SEPARATE OPERATION

			after assembly no holding down required to maintain orientation and location (3)				holding down required during subsequent processes to maintain orientation or location (3)			
			easy to align and position during assembly (4)		not easy to align or position during assembly		easy to align and position during assembly (4)		not easy to align or position during assembly	
			no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)
			0	1	2	3	6	7	8	9
addition of any part (1) where neither the part itself nor any other part is finally secured immediately	part and associated tool (including hands) can easily reach the desired location	0	1.5	2.5	2.5	3.5	5.5	6.5	6.5	7.5
	part and associated tool (including hands) cannot easily reach the desired location: due to obstructed access or restricted vision (2)	1	4	5	5	6	8	9	9	10
	part and associated tool (including hands) cannot easily reach the desired location: due to obstructed access and restricted vision (2)	2	5.5	6.5	6.5	7.5	9.5	10.5	10.5	11.5

			no screwing operation or plastic deformation immediately after insertion (snap/press fits, circlips, spire nuts, etc.)		plastic deformation immediately after insertion						screw tightening immediately after insertion (6)	
					plastic bending or torsion			rivetting or similar operation				
						not easy to align or position during assembly			not easy to align or position during assembly			
			easy to align and position with no resistance to insertion (4)	not easy to align or position during assembly and/or resistance to insertion (5)	easy to align and position during assembly (4)	no resistance to insertion	resistance to insertion (5)	easy to align and position during assembly (4)	no resistance to insertion	resistance to insertion (5)	easy to align and position with no torsional resistance (4)	not easy to align or position and/or torsional resistance (5)
			0	1	2	3	4	5	6	7	8	9
addition of any part (1) where the part itself and/or other parts are being finally secured immediately	part and associated tool (including hands) can easily reach the desired location and the tool can be operated easily	3	2	5	4	5	6	7	8	9	6	8
	part and associated tool (including hands) cannot easily reach desired location or tool cannot be operated easily: due to obstructed access or restricted vision (2)	4	4.5	7.5	6.5	7.5	8.5	9.5	10.5	11.5	8.5	10.5
	part and associated tool (including hands) cannot easily reach desired location or tool cannot be operated easily: due to obstructed access and restricted vision (2)	5	6	9	8	9	10	11	12	13	10	12

		mechanical fastening processes (part(s) already in place but not secured immediately after insertion)				non-mechanical fastening processes (part(s) already in place but not secured immediately after insertion)				non-fastening processes	
		none or localized plastic deformation				metallurgical processes					
							additional material required				
		bending or similar processes	rivetting or similar processes	screw tightening (6) or other processes	snap fit, snap clip, press fit, etc.	no additional material required (e.g. resistance, friction welding, etc.)	soldering processes	weld/braze processes	chemical processes (e.g. adhesive bonding, etc.)	manipulation of parts or sub-assembly (e.g. orienting, fitting or adjustment of part(s), etc.)	other processes (e.g. liquid insertion, etc.)
		0	1	2	3	4	5	6	7	8	9
assembly processes where all solid parts are in place	9	4	7	5	3.5	7	8	12	12	9	12

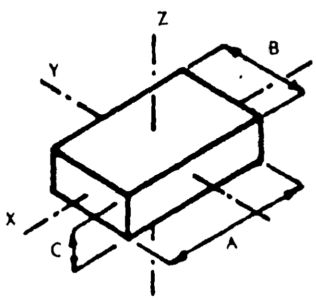
CHART 2-2

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 f-ature, 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	MANUAL HANDLING REQUIRED
	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	
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 HANDLING-ADDITIONAL FEEDER COSTS, DC

FIGURES TO BE ADDED TO FC, OBTAINED FROM CHARTS 4-2 or 4-3

					parts will not tangle or nest				tangle or nest but not severely				severely nest	severely tangle
					not light		light		not light		light			
					not sticky	sticky	not sticky	sticky	not sticky	sticky	not sticky	sticky		
					0	1	2	3	4	5	6	7	8	9
parts are small and non-abrasive	parts do not tend to overlap during feeding	not delicate	non-flexible	0	0	1	2	3	2	3	3	4	MANUAL HANDLING REQUIRED	
			flexible	1	2	3	4	5	4	5	5	6		
		delicate	non-flexible	2	1	2	3	4	3	4	4	5		
			flexible	3	3	4	5	6	5	6	6	7		
	parts tend to overlap during feeding	not delicate	non-flexible	4	2	3	3	4	4	5	4	5		
			flexible	5	4	5	5	6	6	7	6	7		
		delicate	non-flexible	6	3	4	4	5	5	6	5	6		
			flexible	7	5	6	6	7	7	8	7	8		

		very small parts					large parts				
		rotational		non-rotational			rotational		non-rotational		
		L/D≤1.5	L/D>1.5	A/B ≤ 3 A/C > 4	A/b > 3	A/B ≤ 3 A/C ≤ 4	L/D≤ 1.5	L/D>1.5	A/B ≤ 3 A/C > 4	A/B > 3	A/B ≤ 3 A/C ≤ 4
		0	1	2	3	4	5	6	7	8	9
parts are very small or large but are nonabrasive	8	2	2	2	2	2	9	9	9	9	9

		parts will not severely tangle or nest									severely tangle or nest
		small parts					large parts		very small parts		
		orientation defined by geometric features			orientation defined by non-geometric features		orientation defined by geometric features	orientation defined by non-geometric features	orientation defined by geometric features	orientation defined by non-geometric features	
		non-flexible		flexible	do not overlap	overlap					
		do not overlap	overlap								
		0	1	2	3	4	5	6	7	8	9
abrasive parts	9	2	4	4			9		4		

CHART 4-4

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

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CHAPTER 7

SIMULATION OF FLEXIBLE ASSEMBLY CELL USING IGRIP

7.1 HISTORY

From its very definition a FAS is a very complex entity. It needs to be able to process simultaneously a variety of Sub Assemblies in the right sequence. The integration of materials handling, storage and transportation devices with the process in the FAS can be more difficult to achieve than the integration in a dedicated system. Thus producing a efficient and effective design for a FAS is not an easy task.

There exists a basic dilemma. Over design results in a system possessing excessive capabilities which are unnecessary. It increases the capital investment required and may lead to the rejection of the entire concept because of non-cost effectiveness. Acceptance of an inadequate of an inadequate system is perhaps even more costly because once a system is installed, mistakes are more difficult to rectify.

Graphical simulation is one of the tools available when designing or evaluating a FAS. It can give the system designer information to identify the excesses and deficiencies in advance. It can also be used to predict how a system will perform. With the advantage of speed, a designer can consider alternatives and incorporate changes easily. Interaction between components of a system is normally difficult to achieve normally using drawing in a two dimensional static mode. CAD can overcome problems of visualization when dealing with the dynamic nature of FAS elements such as industrial robots. However, it must be stressed that graphical simulation does not by itself provide solutions and does not remove the onus from the designer but employed sensibly, it can provide improvements.

There has been a dramatic increase in the use of simulation in manufacturing during the past few years. Increased international and competition in many industries has resulted in a greater emphasis on using automation to improve productivity and also to reduce cost. Since automated systems are often quite complex, they typically can be analyzed only by a powerful tool like simulation. Reduced computing costs and improvements in simulation languages have also led to increased use of simulation. Finally, the availability of graphical animation has resulted in greater understanding and use of simulation by industries.

7.2 THE ADVANTAGES AND DISADVANTAGES OF SIMULATION

Here are some of the 7.2 advantages of simulation:

1 Realism.

2 Nonexistent systems.

3 Time compression.

4 Deferred specification of objectives.

5 Experimental control.

6 Reproducibility of random conditions.

7 Training.

8 Winning over the client.

9 Inexpensive insurance.

Along with its many advantages, simulation is subject to important disadvantages. Among them are these:

1 Failure to produce exact results.

2 Lack of generality of results.

3 Failure to optimize.

4 Long lead times.

5 Costs for providing a simulation capability.

6 Misuse of simulation.

7.3 OBJECTIVES IN SIMULATION OF MANUFACTURING SYSTEMS

7.3.1. Benefits of Simulation in Manufacturing:

The general benefit of simulation in manufacturing is that it allows managers to obtain a system wide view of the effect of changes on their manufacturing system (whether it exists or not). Specific benefits of simulation in manufacturing are increased throughput, reduced in-process inventories, increased utilization of machines and workers, increased on-time deliveries and reduced capital requirements.

7.3.2. Manufacturing Environments In Which Simulation Is Applied:

The following are three situations in which simulation is applied in manufacturing:

1 New equipment and buildings are required.

2 New equipment is required in an old building.

3 Upgrading of existing equipment or its operation.

7.3.3. Manufacturing Issues That Simulation Is Used To Address:

1 The need for and the quantity of equipment and personnel.

2 Performance evaluation.

3 Evaluation of operational procedures

7.3.4. Measures Of Performance Used In Manufacturing Simulation Studies:

1 Throughput.

2 Time in systems for jobs.

3 Time jobs spend in queues.

4 Time that jobs spend being transported.

5 Sizes of in-process inventories.

6 Utilizations of equipment and personnel.

7 Proportion of time that a machine is blocked.

8 Proportion of jobs produced which must be reworked or scrapped.

9 Return on investment for a new or modified manufacturing system.

10 Payback period.

7.4 SIMULATION SOFTWARE

Simulation modeling involves creating a model using computer software. There are three basic possibilities to obtain a working model:

7.4.1 Write your own program, in a general-purpose computer language such as FORTRAN, Pascal, and C etc:

The advantages of using a general-purpose language are that the language is probably already known by the analyst, that the required computer execution time may be less than for a model written in a simulation language since the program is tailor-made for the application. The disadvantage is it takes a long time to develop.

7.4.2 Acquire a simulation package and write a model in that language:

The principal advantage of these systems is that, several man-years having generally gone into their development, they provide powerful aids to modeling. They also provide a structure within which the model will be developed and once a programmer is used to this way of thinking. Their cost may be considerable, up to about $60,000, but this is small in comparison to the benefits which can be obtained from their use. Because of the need to acquire skill in their use, packages may be more appropriate for use by someone who is going to specialize in simulation rather than the manufacturing engineer who has many responsibilities and regards simulation as just one of his tools. The following list of functions which should be provided by a simulation package:

1 The timing control mechanism.

2 A data base or file structure.

3 A method of defining the initial conditions in the model.

4 Random number generation and sample from distributions.

5 Record observations, analyze results and print reports.

6 Display histograms and other forms of chart of results.

7 Error checks and diagnostics.

8 Display the state of the model at any point in time.

7.4.3 Acquire and use an already written generic model:

A generic model is a model of a specific type of system written in such a way that certain parameters can be altered by the user through the data. For example, a generic manufacturing system model might ask the user to define the number of machines in the system model might ask the user to define the number of machines in the system to be modeled, and then proceed using that information. The authors of these kind of models have studies a large number of systems and have included in the program as many as possible of the features which that type of system may exhibit. This avoids completely any computer programming, and only requires a data deck to be "punched-up" by the user, so they are usually easily learned by nonspecialists, such as manufacturing engineers. The disadvantage is incapable of handling some special features of real systems.

7.5 JUST-IN-TIME CONTROL SYSTEMS

Most manufacturing firms are embracing the ideals of Just-in-time manufacture. This requires a new approach to organizing manufacturing operations. Flexible manufacturing is a key technique for achieving the reduction in lead time and work in progress levels which JIT methods aim at. One of the effects of this change is that manufacturing systems are now required to operate on a pull method rather than on a push basis. This change in approach demands a re-think about simulation modeling of manufacturing systems. As with manufacturing systems, many simulation models are based on the push principles. Jobs to be processed arrive in the system -- they are pushed into it. Then the logic of the model tests the queues and discovers whether operations can take place, so that the job is pushed one further stage along its way to completion. Finally the job reaches the completion of its last operation and leaves the system. To implement the JIT approach we need a method of pulling work through the system. To do this in simulation model is no easier or no complicated than it is in real life. The decision rules must be framed to suit. New packages will be developed which approach model building process from this standpoint.

7.6 INTRODUCTION OF IGRIP SOFTWARE PACKAGE

IGRIP software package is a computer graphics system used for workcell layout, simulation and off-line programming.

Devices used in the workcells may be added by modeling them within the part Modeler. Parts generated on other CAD systems may be read in via the IGES, DES or other input data translators that are provided with the IGRIP package.

Parts are put together to define devices with multiple degree of freedom. A device has both geometric and non-geometric information stored with it. Non - geometric information including kinematics, dynamics, velocities etc. can be entered through interactive menus.

A workcell is composed of devices, positioned relative to each other. Devices used in the workcell may be selected from a library of robots, conveyors, tables, end-effectors, and other devices provided with the system, or modeled by the user.

IGRIP has the capacity to generate robot programs interactively. Once the workcell has been created, programs can be developed with the sure observing immediate program statement execution. Several devises can be simulated simultaneously. Input/Output signaling can be set up between devices during a simulation. In addition, collisions between any of the devices in the cell may be deleted, displayed, and recorded automatically as the simulation proceeds.

The IGRIP simulation system is brought up by invoking the 'igrip' executable file located in the /usr/deneb/igrip.4d directory. To start up IGRIP move to the IGRIP directory by entering cd /usr/deneb/igrip*. At this point enter 'igrip -f' to invoke the fullscreen mode of IGRIP.

The IGRIP menu system is divided mainly into Contexts, which are arranged across the top of the IGRIP screen, each of which has a group of subdivisions called Pages.

The Contexts are :

CAD	DEVICE
LAYOUT	MOTION
DIMENSION	USER
ANALYSIS	SYSTEM

The IGRIP menu:

CAD: The CAD Context allows the user to create and modify 3-D surface or wireframe geometry used to represent Parts.

DEVICE: The DEVICE Context allows the user to build and modify Devices by putting together the Parts built in the CAD context.

LAYOUT: The LAYOUT Context allows the user to lay out a workcell. This includes positioning Devices, creating Paths for motion definition, connecting I/O signals and creating Collision Queues.

MOTION: The MOTION Context allows the user to define and execute motion for Devices. Motion can be commanded interactively or through Program control (when running a simulation). Simulation Programs can also be downloaded to specific controller or generic formats.

DIMENSION: The DIMENSION Context allows the user to create and manipulate various kinds of dimension entities to document workcell layouts and geometric data. Dimensions are fully three dimensional planar entities, and can be translated and rotated in space with respect to a coordinate system that is local to the dimension. Dimensions are also dynamically associative, or ''data-driven'', which implies that the dimensions are attached to geometry, and are continuously updated to reflect the current state of that geometry.

USER: The USER Context allows customerization of the user interface to define custom Menu Pages with functions taken from other Pages or functions to invoke CLI(Command Line Interpreter) macro files.

ANALYSIS: The ANALYSIS Context allows the user to perform various forms of analysis. Functions on the MEASURE Page allow identification of various items in the world, as well as the determination of the distances and angles between them. The units for reporting as well as the Frame of reference may be set by the user. Entity properties such as area and volume may be queried using functions on the PROPERTIES Page. All analysis functions utilize ''Analysis Registers'' that can be used in conjunction with IGCALC.(IGCALC is an arithmetic expression evaluator that can be accessed by picking the DENEB logo. It includes pre-defined System Variables, user defined variables and trigonometric functions) Analysis Registers are pre-defined IGCALC registers which are automatically assigned the most recent values for a parameter that result from analysis queries and calculations. Some of the Registers and the data values they represent:

x, y, z: x-, y-, and z-coordinate of a point respectively

dx, dy, dz: distance in the x-, y-, and z-direction respectively

d: total Cartesian distance

V: Object volume

A: Object area

dia: Polygon diameter

ang: angle between the entities

R, P, Y: Roll, Pitch, and Yaw angle about Z, Y, and X axis respectively

SYSTEM The SYSTEM Context provides system utilities to modify the system environment and world attributes as well as to interact with the UNIX file system.

CLI The CLI(Command Line Interpreter) Button is used to enter CLI commands interactively. This enables the expert user to type in a command from any Context without switching to the relevant Context.

7.7 ADVANTAGES AND DISADVANTAGES OF IGRIP

7.7.1 ADVANTAGES

(i) off-line programming

After a program is created in computer terminal, and the operation is correctly and smoothly, the program can be downloaded to the machines or robots. So the production of the machines and robots can not be interrupted. It saves production time and cost.

(ii) Observation

IGRIP uses CAD system to build the model as per real world system, so some constraints or obstacles of the system are found easily. This function provides IGRIP as a powerful tool for plant layout design.

7.7.2 DISADVANTAGES

(i) High installation cost

The hardware and software of IGRIP cost US$160,000. Compared with other simulation packages such as GPSS, SIMAN, WITNESS or SIMFACTORY, the cost of these packages is US$10,000 - US$30,000 only.

(ii) Time consuming for building the model

Programmer must spend long time to study the manufacturing system, take measurement of the machines or robots, find out the degree of freedom of the motion components of the machine, define the path of movement, and the speed, compare with other systems, cycle time is the only element to run a simulation model.

(iii) Difficult to repeat the sequence in simulation

For example, 10 program lines control a robot to grasp a part "A" and transport from point 1 to point 2. Manufacturing engineering can not use "FOR loop" or "REPEAT loop" to repeat the sequence in a simulation. In the second sequence, the part at point 1 is part A#2, for part A#2, an addition 10 program line for part A#2 are needed to continue the sequence. A "PROCEDURE" subroutine may reduce the size of the program.

The repeat sequence can be used in download program, in real world,

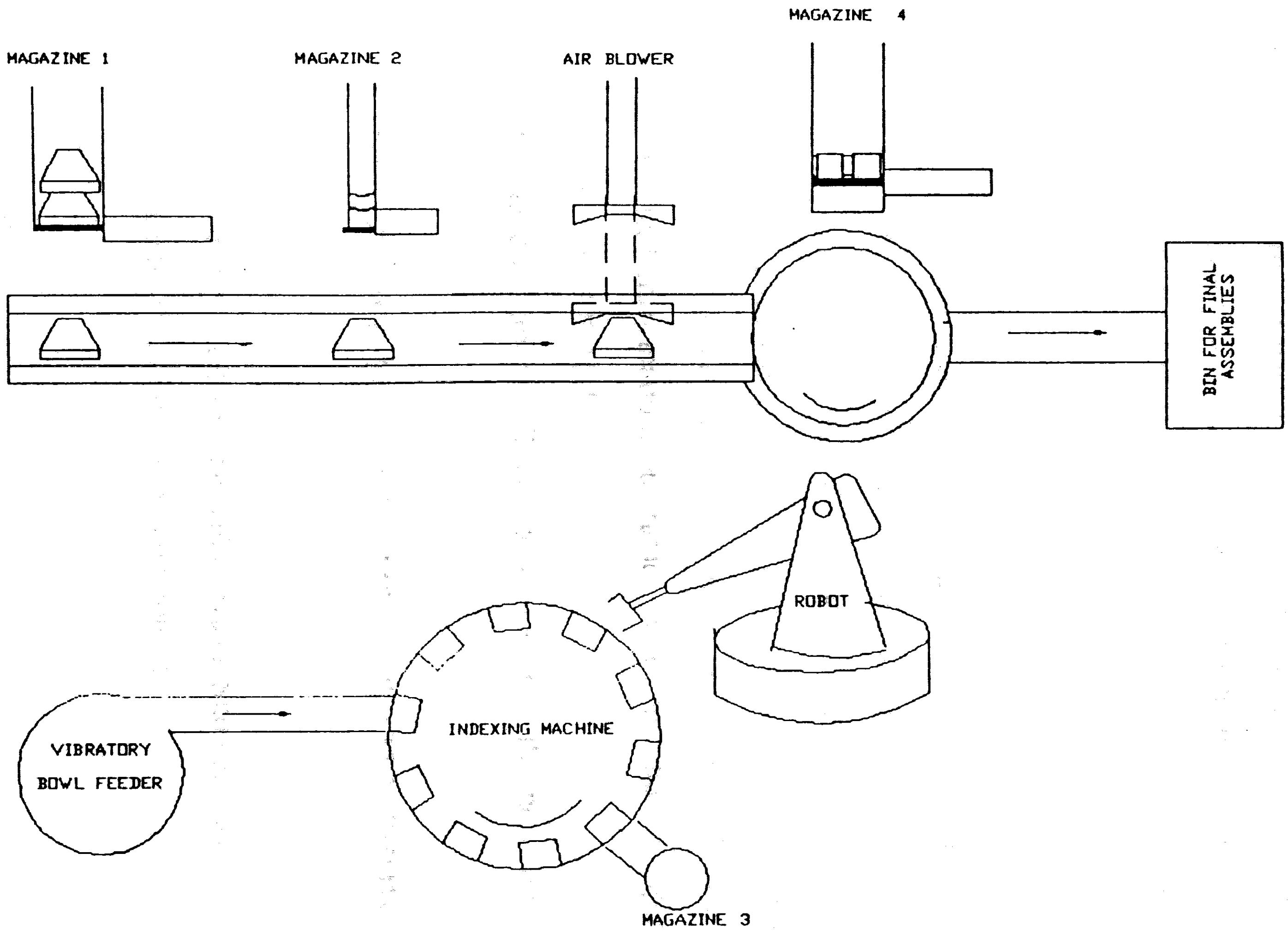

fig 17. Flexible Assembly Cell

For Safety Water Shower Assembly

when a robot close gripper, a part is grasped tightly then picked to somewhere. In IGRIP simulation programming, a part name is necessary for the "GRAB" or "ATTACH" command, a command grabs part A can not grab part A#2.

(iv) Analysis function

If someone uses a stop watch to collect the data of a cycle time, the time gathered can not be used to evaluate the efficiency of the manufacturing system. The reason for this is that IGRIP does not have statistical distribution function for part arrival time, machine downtime and repair time etc. (as other simulation packages have). The main usage of the IGRIP is not to provide statistical information, but rather to act as a host computer to control the operation of the system.

According to the developer -- Deneb Robotics Inc., the new version has the statistical function will be available in 1991.

7.8 SIMULATION MODEL FOR THE SAFETY WATER SHOWER ASSEMBLY

The Flexible Assembly Cell for the safety water Shower Assembly is as shown fig 17, Consists of the following components.

1 Conveyor

2 Rotating table

3 Magazine 1

4 Magazine 2

5 Air blower

6 Vibratory Bowl

7 Indexing Machine

8 Magazine 3

9 Robot

10 Magazine 4

11 Bin

12 Shutter Assembly for magazine

The above mentioned components is modeled in IGRIP software system. The actual dimensions are used to model the cell component on the system.

Conveyor: This conveyor runs on a table in the work cell to move the sub-assemblies from one assembly operation to the other.

The table can be made of either steel or wood. The table is 3000 m.m long, 300 m.m. width and 100 m.m thickness. The table has legs with dimensions 50x50x1000 m.m.

Rotating Table: This rotating table connects the conveyor table and the sliding table. This rotating table is mainly used to assemble the conical part and re-designed part. When the conical part runs on the conveyor and reaches the rotating table. By the time the redesigned part is picked by the robot from the indexing table, and holds the part and the rotating table rotates. Thus the screwing operation takes place.

The round table is of diameter 450 m.m and thickness 100 m.m. This table is supported by a pillar of diameter 100 m.m. and length 950 m.m. which rests on 250 diameter and 50 diameter block. The Actual rotating disc which rotates on the round table is of diameter 300 m.m and thickness 10 m.m.

Magazine 1: This Magazine is to hold the conical parts. It Acts as a buffer for the conical part. The parts will flow from the magazine to the conveyor by the gravity force. This Magazine has a shutter assembly which controls the inflow of the parts on to the conveyor.

The magazine 1 is of cylindrical shape of inner diameter 36 m.m, out diameter 40 m.m, length 425 m.m.

The shutter for the magazine 1 has 100x100x100 m.m. block. This block has a plate of 45 m.m. width, 160 m.m long and 5 m.m. thickness, which slides under the magazine1.

The magazine is supported by a stand.

Magazine 2: This Magazine is to hold the Rubber parts. It Acts as a buffer for the Rubber part. The parts will flow from the magazine to the conveyor by the gravity force. This Magazine has a shutter assembly which controls the inflow of the parts on to the conveyor.

The magazine 2 is of cylindrical shape of inner diameter 15.5 m.m, out diameter 20 m.m, length 200 m.m.

The shutter for the magazine 2 has 50x50x50 m.m. block. This block has a plate of 15 m.m. width, 100 m.m long and 5 m.m. thickness, which slides under the magazine 2.

The magazine is supported by a stand.

Air Blower: This blower is to blow the air on to the ongoing conical parts. This conical part is just passed from the magazine 2 where the rubber part to sit in it's position. We need the blower on to the part.

The Air blower has a tube of inner diameter 15 m.m, outer diameter 20 m.m. and 250 m.m long. The conical shape part at it's one end has inner diameter of 15 m.m, outer diameter of 20 m.m, the other end has a inner diameter of 25 m.m. and outer diameter of 30 m.m. long.

It is supported by a stand.

Vibratory Bowl: The vibratory bowl feeder is to feed the CAP part into the indexing machine in it's right position.

It acts a buffer for the cap parts. The cap parts are dumped into the vibratory bowl. The bowl as it rotates the parts are arranged in the right position and are fed into the indexing machine.

The vibratory bowl is circular in shape with inner diameter 200 m.m, outer diameter 208 m.m, and length 25 m.m, It has a outlet at one of it's edges. The outlet has 30 m.m width and 175 m.m. long and it goes right near to the indexing machine. This circular shape bowl rests on a conical casing, in which the hardware is fixed. The conical casing is of 100 m.m diameter at it's bottom. The whole device is fixed on a stand in suitable position.

Indexing machine: The indexing table is used to move the sub-assemblies from one assembly station to the another assembly station in a given interval of time. the indexing machine is mainly used to hold the CAP part in one of the slots and moves to the different assembly stations. So the diameter of the indexing table depends on the external diameter of the cap part.

$$2\pi r = Circumference = no\ of\ slots * dia\ of\ the\ cap\ part$$

$$r = \frac{40 * 22}{2\pi}$$

The diameter of the indexing table is 280 m.m, The thickness is 25mm. the indexing table has 20 slots with 22X22X21mm diameter, to hold the cap parts. The device is supported by a stand made of iron as base of 200mm diameter, 30mm thickness and 1000mm length.

Magazine 3 : Magazine 3 is to hold the redesigned part. It acts as a buffer for the redesigned part. The parts will from magazine on to the indexing table from the gravity force. This magazine has a shutter assembly which controls the flow of parts on to the indexing table.

The magazine 3 is of cylindrical shape of inner diameter 16.5mm, outer diameter 19mm and 500mm long.

This shutter for the magazine has 100X100X100mm block. This block has a plate of 45mm width, 160mm long and 5mm thickness, which slides under the magazine 3.

The magazine is supported by a stand.

Robot: The robot is used to pick this sub assembly from the indexing machine to the rotating table and holds the redesigned part firmly in the conical part till the rotating table rotates for the screwing operation.

The PUMA 550 Robot is investigated for this kind of operation.

Magazine 4: The magazine 4 is to hold the cross rods. It acts as a buffer for the cross rod part. The parts will flow from the Magazine 3 on to the stage where the part is going to stay for a while. When the shutter is open and the part is pushed by the push rod in to the conical part, thus the insertion operation takes place.

The magazine 4 is of rectangular shape of 32mmX8.2mmX450mm. It has a stage at a distance of 10mm from the bottom edge. The shutter assembly is fixed to the stand to which the magazine 4 is also fixed. The shutter has a sliding plate as well as push rod. The plate has a 10mm width, 60mm length, 5mm thickness. The push rod has 7mm diameter and 70mm length.

Bin: The bin is used to collect the final products.

The bin has the dimensions of 300X300X300mm. The bin is accompanied by a cart with wheels. The cart has a dimensions of 320X320X20mm it is at a height of 700mm and is supported by 4 legs. The wheels on which the whole device is mounted has a diameter of 40mm.

7.8.1 Description of the Assembly Cell:

The Conical parts are delivered from the Magazine1 on to the conveyor. As the conveyor moves, the conical part also moves to next assembly station, where the rubber part is added. The conical part with the rubber part moves to to the next station where the air blown in order to make sure that the rubber part sits in it's position.

Meanwhile, the cap parts from the vibratory bowl feeder are feeded into the indexing machine. The indexing machine rotates with the cap part and moves to the next assembly station, where the redesigned parts are delivered from the Magzine3 in to the cap part, which is in one of the indexing slots. Now as the indexing machine rotates the cap and the redesigned part also moves to the next pickup station, which is the Robot Station.

Now the Robot picks up the subassembly and places it on top of the conical part sub-assembly, which is already present on the rotating table. Now the table rotates, thus the two sub-assemblies are joined.

Here the crossrod part is also added, which is delivered from magazine4. Thus the final assembly is dropped into the collecting bin.

7.8.2 Procedure of Model Building.

In the IGRIP Software the model building takes place in different phases.

Cad: Create part is the module in which geometry is modeled using the IGRIP part modeling functions. The part Modeler allows the user to design parts to be assembled into devices for use in workcell layouts. All parts consists of one or more objects. Objects are composed of one or more sub-objects. Sub-objects are composed of geometrical "Pieces" such as polygons and lines. A user may easily create simple objects by invoking CAD primitives. CAD Primitives include BLOCK, CYLINDER, CONE, WEDGE, PIPE, SPHIRE, and surface of Revolution, which all produce polygon based data. Insert line, Circle and Helix operations produce wire frame data that can be polyganalized if desired. Each invocation of these primitive operators produces a "new", that is, additional object in the scene. For example, objects can be translated and rotated relative to each other in the create part workspace. Objects can be saved together as one static entity or as separate entities.

Device: The parts are retrieved as devices, then define the degree of freedom (DOM) and kinematic for the parts, in order to program the motion of this part later. These two parts must be in the correct location according to the workcell layout.

Layout: Path and Tag points are created to control the motion path and record the positions. Input/Output connections permit device's activities to be coordinated with other activities in the workcell.

Tag points and I/O connections act as sensors, relays, or limit switches in real world manufacturing system.

Motion: The Graphic Simulation Language, GSL -- procedural language is used to construct programs for the devices in a simulation to govern their actions and behavior. GSL syntax is similar to that of Pascal, with specific enhancements for device motion, display control, viewpoint choreography, and simulation environment inquires.

Miscellaneous: Other menus such as Dimension, User, Analysis and System support the model building and analysis.

7.8.3 PROGRAMMING

Compare to the model building, programming is a easy task. You do not type a text, most of the commands you can see on screen. You move a mouse to a desired command then press a mouse button, the on-line instruction will tell you the sequences step by step. Most of the command inputs take a few clicks of mouse button. There are 14 programs for our flexible assembly cell.

The programs are:

1 Program for cone.

2 Program for cone_shutter.

3 Program for rubberpart.

4 Program for rubberpart_shutter.

5 Program for air blower.

6 Program for cap.

7 Program for indexing table.

8 Program for redesigned part.

9 Program for redesigned part_shutter.

10 Program for PUMA 550 robot.

11 Program for rotator.

12 Program for crossrod.

13 Program for crossrod_shutter.

14 Program for pushrod.

The above mentioned programs are attached in Appendix 1.

The IGRIP software package is available in room 2320 Infotech building, NJIT. The thesis work is done under user account BYG5973.

CHAPTER 8

CONCLUSIONS

The Safety Water Shower Assembly had seven Components. Now using the Boothroyd Dewust Principles, the components are reduced to Five. Two parts (Cylindrical part and the Ball part) are replaced by the new redesigned part.

By Analyzing the Assembly systems, the operating cost is reduced from 13 cents to 3 cents. The operation time is reduced from 34 seconds to 12 seconds. These drastic changes are achieved when we went from the manual to flexible assembly. When ever there is high production rate, it is advisable to go for automation.

A user friendly Expert System Package for Assembly selection has been developed using the VP-Expert software. The selection process has been converted into the rule based knowledge system. The package will ask you few questions about your company like Annual Production, total number of parts in the assembly and will make the decisions for the Assembly selection. To use the this assembly selection process, one doesn't necessary has to know about the Assembly.

The IGRIP Simulation Software is used to Simulate the Safety Water Shower Assembly Cell. This assembly cell is modeled on Silicon Graphics Work Station. Using the IGRIP Assembly Cell Simulation / Off- line programming enables the engineer to download programs to a system with Robot in a Assembly station and to bring the Robot up to speed in a significantly shorter amount of time than if programmed all on -line.

IGRIP allowes the engineers to verify programs for exact collisions prior to down loading, thus avoiding potential damage to Assembly Cell environment, as well as the programs for debugging. The engineers are able to correct the simulation programs for error in workcell setup, and are able to obtain close approximation to the actual cycle time before running the actual programs.

IGRIP provids means of varifying the station process without the need for visiting the plant site. The simulation also provides a realistic visual representation of the Assembly process which could be used as a reference by the manufacturing engineers.

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10. Appendix

```
PROGRAM shutter_cone
VAR
---------- Main Declaration Section
BEGIN MAIN
----------------------------------
  $SPEED = 1000
  MOVE RELATIVE( 0, 53, 0 )
dout[10]=on
wait until din [ 0 ] == on
  MOVE RELATIVE( 0, -53, 0 )
delay 100000
----------------------------------
---------- END MAIN ----------
END shutter_cone
```

```
PROGRAM cone
VAR
---------- Main Declaration Section
td1  : POSITION
path_a  : PATH
ta1  : POSITION
ta2 : POSITION
ta3  : POSITION
ta4  : POSITION
ta6  : POSITION
ta7  : POSITION
BEGIN MAIN
----------------------------------
----------------------------------
dout [10 ] =off
 WAIT UNTIL DIN[ 10 ] == ON
  MOVE RELATIVE( 0, 0, -58 )
dout[0]=on
----------------------------------
  MOVE ALONG path_a FROM 1 TO 2
dout[8]=on
delay 60000
  GRAB 'rubber' AT LINK 1
  MOVE ALONG path_a FROM 2 TO 3
dout[11]=on
delay 10000
  MOVE ALONG path_a FROM 3 TO 4
  WAIT UNTIL DIN[ 3 ] == ON
  GRAB 'red_part' AT LINK 1
  GRAB 'rod' AT LINK 1
  GRAB 'cap' AT LINK 1
```

```
  MOVE TO ta6
--  MOVE TO ta7
  MOVE ALONG path_a FROM 6 TO 7
---------- END MAIN ----------
END cone
```

```
PROGRAM shutter_rubber
VAR
---------- Main Declaration Section
BEGIN MAIN
----------------------------------
  wait until din[8] == on
  MOVE RELATIVE( 0, 20, 0 )
  DOUT[ 9 ] = ON
  WAIT UNTIL DIN [ 9 ] == ON
  MOVE RELATIVE( 0, -20, 0 )
----------------------------------
---------- END MAIN ----------
END shutter_rubber
```

```
PROGRAM rubberpart
VAR
---------- Main Declaration Section
BEGIN MAIN
----------------------------------
  WAIT UNTIL DIN[ 9 ] == ON
  MOVE RELATIVE( 0, 0, -35 )
  DOUT[ 9 ] = ON
----------------------------------
---------- END MAIN ----------
END rubberpart
```

```
PROGRAM air_rod
VAR
---------- Main Declaration Section
BEGIN MAIN
----------------------------------
  WAIT UNTIL DIN[ 11 ] == ON
  MOVE RELATIVE( 0, 0, -20 )
----------------------------------
---------- END MAIN ----------
END air_rod
```

```
PROGRAM cap
VAR
---------- Main Declaration Section
path_b  : PATH
BEGIN MAIN
----------------------------------
$speed = 500
  MOVE ALONG path_b FROM 1 TO 2
dout[12]=on
----------------------------------
---------- END MAIN ----------
END cap
```

```
PROGRAM index_table
VAR
---------- Main Declaration Section
BEGIN MAIN
----------------------------------
  $SPEED = 100
  WAIT UNTIL DIN[ 12 ] == ON
  GRAB 'cap' AT LINK 6
  MOVE JOINT 6 BY 108 NOSIMUL
dout[14] =on
delay 1000
  WAIT UNTIL DIN[ 13 ] == ON
  GRAB 'red_part' AT LINK 6
  MOVE JOINT 6 BY 90 NOSIMUL
  DOUT[ 16 ] = ON
----------------------------------
---------- END MAIN ----------
END index_table
```

```
PROGRAM rsdesin_part
VAR
---------- Main Declaration Section
BEGIN MAIN
----------------------------------
  WAIT UNTIL DIN[ 15 ] == ON
  MOVE JOINT 3 BY -70 NOSIMUL
  DOUT[ 13 ] = ON
----------------------------------
---------- END MAIN ----------
END rsdesin_part
```

```
PROGRAM plate_redesign
VAR
---------- Main Declaration Section
BEGIN MAIN
---------------------------------
  WAIT UNTIL DIN[ 14 ] == ON
  MOVE JOINT 2 BY 20 NOSIMUL
  DOUT[ 15 ] = ON
---------------------------------
---------- END MAIN ----------
END plate_redesign
```

```
PROGRAM robot_a
VAR
---------- Main Declaration Section
tc1  : POSITION
ta5  : POSITION
BEGIN MAIN
---------------------------------
$config = 2
  GRAB 'gripper' AT LINK 5
  WAIT UNTIL DIN[ 16 ] == ON
  MOVE TO tc1
  GRAB 'cap' AT LINK 5
  GRAB 'red_part' AT LINK 5
  MOVE TO ta5
  DOUT[ 7 ] = ON
---------------------------------
---------- END MAIN ----------
END robot_a
```

```
PROGRAM rotator
VAR
---------- Main Declaration Section
  ta4 : POSITION
--  td1 : POSITION
BEGIN MAIN
---------------------------------
  $SPEED = 100
  WAIT UNTIL DIN[ 7 ] == ON
-- ATTACH DEVICE 'cone#2' AT TAG 'ta4'
  GRAB 'cone#2' AT LINK 6
  MOVE JOINT 6 BY -90 NOSIMUL
  DOUT[ 6 ] = ON
---------------------------------
---------- END MAIN ----------
```

```
END rotator



PROGRAM crossrod
VAR
---------- Main Declaration Section
BEGIN MAIN
---------------------------------
  $speed = 1000
  WAIT UNTIL DIN[ 5 ] == ON
  MOVE JOINT 3 BY -12 NOSIMUL
  DOUT[ 4 ] = ON
  MOVE JOINT 2 BY -94 NOSIMUL
  DOUT[ 3 ] = ON
---------------------------------
---------- END MAIN ----------
END crossrod



PROGRAM shutter_crossrod
VAR
---------- Main Declaration Section
BEGIN MAIN
---------------------------------
  $speed = 1000
  WAIT UNTIL DIN[ 6 ] == ON
  MOVE RELATIVE( 0, 35, 0 )
  DOUT[ 5 ] = ON
---------------------------------
---------- END MAIN ----------
END shutter_crossrod



PROGRAM pushrod
VAR
---------- Main Declaration Section
BEGIN MAIN
---------------------------------
  $speed = 1000
  WAIT UNTIL DIN[ 4 ] == ON
  MOVE JOINT 2 BY -94 NOSIMUL
---------------------------------
---------- END MAIN ----------
END pushrod
```