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LAYOUT DESIGN ANALYSIS AND INSTALLATION OF A CART-ON-TRACK CONVEYOR SYSTEM IN A FLEXIBLE MANUFACTURING CELL

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Abstract

The Manufacturing Technology Laboratory is establishing a major research and educational area in materials handling, in addition to its traditional areas in manufacturing processes and automated production systems. An automated guided vehicle system, a cart-on-track (Mini Cartrac) conveyor system, and an automated storage/retrieval system are currently being installed. Major problems being solved in the laboratory are the layout design analysis, installation of these systems, and getting them to operate.

The thesis is concerned with the Cart-on-track conveyor system and the problems encountered in planning, installing, and operating such a system. The thesis consists of three major parts. First, Chapter 1 provides a literature review on automated materials handling and flexible manufacturing systems (FMS). Second, Chapters 2 and 3 describe the unique characteristics and components of the Mini-Cartrac and its application in a FMS. These chapters might be thought of as a user's or operator's manual. Third, Chapters 4, 5, and 6 are the research portions of the thesis which discuss alternative layout plans of the handling system with relative advantages and disadvantages of each. Evaluation of these alternatives resulted in the selection and final design of the Cart-on-track configuration that has been installed. This third part also deals with the system installation and interfacing of the Mini-Cartrac with other materials handling systems, robots, and other work stations. This discussion serves as the background and justification for the proposed FMS configuration in the Manufacturing Technology Laboratory.

Chapter 1
Introduction

1.1 Determining Materials Handling Requirements

Material handling is a critical consideration with respect to the automated factory in which great amounts of in-process material are moved from place to place, stored for future use or fed into manufacturing operations. In its modern role, material handling is becoming more and more automated. The older systems of conveyors, pallet trucks, bridge cranes, etc., are still in wide use but, increasingly, installations are coming on line that incorporate such innovations as automated guided vehicle systems and automated storage/retrieval systems [9].

Material handling systems in automated factories typically cost more initially than material handling systems in traditional factories. These higher costs are due to the less forgiving environment of an automated factory [15]. The cost of materials handling is also a significant cost that is estimated as high as two/thirds of the manufacturing cost, since materials and components in manufacturing spend between 75 and 90 % of their time in material handling and storage [3]. This fraction varies according to the type and quantity of production and the degree of automation in the materials handling function [5].

As in all material handling operations, the prime objective is the same: get the right materials and tools to the right place at the right time and at low cost, without damage to the materials [5, 9].

1.2 Automated Materials Handling Objectives

Material handling is an important factor in the entire facility design as well as the success of the enterprise. Too much emphasis cannot be placed on the importance of determining the most efficient plan for the flow of materials, information and people. The importance of the material handling pattern in any facility as it influences production can be analyzed in advance for cost, quality and time using various means of measurement. In designing material handling systems for the automated factory, the following objectives should be considered [15, 17]:

1. Create an environment that results in the production of high quality products.

2. Provide planned and orderly flows of material, equipment, people and information.

3. It should be capable of operating at a variety of speeds and should be able to handle a variety of loads.

4. Unit load sizes, configurations and capacities should be standardized, and all "special" equipment should be very closely reviewed.

5. Accommodate higher or lower production volumes.

6. The material handling system should be designed to be easily expanded or contracted; i.e., modular.

7. Reduce work-in-process.

8. Provide controlled flow and storage of materials.

9. Integrate processing, inspection, handling, storage and control of material.

10. Eliminate manual material handling at work stations and between work

stations.

11. Deliver parts to work stations in predetermined quantities and physically positioned to allow automatic transfer and automatic parts feeding to machines.

12. Deliver tooling to machines in a controlled position to allow automatic unloading and automatic tool change.

13. Utilize space most effectively, considering overhead space and impediments to cross traffic.

14. The optimization of material handling systems within each cell is not nearly as important as the optimization of the total facility's material handling system. Therefore, it is only after the total system is planned that handling systems within the cells should be planned within the context of the overall system.

15. All material handling systems should support automation within the factory. This is applicable to both manufacturing automation and information and control automation.

16. The system must also provide the proper material orientation and report to the control system all move transactions. There is no control in an automated factory if the material handling system does not support the control system.

17. It must be able to operate modularly and should allow implementation of one section at a time.

1.3 Basic Elements of a Flexible Manufacturing Cell

A flexible manufacturing system results from a combination of three basic elements: work stations (fully manual to fully automatic), computer controls and automated material handling the integrator of the system [18].

Work Stations: A manufacturing cell consists of one or more work stations that are grouped together to produce a family of parts. The stations can be any combinations of manual, semi-automatic or fully automatic operations. They require fewer but more versatile machines, techniques and processes. Semi-automatic and fully automatic work stations may utilize NC machines, robots, automated inspection devices and hard automation techniques [18]. These can be set up to carry out many different functions. Some of these functions are:

----Assembly: placement, fastening and welding.

----Machining: milling, drilling, tapping, turning, boring, facing and grinding.

----Inspection: dimensions, locations, geometry and finish.

----Work piece loading/unloading: placement, fixturing, re-orientation on fixtures, clamping.

----Heat treatment, painting and finishing.

Computer Control: "The coordination and control of the parts handling and processing activities is accomplished under command of the computer. One or more computers can be used to control a single FMS" [6]. The data files, such as; part program file, routing file, part production file, pallet reference file and etc., are needed to carry out the various functions which the computer performs. Among these functions are [6]:

1. CNC-computer control of the individual machines.

2. DNC-direct computer control of all the machine tools in the FMS.

3. Both CNC and DNC functions can be incorporated into a single FMS.

4. Part program storage.

5. Distribution of part programs to machines and robots at work stations.

6. Sequencing and tracking different loads to selected work stations, based on variable routing instructions.

7. Collecting real-time data regarding operation of the work station equipment and production.

8. Communicating with a host computer system.

9. Performing other process monitoring functions as required.

Various types of computer-prepared reports are also required during operation of the FMS. Some of these reports are utilization reports, production reports, and tool status reports.

Automated Materials Handling: Within manufacturing cells and FMSs, work-in-process must be transported quickly and reliably from one workstation to the next. Stored workpieces must be easily accessible and recovered rapidly when required.

1.4 Integrated Islands of Automation and Its Benefits

Today's manufacturing plants often have sophisticated workstations located throughout the factory. Even though automated machines may be in use, the total result is "islands of automation" in which the machinery itself is very efficient, but its actual utilization time (and therefore its return on investment) is low and large stores of work-in-process and parts are required to support it. Robert A. Pierson, divisional general manager, Webb Rack Storage Systems and

Unibilt Divisions [14], notes that "Material handling used to deal with islands of manufacturing, then came islands of automation. Now material handling provides a mechanical and control network for implementing integrated manufacturing."

Typical islands of automation include numerically controlled machine tools, robots, automated storage/retrieval systems and flexible machining systems. In some cases, the islands are very small (e.g., an individual machine or work station); in other cases they are department-sized. In meeting with the prime objective, modern material handling systems must also be able to integrate with computer-controlled manufacturing and distribution systems of all kinds. In fact, without integrated material handling, many of these modern manufacturing systems would remain "islands of automation" unable to reach maximum effectiveness because they are not tied into an overall computer-integrated system [9].

Every system is, by definition, an integrated system. And system integration is the process of bringing independent systems together in a condition of harmonious, orderly interaction. In many people's minds, system integration is equated with automation and computerized control. These are important tools. However, while increased automation is certainly the trend, it is not necessarily the only path to integrated material handling. The real key is coordination of both activity and information [3]. Such a fully integrated system can increase utilization of high-investment machinery to 80-90 %, as opposed to the 10-15 % rate of traditional methods [18].

After the manufacturing processes and "islands of automation" have been integrated, the benefits will begin to accrue, including [18]:

Reduced Inventory: Automated material handling systems ensure constant availability of products to the cell. Because parts and work-in-process are delivered to work cells as needed, in-process inventory is minimized and less floor space is required around the machines. Also, as the operation approaches "just-in-time" production, the warehousing of raw materials and of finished products will be greatly diminished, reducing the cost of goods produced.

Greater Manufacturing Flexibility: Manufacturing cells, with highly versatile NC machines and tool changing capability, can easily produce different products to meet the demands of the market place. Engineering design changes can be accommodated with less changeover and set-up time. Also, required spare part and "special job" production can be mixed in without significantly disrupting normal production activities.

Improved Product Quality: Production methods are important influences on product quality. Cellular manufacturing often includes a high level of automation, and the consistently precise interfacing of workpieces and automatic equipment that is attainable through the application of modern automated material handling systems will lead to more consistent quality. The reduced number of machine setups needed and fewer workstations utilized are also important factors contributing to a better product.

Reduced Direct Labor Cost: In unmanned flexible manufacturing, much machinery is operated under computer control (either CNC or DNC), eliminating the need for operators. Also, manual workstations are often staffed by multi-skilled personnel to carry out functions in which automation cannot be justified.

1.5 Types of Automated Materials Handling Systems

Though material handling contributes to integrated manufacturing from receipt of raw material to delivery of finished product, there are certain systems that are the most viable options for handling and transportation in an FMS. The following is a brief overview of some of the equipment that should be considered in the automated factory.

Automated Guided Vehicle System (AGVS): The guided vehicle usually carries the work piece on a machine pallet or fixture base, from work cell to work cell or it may transport trays of parts that are manually or robotically chucked, fixtured or locked onto machine tables at workstations. The AGVS control system allows for virtually unlimited computer controlled operation of the AGVs. The ease of altering or expanding an AGVS makes these systems among the most flexible material handling equipment for the automated factory.

Powered Conveyors: Powered conveyors can be used for basic transportation between flexible machining cells or for positioning parts to interact with robots or other positioning devices. Asynchronous conveyors based on the principle of rotating tubes are used to position loads precisely for robots, as well as to move loads at high speeds. In machining centers, specialized conveyors can be designed to handle any type of part from operation to operation [14].

Overhead, Power-and-Free Conveyors: Overhead, power-and-free conveyors offer flexibility to a manufacturing operation. With the carrier's identity being automatically scanned on the move, loads can be selectively diverted to work stations.

Self-Powered Monorails: These systems have independently driven trolleys that can run on the level or uphill. A master controller directs the trolleys in highly flexible travel configuration. They can be given the capabilities of forward and reverse operation, multiple speed, shortest path routing, system blocking, etc. Although monorails do not compete with power-and-free conveyors in high volume applications, in low-to-medium volume areas, the flexibility of the monorails makes the equipment a viable option for FMS [15].

Robots: These devices can perform either part or all of the transport function. They are often used as workpiece/machine tool interfaces at work stations. For example, to remove a workpiece from the transport system carrier, place it in a machining center and then return the workpiece to the carrier [18].

Automated Storage and Retrieval Sytems (AS/RS): As flexible manufacturing systems increase their output and the variety of parts that will be produced in small lots, an AS/RS fills the need for buffer storage. Some new FMSs are being designed with raw stock being stored in an AS/RS and delivered to machines by automatic guided vehicles [14]. The AS/RS can also provide quick access to the jigs, fixtures and tooling required by the FMS.

Carousels: A carousel consists of horizontal revolving bins that bring the bin requested to a forward pick station. They are not new. However, the replacement of the order picker at the end of the picking aisle with a storage and retrieval robot is new. The robot can retrieve and store tote pans in the bins. When this robot is properly interfaced with a conveyor system, the opportunity for truly automated storage and retrieval via a carousel is realized [15].

Automatic Identification Systems: Integrated manufacturing cannot be accomplished without the ability to identify parts and products automatically for the purpose of accounting and direct their movement by means of computers and programmable logic controllers [15]. An automatic identification system consists of;

1. An item to be identified.
2. A label to be read to identify the subject.
3. A device which is to read the code.
4. The memory control to which the code is to be sent and stored.

Bar code scanning is the lowest cost, most universal approach to automatic identification. However, in the harsh environment of some manufacturing applications, radio frequency (RF) systems are being used on more and more occasions [14].

Chapter 2
Conveyors and Cart-on-Track (Cartrac) Conveyor Systems Characteristics

2.1 Introduction to Conveyors

Conveyors represent a basic element of the automated factory. They are used when material is to be moved frequently between specific points over a fixed path. Conveyors can transport loads at floor level or overhead, move them vertically, carry them up inclines or down spiral chutes, around corners or along straight runs. Some models transport loads in sequence; others have the capability of allowing one load to bypass another to change routings, or to make it easy to shunt materials out of the main delivery path without impeding the flow. Conveyors can handle items of practically any size or shape (individual parts, products in cases or tote boxes, or any material that can be put in a container or stacked on a pallet) [1].

Conveyors can be interfaced with production equipment or with other types of handling equipment to automate materials handling through one section of the factory or through an entire manufacturing operation. Conveyors are also used to deliver parts within "islands of automation", or to link them together, and to provide live storage, and sort products. While conveyors can be classified in several ways, the most useful is by the method of mounting: overhead, above floor and in-floor. Each group has various advantages and limitations for different applications in the automated factory [1].

Overhead Conveyors: Overhead conveyors do not create any obstructions on the work floor. They are mounted along overhead pathways and can therefore transport materials over aisles or production equipment. Some overhead conveyors provide live storage. Others are used simply for point-to-point deliveries, interfacing with workers on the plant floor through vertical lifts, drop sections or by the conveyor's ability to move goods up and down inclines.

Above-Floor Conveyors: Above-floor conveyors include a variety of types - cart-on-track, roller, belt, and carrier chain are the most popular ones. These conveyors are supported by a permanent frame which raises the conveying bed above the plant floor. This arrangement makes the load handling easier for fork trucks while simplifing manual loading and unloading.

In-Floor Conveyors: In-floor conveyors have some of the advantages of both overhead and above-floor conveyors. Because the conveying medium is mounted beneath the surface of the floor, cross-over traffic is at least theoretically possible. At the same time, loads are accessible to fork trucks or manual loading. Towlines are the typical type of in-floor conveyor in the automated factory [1].

2.2 Cart-on-Track Conveyor Systems

Cart-on-track transport systems (also called spinning tube conveyors) provide a precise, efficient means of conveying products to aid in manufacturing and distribution center processes. These systems have been proven effective in increasing productivity, while at the same time reducing overall operating costs and product damages. The modularity of the systems facilitates installation in new or existing buildings and provides the flexibility necessary to adapt to changing industrial requirements. One of the cart-on-track conveyor suppliers is SI Handling, Inc., Easton, PA, whose product is known as Cartrac.

This method of transporting materials is operating successfully in facilities throughout the world. They benefit manufacturing plants by providing an interface with manufacturing processes and assembly operations. The systems are easily integrated with manual or newly developed automated manufacturing processes. In the warehouse or distribution center, Cartrac systems safely convey products integrating with order selection and automated storage and retrieval functions. They are especially useful with products which are bulky, delicate, or otherwise difficult to convey and require accurate positioning, and where environmental conditions are detrimental to employee health. In all of these applications, cartrac systems are used to improve productivity and to effectively control flow in the workplace [2].

2.3 Capabilities

The capabilities of this Cartrac system have solved many difficult production and distribution problems. Nonsynchronous, independent movement permits carriers to be individually indexed throughout the system. Carriers move from one station to another without affecting the rest of the system operation.

Controlled acceleration and deceleration is especially useful in applications where delicate and stable loads must be transported. This smooth movement prevents product damage often incurred by fork truck or manual transport. Controlled acceleration/deceleration also enables carriers to be precisely positioned for interface with other production equipment. Position can be as precise as + or - 0.005 in. in three planes. This precise positioning is a necessity when the transport system is integrated with precise automated machining and assembly operations.

Different speeds may be used simultaneously in separate sections of a system, according to the user's requirements. Speed can be varied from 0.5 to

600 or more feet per minute [2]. In addition, this capability permits individual sections of a system to be shut down in order to conserve energy or perform routine maintenance procedures.

Cartrac systems have been proven to be operationally effective in environmentally harsh industrial and warehousing applications. These systems can be used in freezers with temperatures as low as -40 degree F and in ovens where temperatures reach 200 degree F. They function in the presence of dirt, dust, and chemicals and in environments that would otherwise be unsafe for employees. In addition to these capabilities, Cartrac systems increase efficiency through better use of manpower and space, resulting in greater system throughputs. The system's modular design allows for easy installation in new and existing facilities and can be totally relocated if necessary. Vertical movement is possible to connect multiple levels in a building. Right angle and radius turns can be accomplished. The system can be mounted on or beneath the floor, or hung from a wall or ceiling [2, 12, 13].

The basic objectives of using the system are as follows:

----More process time in work stations.

----Increased production.

----Decreased work-in-process.

----Stop-and-go assembly.

----Flexible routing.

----Insures load stability.

----Minimal maintenance.

----Low spare parts inventory.

----No special skills required for maintenance personnel.

----Cartrac's adaptability meets specific application's needs.

----Accommadates future expansion.

----Flexible, initial design.

----Ease of installation.

----Improved interface capabilities with peripheral devices.

----Improved product quality through tighter tolerances.

2.4 System Operation

Operation of the Cartrac system is simple, with only one powered subassembly. That subassembly is the drive tube which is mounted between the rails of a two-rail section of track. Sections of track are connected together according to the system layout. Carriers are mounted on and guided by this track and propelled by the drive tube within (Figure 2-1).

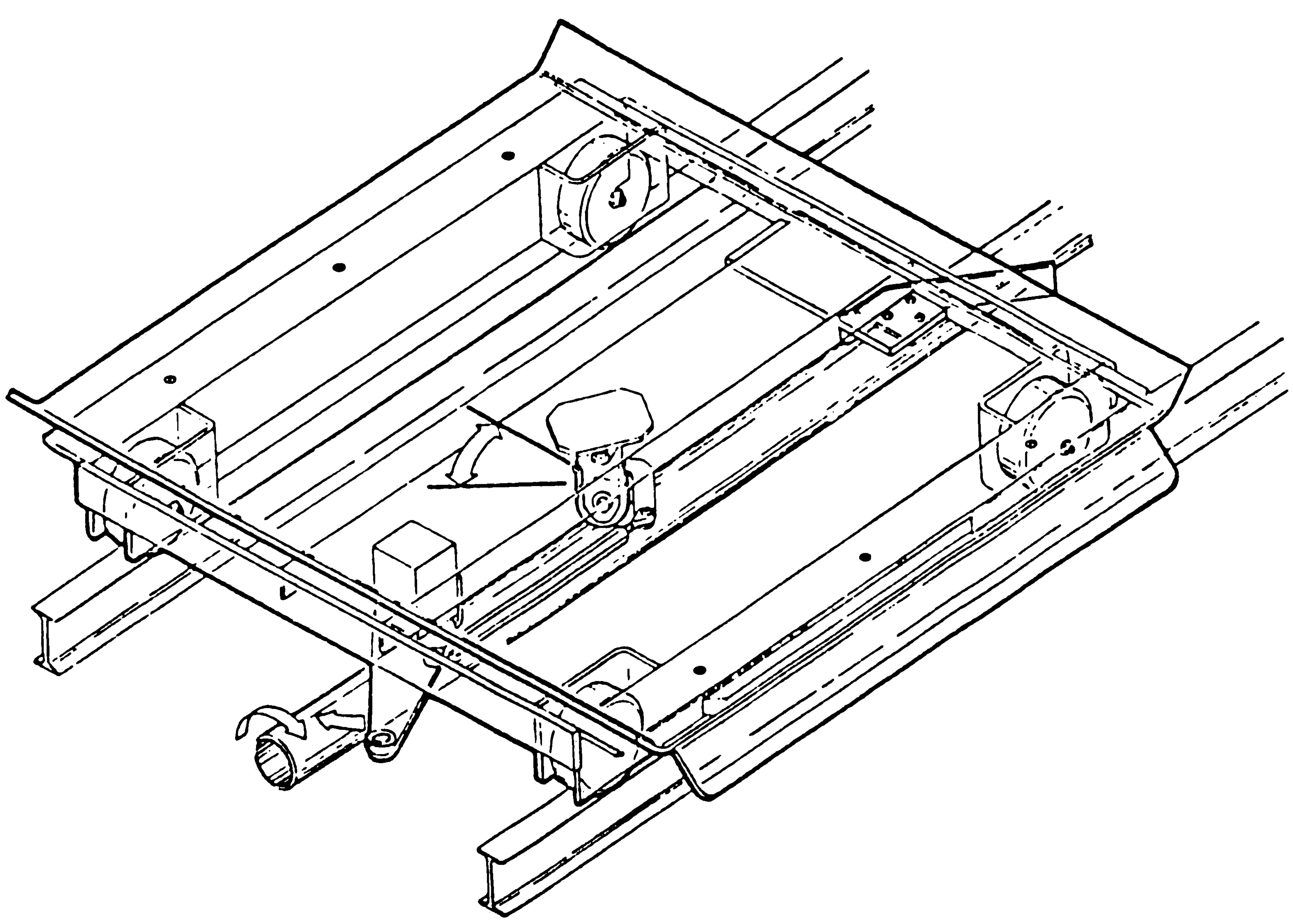

Figure 2-1: System operation [2].

A spring-loaded drive wheel, mounted on the underside of the carrier, is pressed against the drive tube. Contact between this drive wheel and drive tube creates a forward motion of the carrier. When the drive wheel centerline is parallel with the drive tube, there is no driving force and the wheel merely rotates in place. As the angle between the drive tube and drive wheel centerline increases, a thrust is generated which propels the carrier forward. Maximum carrier speed is obtained when this angle reaches 45 degree. Carrier speed can be decreased by decreasing the angle and therefore reducing the thrust (Figure 2-2).

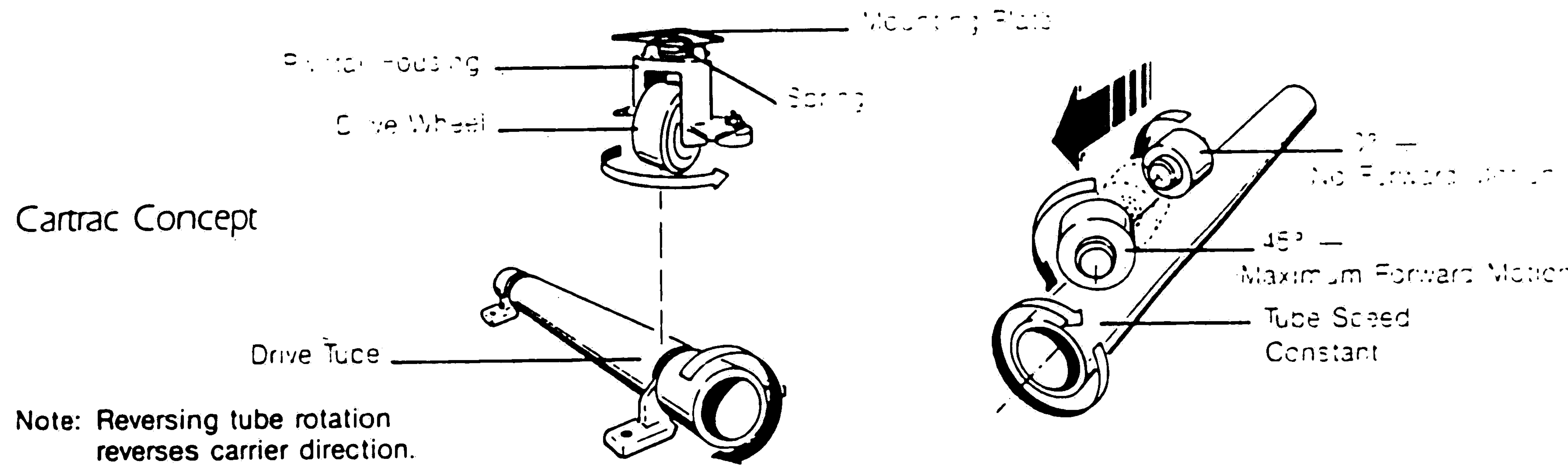

Figure 2-2: Cartrac concept [13].

A pivoting housing contains the drive wheel and limits its movement between 0 degree to 45 degrees. This pivoting housing also provides for independent control of carrier and tube speeds. Specially designed queue station control bars are located on the track throughout the system layout to control the position of the pivoting housing. These control bars provide for the precise positioning and controlled acceleration and deceleration of each carrier. For accumulation capabilities, a cam follower arm on the front of each carrier is linked to the pivoting housing. A cam is also located at the rear of the carrier (see Figure 2-1). Contact between the cam follower arm of one carrier and the cam of another provides controlled acceleration or deceleration in the accumulation of carriers.

2.5 System Control

Controls for the Cartrac system can be simple or sophisticated, depending on individual requirements and capital available to invest in the system. As with the Cartrac system layout, control systems can be updated to meet future needs and expanded to incorporate additional operating functions.

The most basic control system is one that functions only to regulate carrier traffic flow. Once power is supplied to the system, the operator has no individual control over the different sections of the layout. Carriers travel in a predetermined path, with no remote identification capabilities. In advanced control systems, operators monitor the movement of each carrier in relation to the total system layout. Addressing capabilities can determine where a carrier must go, what path it should take and what it must do once it reaches that destination. The operator has a means of identifying the location of each carrier at any time. Advanced control systems are imperative if the system is to be interfaced with other warehousing or manufacturing operations. These systems are easily integrated with advanced manufacturing processes such as industrial robots and computer controlled machine tools. In the modern distribution center, computerized order-selection systems are interfaced with Cartrac systems to guarantee the quick, efficient delivery of customer orders.

Controls for the Cartrac system can also be linked to corporate management functions such as inventory control, shipping and receiving and up-to-the-minute status reports. This unique data highway is possible through the use of programmable logic controllers, microprocessors, and large scale process control computers.

2.6 Applications

Cart-on-track material transport systems can easily be applied for use in any manufacturing or distribution center. Its versatility and flexibility permits its use with products as diverse as fruits and vegetables to large 12-cylinder diesel truck engines. A rapidly growing function of Cartrac systems involves the movement of parts within a manufacturing facility from one machine tool operation to another. This application eliminates the need for batch handling of parts between machines and leaves the area uncluttered of in-process work. Parts are delivered, as required, by the carriers which then move on to the next operation after work has been completed. Mechanization of manufacturing operations is easily accomplished. Because of its accurate positioning capabilities, the Cartrac system can be effectively integrated with robots or automatic cycling devices. Preprogrammed routing indexes parts directly from one operation to the next. Production rates can be predetermined by adjusting the transport system's rate of travel.

They can also be applied to assembly operations. Many types of materials and parts can be transported with ease by specially designed fixtures mounted on the carriers (Figure 2-3). By maintaining a fixed, constant speed, the system assures that predetermined production rates will be met. System layout can be designed so that one main system is used for final assembly, while subsystems are employed to carry parts to the main system. With advanced computer capabilities, carriers can be randomly selected to move materials from one station to another in any desired sequence.

The Cartrac system is also used to link products to high-rise automated storage and retrieval systems (AS/RS). Parts are carried to and from production areas by the transport system and are manually or automatically placed in storage or production vehicles. This transport method optimizes the available space within a warehouse and provides a constant control of inventory. With this system, the cost of fork truck maintenance and fuel is significantly reduced. A facility may employ one Cartrac system for in-process work and another for AS/RS, or the functions can be combined to form one large system.

Order picking is a distribution center function which lends itself well to the use of this type of transport system. The system can be employed in conjunction with manual or automatic product selection to achieve higher productivity rates and reduce product damage. The order-picking transport system is designed as a closed loop circuit with designated stations established for selection and replenishment operations. The improved product flow feature maintains an uncongested traffic pattern and optimizes space utilization of the facility [2, 12, 13].

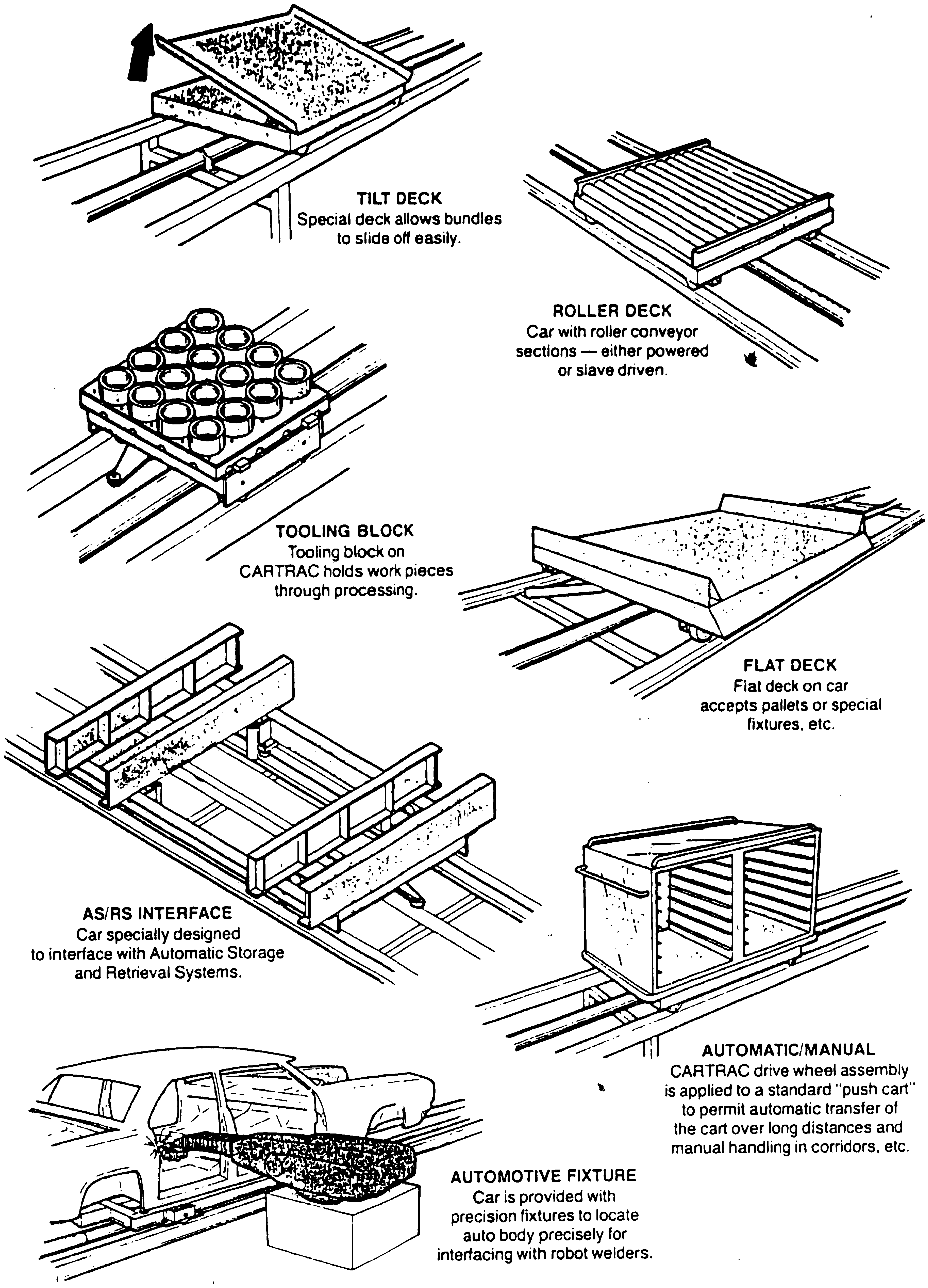

Figure 2-3: Cartrac cars for all purposes [12].

Chapter 3
Cartrac Conveyor System Components

3.1 Main Assemblies

3.1.1 System Track

A system track mainly consists of a track module and a track support. The function of the track module is to support. guide, and propel the carriers through the system. Tube drives, queue stations, and limit switches are all mounted on the track module. Each track module is comprised of three basic assemblies: the track rails, crossmembers, and the drive tube. These components are illustrated in Figure 3-1.

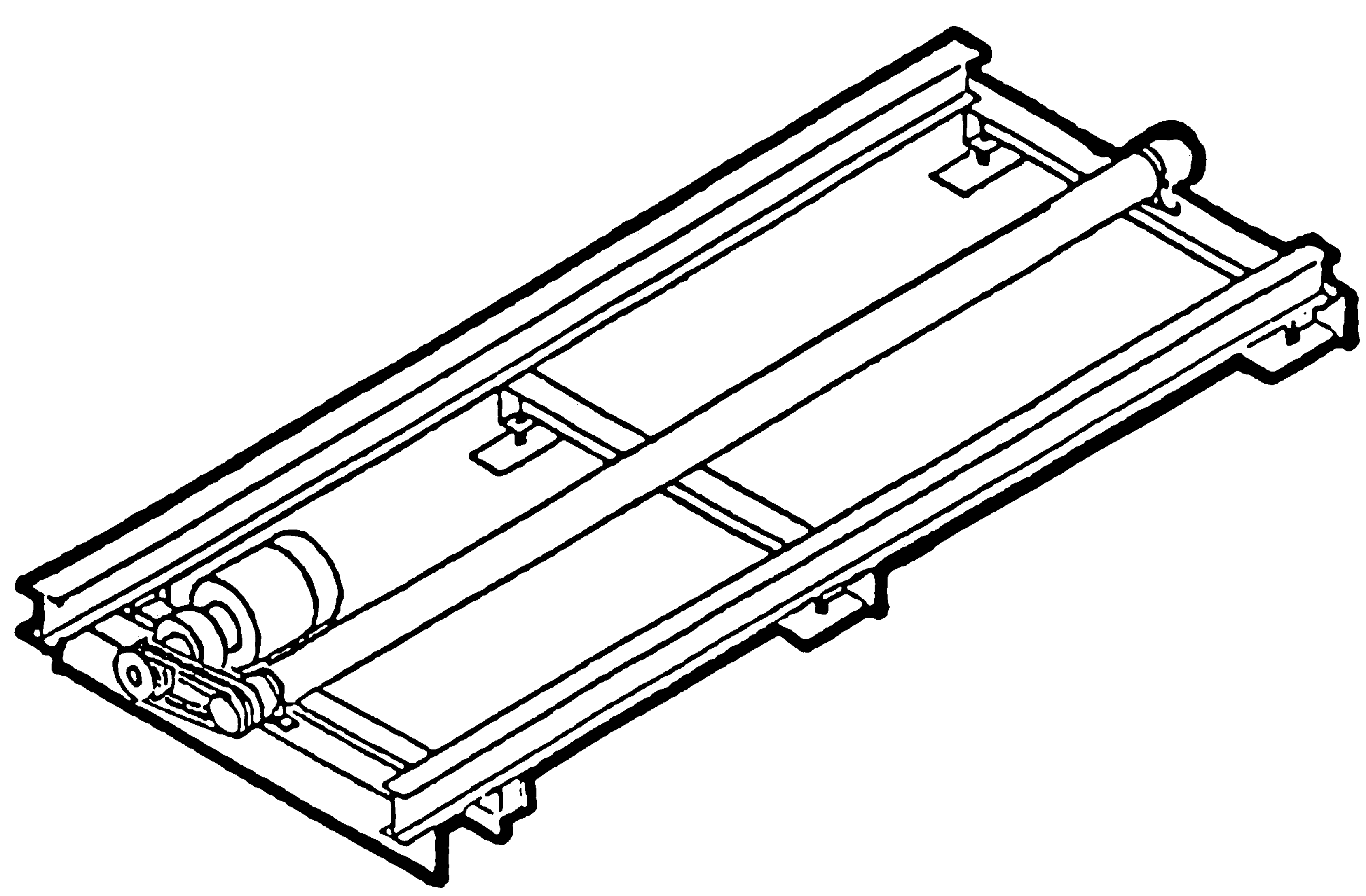

Figure 3-1: The track module [2].

The track rails are formed from I-beams and are designed for the structural strength and rigidity necessary to support both the carriers and the maximum load capacity of the system. The track frame is constructed by weld'ng these rails to steel angle crossmembers. Holes in the crossmembers are provided for mounting the drive tube, track supports, queuing devices and tube drives. The drive tube is constructed of mechanical steel tubing with hex-shaft plugs capping off each end. Hex-bore ball bearing pillow blocks, sealed and permanently lubricated, are clamped rigidly at the tube ends. This hex-shaft/hex-bore bearing combination assures positive bearing rotation, greater reliability, and longer life [2]. When a tube drive is to be located at a track junction, the driven end will require a sheaved tube end to cap off the drive tube and the track modules used in that situation are called double interface track modules. If a tube drive is not required at a track junction, the tubes are joined with a male/female coupling. In that case, the type of track module is a single interface track module.

The track supports provide a rigid base for supporting the track modules at a predetermined elevation above the floor level. A support consists of a top pan and two feet bolted together and anchored to the floor. Track crossmembers are bolted to the top pan [2]. Photocells, solenoid valve panels, single and double actuators (push-pull buttons) are placed on the track support (Figure 3-2).

3.1.2 Tube Drive

The tube drive provides the power necessary to propel the carriers throughout the system. This is accomplished by rotating the drive tubes within the track modules. A tube drive is capable of rotating one or more drive tubes, depending on the horsepower requirements of the system.

The drive package consists of a motor, speed reducer, sheave and bushing, V-belts, and mounting frame. The horsepower and electrical characteristics of the motor are dependent on the system and installation site requirements. A

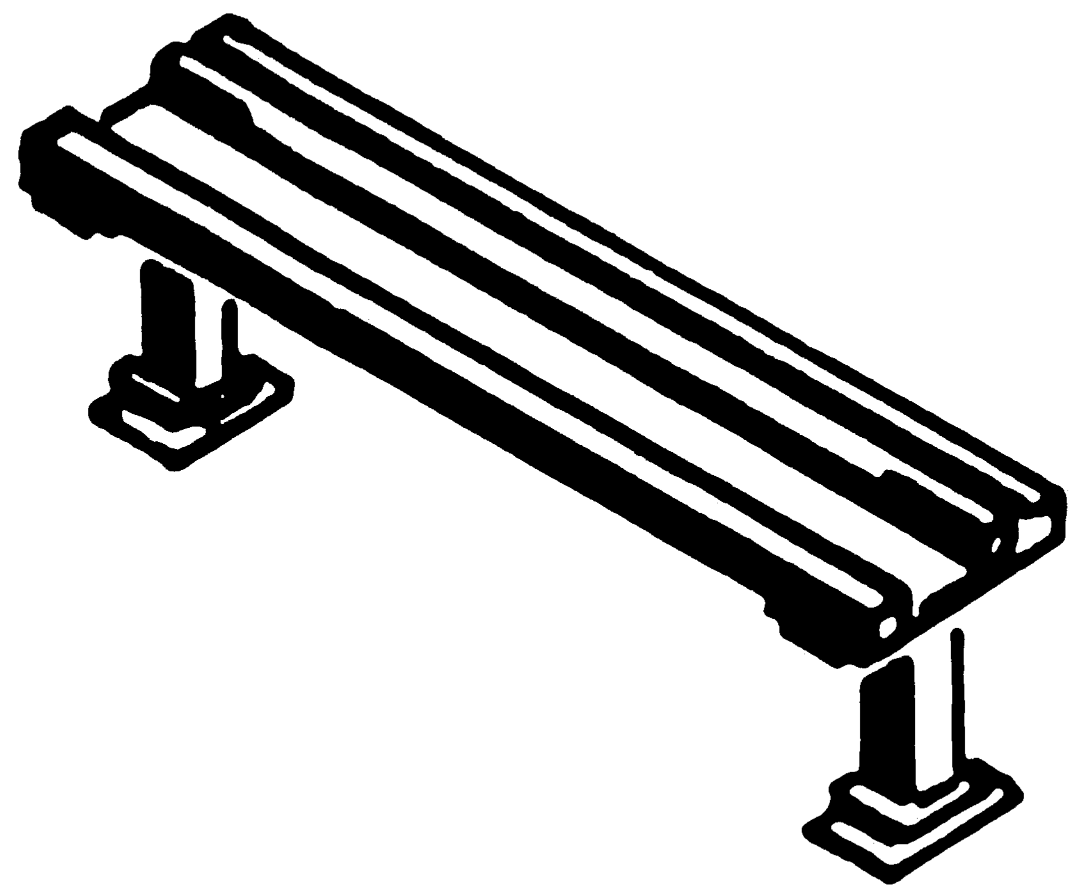

Figure 3-2: Mini-Cartrac system track [13].

flexible coupling connects the motor shaft to the high-speed side of a speed reducer. A grooved sheave is attached to the output shaft of the speed reducer. V-belts transmit power from reducer to the sheaved-tube end of the track module drive tube.

3.1.3 System Carrier

Carriers are the transport vehicles of the Cartrac system. They are propelled through the track layout in a smooth, quiet, and safe manner, stopping as required at the predetermined locations. The chasis is a rigidly formed steel frame, comprised of deck plate, end members, and a center channel (Figure 3-3). A typical carrier is constructed of these assemblies: chasis, drive wheel, guide wheels, travelling wheels, limit switch cam, accumulation nose, and accumulation tail (Figure 3-4). Specially designed fixtures for carrying products or materials are mounted on top of the chasis. The drive wheel is a vertically spring-loaded urethane wheel which provides positive contact with the drive tube. Sealed and permanently lubricated ball bearings on the drive wheel assure smooth, dependable operation.

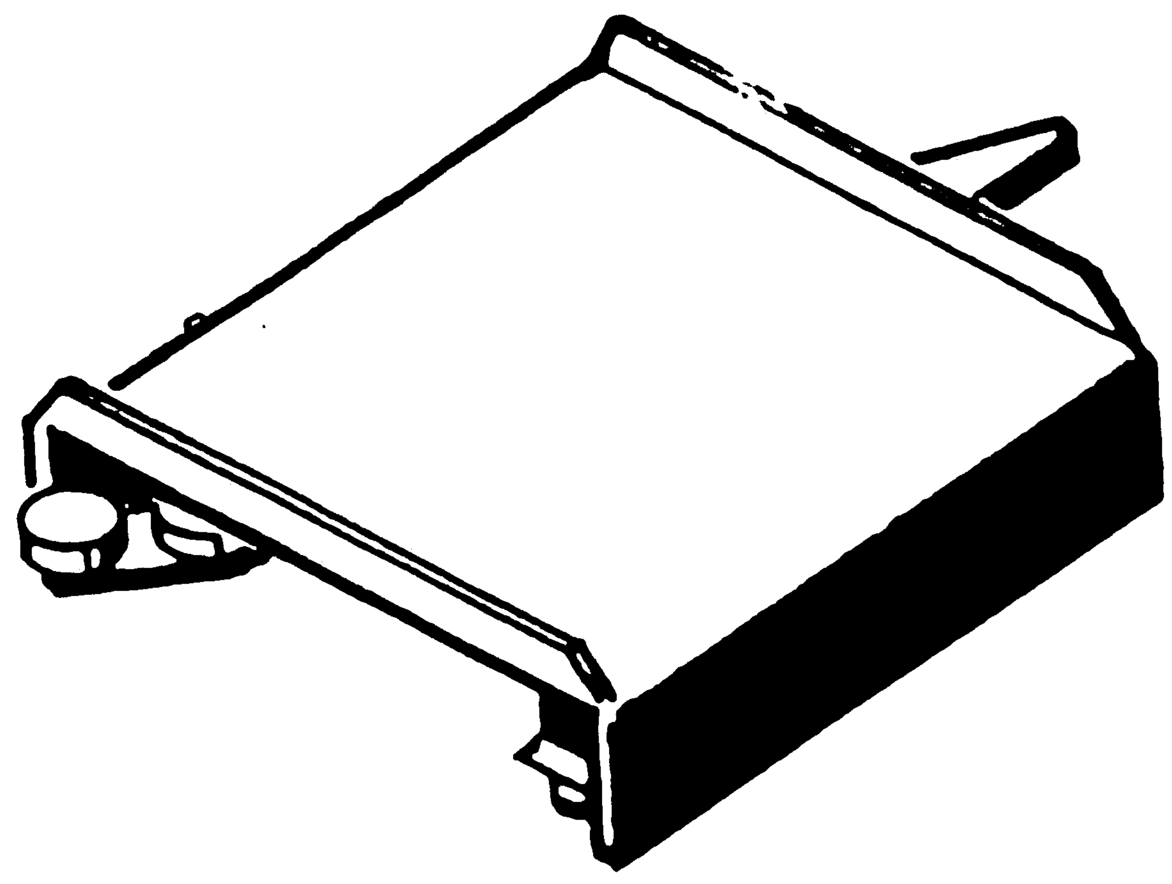

Figure 3-3: Cartrac carrier [13].

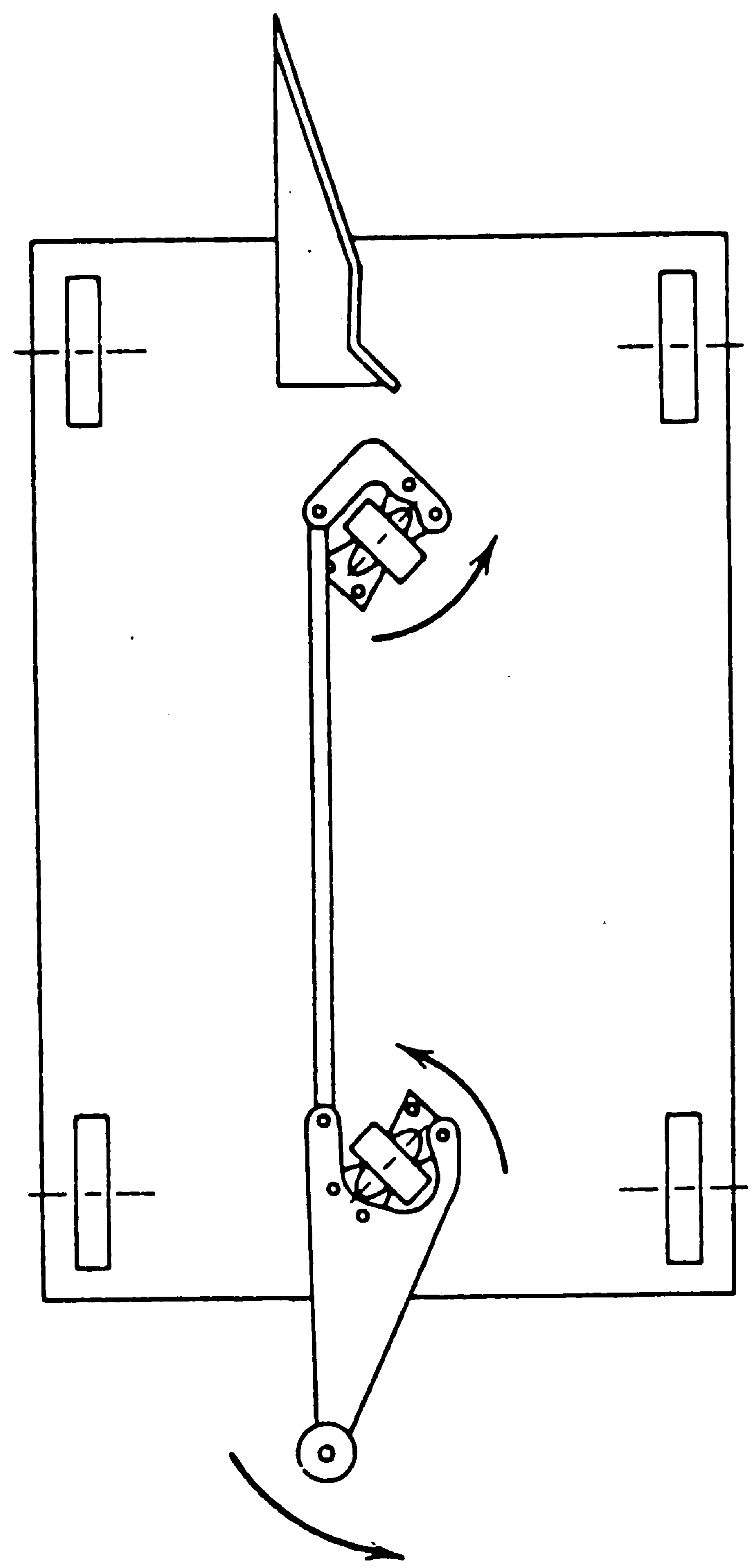

Figure 3-4: Typical carrier subassemblies [2].

The top plate of the drive wheel is bolted to the center channel of the chasis. Two guide-wheel subassemblies are bolted to the deck plate on one side of the carrier while two travelling wheels support the carrier on the opposite side of the guide wheels. Automatic accumulation is made possible through the use of an accumulation nose cam follower (mounted on the front of the carrier) and accumulation tail cam (mounted at the rear of the carrier). The accumulation nose mechanism consists of a cam roller mounted to a pivoting nose plate, which is linked to the drive wheel by a connecting rod. The accumulation tail is a plate with a cam surface. The carrier operates when the spring-loaded drive wheel is compressed against the drive tube. Front and rear guide wheels straddle one side of the track [2].

3.1.4 Right Angle Turntable

Turntables are used to change the carrier's direction of travel by 90 degree (Figure 3-5). In performing this function, the turntable also supports, guides, and propels the carrier throughout the system. The two main components of the turntable are the deck and the supporting frame. The deck is the rotational portion of the turntable. It is supported by a large-diameter ball bearing, and includes a deck plate, track rails, drive tube, queue station, tube drive, and limit switch. A more complex type of turntable is also available which, in addition to changing the carrier direction by 90 degree, also serves as a merge or divert location. In other words, this "T" type turntable may accept carriers from two locations and merge these carriers into a third output location or accept a carrier from one input location and divert it into two possible output locations.

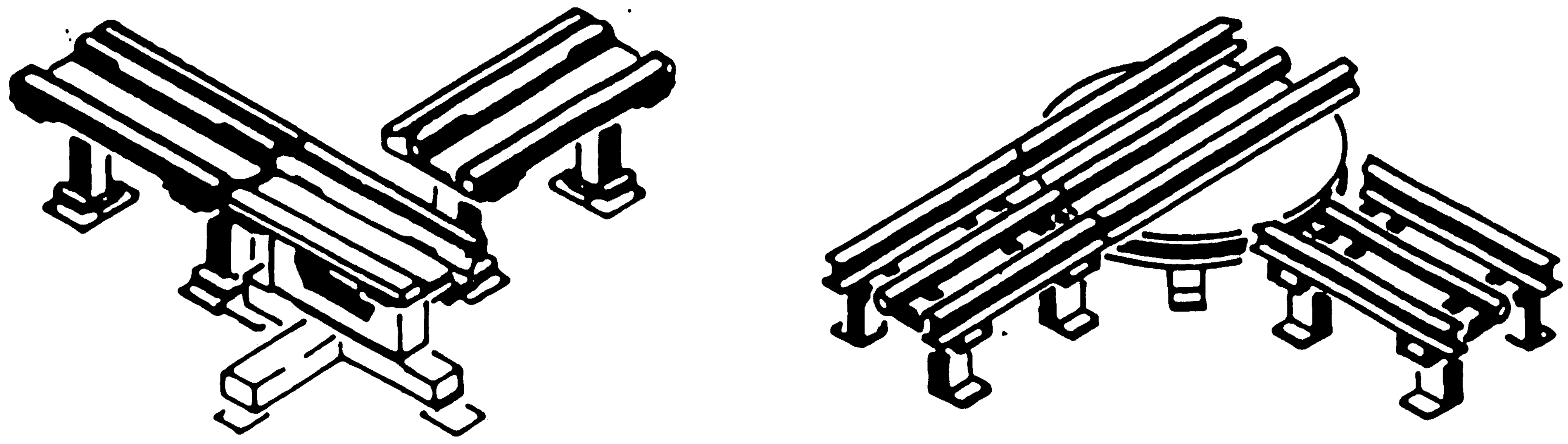

Figure 3-5: Right angle turntable [13].

3.1.5 Radius Turns

Radius turns are also used to change a carrier's direction of travel within the Cartrac system. The turns utilize the basic concept of the track module, incorporating track rails, drive tubes, universal joints, and tube drive units. A radius turn also serves to support, guide, and propel a carrier through the system (Figure 3-6).

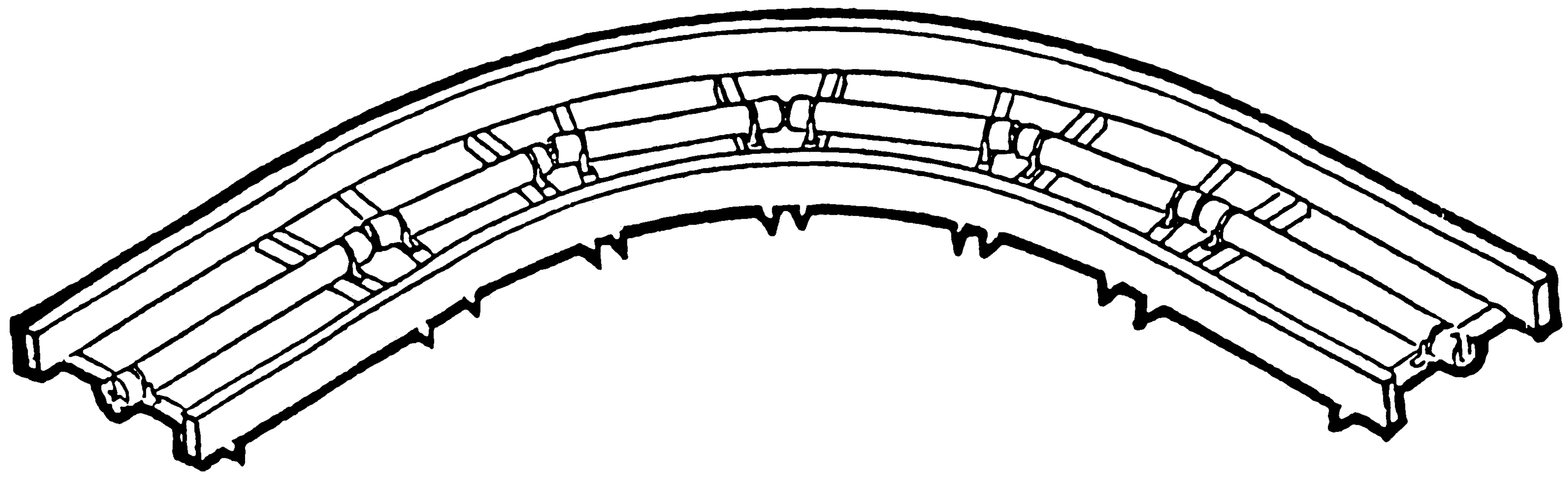

Figure 3-6: Radius turn [2].

Turns are formed by rolling standard track rails to a desired radius. The curved track rails are then welded to steel crossmembers to form a rigid frame. Holes in the crossmembers are provided for mounting and supporting the drive tubes and for attaching the track supports. Two types of drive tubes are used:

fixed tubes with pillow blocks and floating tubes without pillow blocks. Fixed and floating tubes are placed alternately throughout the turn and joined by universal joints. The same hex-shaft/hex-bore bearing combination found on standard track modules is utilized here. The standard tube drive unit powers the drive tubes of the radius turn.

As in the straight track modules, carriers are propelled through the turn by the interaction of the carrier drive wheel against the drive tube. Guide rollers on the swivel wheels of the carrier follow the path of the curved rails, effecting a smooth, uninterrupted change of direction. Supports are bolted to the turn structure in the same manner as on the straight track modules.

3.1.6 Transfer Assembly

Transfers are used to transport a carrier in a perpendicular direction from one path to a parallel path. In doing so, the transfer is capable of discharging the carrier in the original or reverse direction of travel (Figure 3-7).

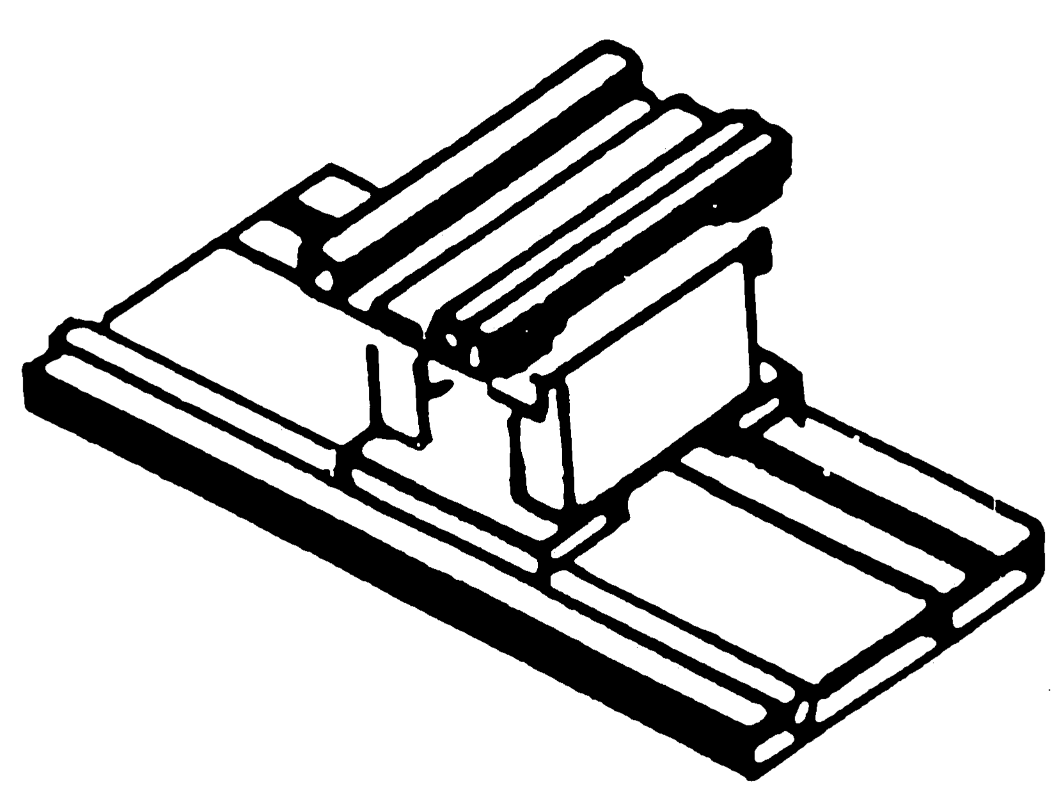

Figure 3-7: Transfer assembly [13].

The two major components of a transfer are the transfer car and transfer track (transfer assembly base level). The transfer car is similar to a carrier, in that it utilizes a chasis with integral drive, guide, and load carrying wheels and a limit switch cam. The fixture mounted on the top of the transfer car is a standard Cartrac track section. It incorporates a tube drive, queue station, drive tube, and limit switch. The transfer track propels the transfer car from one end of the transfer to the other. Its construction is similar to that of a standard track module. It utilizes track rails, crossmembers, drive pan, and drive tube. Tube drive, queue stations or left and right fixed control bars, and limit switches are also included.

3.1.7 Shuttle

A shuttle powered by air pressure works in conjunction with a main track line for moving carriers off the track line in order to interface with a machine or a work station (Figure 3-8). It normally has a standard track module section and utilizes a drive motor, queue station, and drive tube. In dual shuttle, the movement of other carriers through the divided main line while the shuttle is interfacing is made possible by having another access track module on the shuttle.

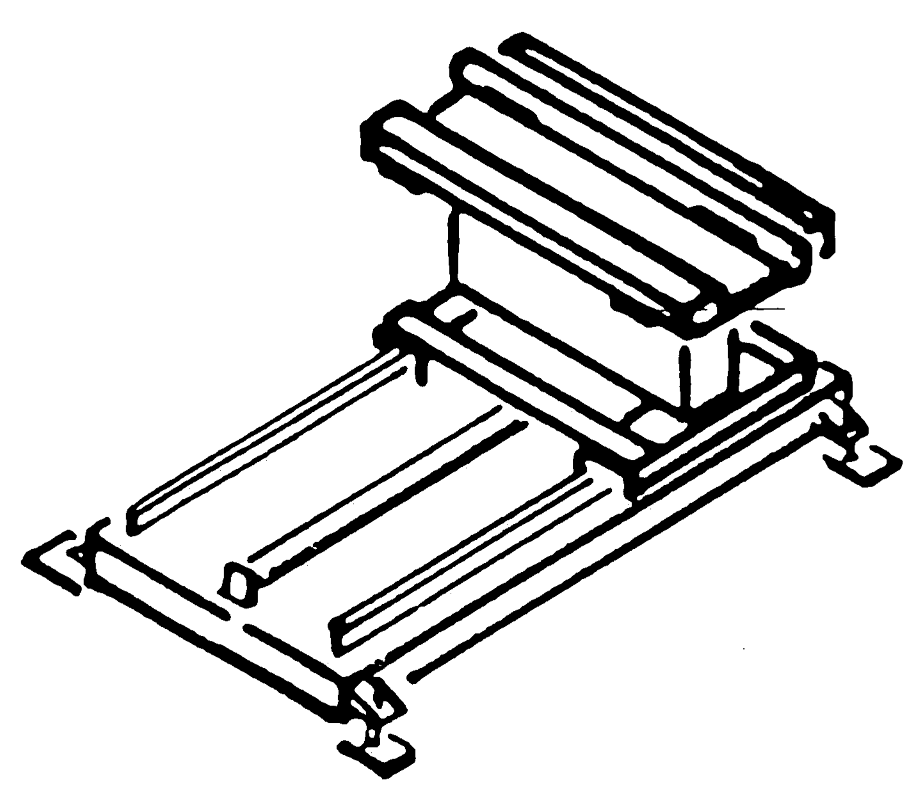

Figure 3-8: The shuttle [13].

The shuttle base level includes two guidance rails and limit switches. As long as the guidance rails permit, the carrier can be moved forward from the main line. That distance depends on the type of application required. When the carrier reaches the far point of the guidance rails, the second access track module interfaces itself with the main track lines.

3.1.8 Access Device

This device provides an opening through the main track line by raising a track module section. The configuration of track module and fixtures on it are the same as in the standard track module. The mechanism also supports the track module (Figure 3-9).

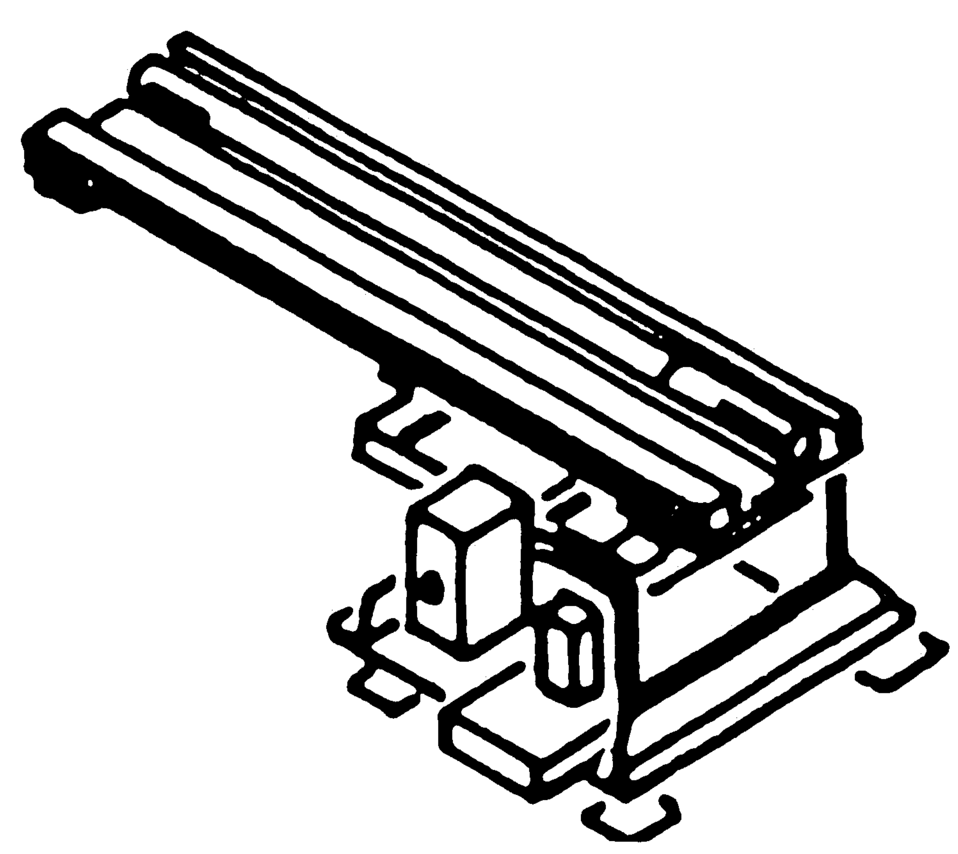

Figure 3-9: Access device [13].

3.1.9 Vertical Lift

A vertical lift is used to lift or lower a carrier smoothly and accurately between two or more levels. It consists of a supporting frame and a track module which is moved up and down by a hoist mechanism and the supporting frame. The track rails and the crossmembers are mounted on the deck plate. It also includes a drive tube, queue station, drive motor, and limit switch (Figure 3-10).

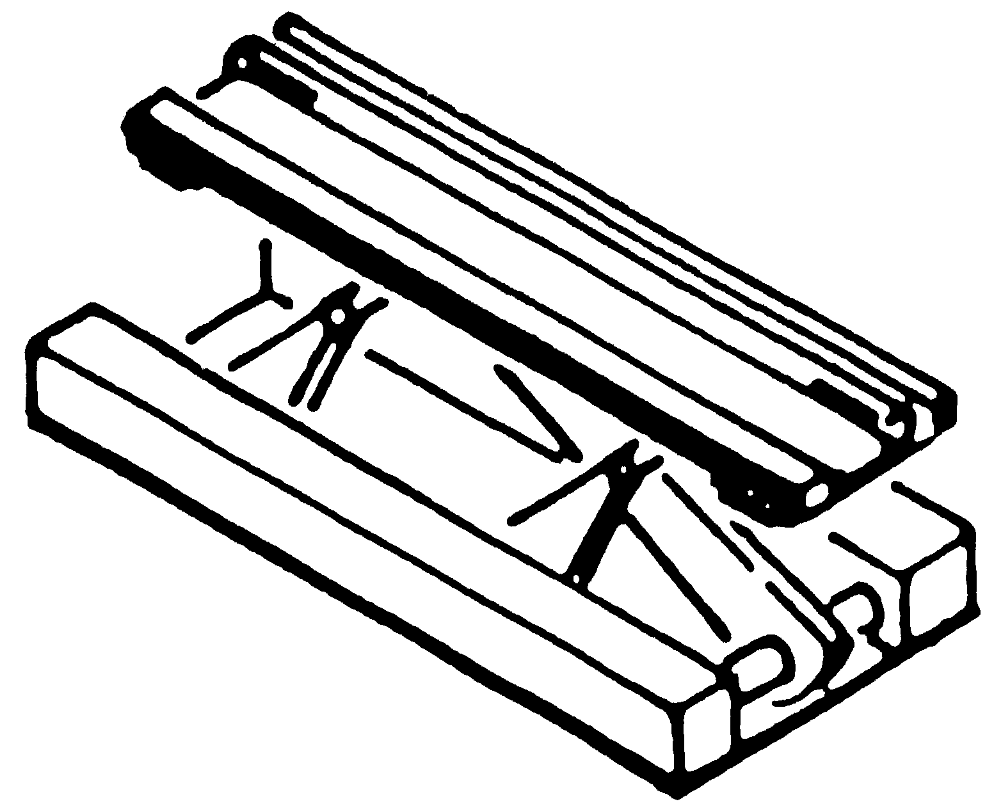

Figure 3-10: Mini-Cartrac lift [13].

3.1.10 Ramp

The ramp enables cars to change elevation without a vertical lift. The elevation changes gradually between the two levels as illustrated in Figure 3-12.

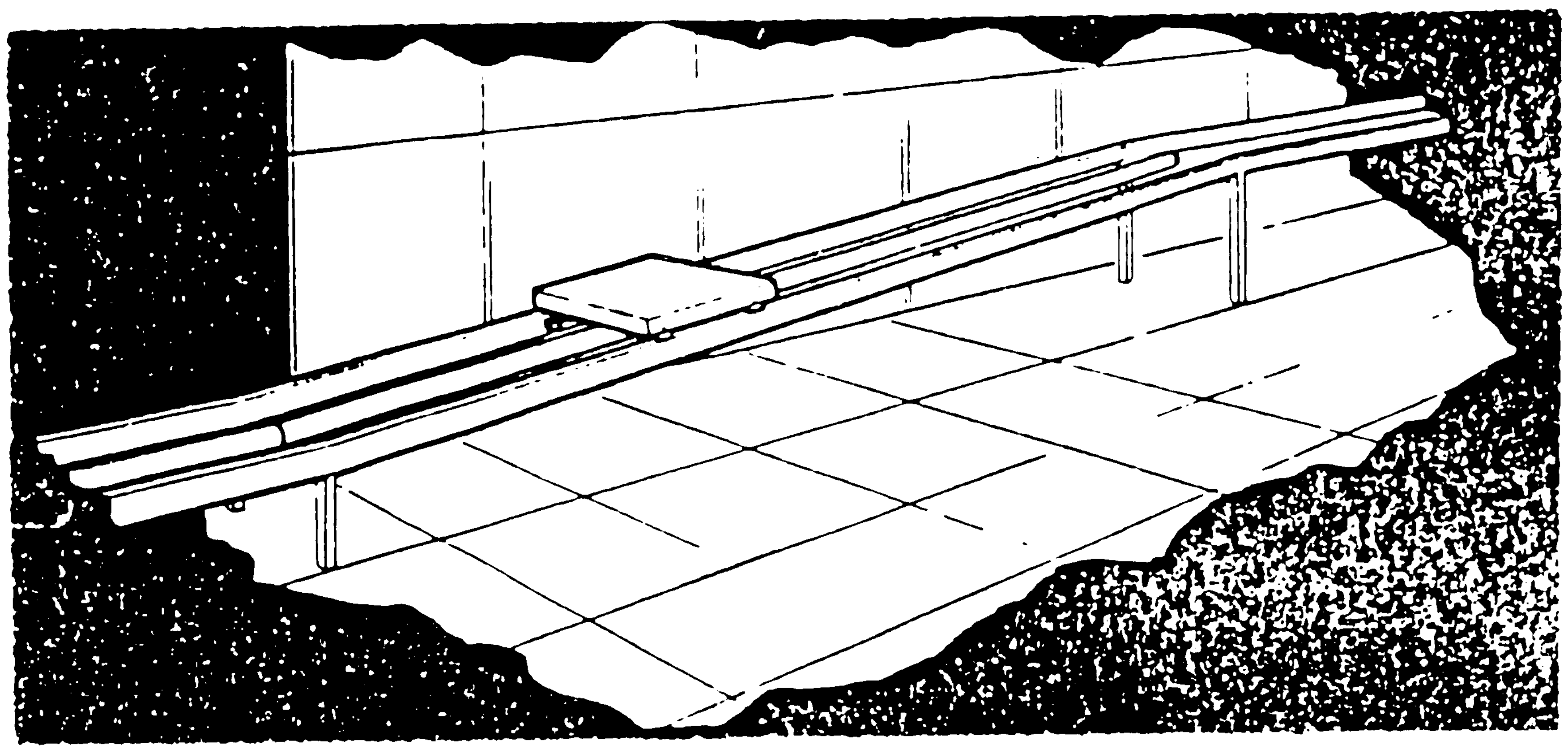

Figure 3-11: Ramp [12].

3.2 Subassemblies

3.2.1 Queue Station

This device is mounted on the track module for stopping a carrier at a specific location, and controlling its deceleration, stopping point, release and acceleration (Figure 3-12). At a queue station, the carrier's accumulation nose contacts the queue station control bar (cam surface). The carrier decelerates at a smooth, controlled rate and is stopped completely when the carrier stop roller contacts the control bar on the queue station. Acceleration can only begin again after the queue station control bar has been manually or electronically pivoted to one side, clear of the stop roller on the carrier. In addition to the main control bar, a safety stop bar may be placed on the queue station for either back or forward travel when required.

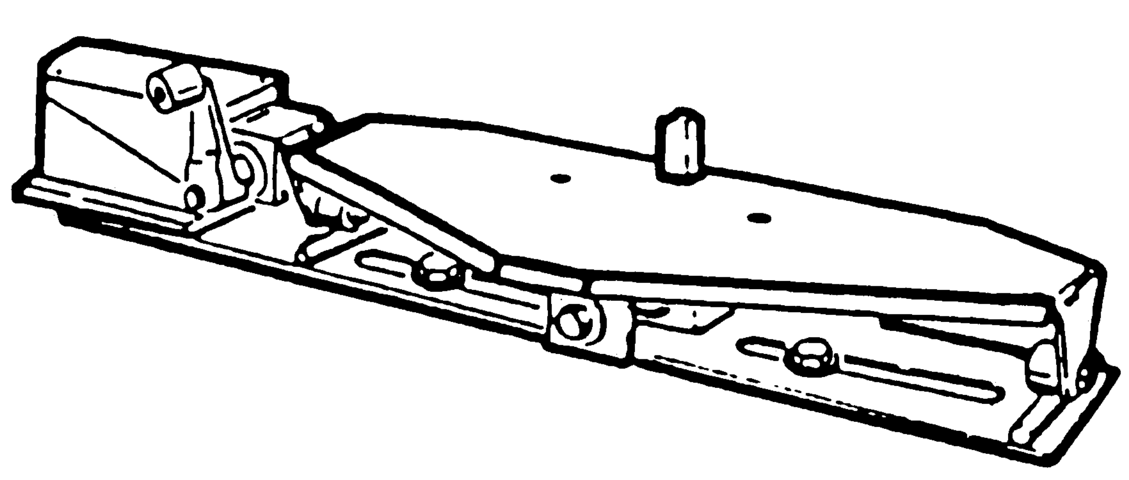

Figure 3-12: Queue station and Limit switch [13].

3.2.2 Trapping Queue Station

A trapping queue station is used for accumulation of carriers on a track module. The track module section also has a tube drive which must be capable of rotating in two directions. The carrier is not allowed to move further in its current direction and accumulation is accomplished on line when a moving carrier comes in contact with a carrier that has stopped. The roller on the front of the approaching carrier contacts the cam plate at the rear of the stopped carrier. The cam plate moves the roller and lever arm, which in turn moves the drive wheel assembly to a neutral position. As a result, the approaching car slows and stops. Any number of carriers may be accumulated in this manner on a straight section of track.

3.2.3 Limit Switch

As explained above, a queue station brings the carrier to a controlled stop and activates the limit switch (see Figure 3-12). In general, the limit switch detects the stopped carrier's present location. The cam bolted to the carrier chassis operates the roller lever on the limit switch thus relaying an electrical signal. Then, the limit switch causes the carrier to be released from the queue station by pivoting the control bar on the queue station. The same logic is also valid for the movement of a transfer car in the transfer assembly, rotational drive unit in turntables, and the shuttle on its guidance rails. However, a second limit switch is needed in these cases. Some examples for the operation of limit switches are as follows [2]:

Transfer assembly: The carrier presence activates the transfer car limit switch which initiates transfer car travel. The transfer car travels to its predetermined destination where it is stopped by a queue station or a fixed control bar on the transfer track. The presence of the transfer car activates another limit switch which in turn causes the carrier to be released from the transfer car.

Right Angle Turntable: The limit switch detects the carrier's presence and activates the rotational drive unit. This rotational drive unit, which is mounted on the supporting frame, rotates the carrier 90 degrees. A second limit switch senses that the carrier has completed its rotation, pivots the queue station control bar, and the carrier accelerates forward.

Shuttle: As a carrier is stopped by the queue station control bar, the presence of the carrier activates the shuttle to move forward by means of a limit switch. After the required shuttle position for interfacing is reached, the second limit switch activates the interfacing equipment.

3.2.4 Photocell

A photocell is used to identify if a carrier is on the transfer car. Photocells are located at the loading or unloading points of the transfer assembly in the Cartrac system. These devices can identify the carriers by means of the reflector mounted under the carrier's deck plate.

3.2.5 Single and Double Actuator

Basically, an actuator is a pull-push button. It is placed at certain points where transfer cars interface with the main track line. They operate simultaneously as the limit switch initiates transfer car travel or causes the carrier to be released from the transfer car or a queue station. The pull or push movement of the transfer car is necessary for precise interfacing. If the transfer car interfaces with the two track sections, the double actuator is needed.

3.2.6 Solenoid Valve Panel

The air pressure accommodates the power necessary to pivot a queue station or trapping queue station control bar to one side, to move a shuttle forward or backward, and to pull or push a transfer car in interfacing with the track module section(s) by means of a single or double actuator. A solenoid valve panel is the distribution center of that power. There could be more than one air distribution centers in a cartrac system. A typical system layout uses all of these components to create an orderly flow of traffic throughout the facility. Through the use of limit switches and advanced electronic sensing devices, the system is able to interface with modern manufacturing and warehousing processes.

Chapter 4
Cartrac System Layout Design for the Manufacturing Technology Laboratory

4.1 The Manufacturing Technology Laboratory

The Manufacturing Technology Laboratory is establishing a major research and educational area in materials handling, in addition to its traditional areas in manufacturing processes and automated production systems. A local company, SI Handling Systems Inc., Easton PA, has provided an automated guided vehicle system (AGVS-Unit Load Carrier), Mini-Cartrac conveyor system, and an automated storage/retrieval system (AS/RS) as part of a joint research project performed at Lehigh. These systems are being installed in the laboratory where major current problems being solved are the layout design analysis, the installation of these systems, and getting them to operate.

4.2 Desired Objectives in Layout Designing

Since the Cartrac system has been used for a while before being delivered to Lehigh University. it had already had a layout configuration. According to that plan, the system has a loop including the shuttle, and a carrier accumulation track section which is located outside and interfaced with the loop (see Figure 4-2).

In one part of the Manufacturing Technology Laboratory, a CNC horizontal machining center has been installed and its location will not be modified. Since it is a bulky system and has some auxiliary equipment, it would be impractical to remove and replace it. Another decision had been made for the exact location of the AS/R system which is being installed next to the

CNC horizontal machining center. Besides that a CNC turning center will be located in front of the CNC horizontal machining center.

A mechanical interface design fixture was developed by Richard Davis Jiranek as his masters thesis [8], 1986. That fixture design might be used in conjunction with the production equipment and Cartrac system.

Having the above situation, we can describe our objectives for the Mini-Cartrac system as follows: interfacing with CNC horizontal and turning machining centers, AS/RS, AGVS, and robot or other work stations for integrated materials handling and manufacturing. In order to meet these objectives, there seemed to be two ways being followed: to use the layout configuration which was previously determined or to design a new layout configuration. In the second case, it should be pointed out that only the delivered equipment must be considered in planning. Since the Cartrac system is computerized and is very expensive, to get new equipment from the supplier is not the optimum solution for this problem. Existing control software can be adapted easily for a new layout plan, because Cartrac's real time computer communication capability enables the carriers to be efficiently sequenced for rapid accommodation of changing production needs, and computer controls are modular and upwardly expandable to support future needs.

4.3 Predetermined Layout Plans

There were several predetermined layout plans, one of which was the same original layout configuration that the Cartrac system had before being delivered to Lehigh.

4.3.1 Analysis of These Plans

A layout plan was submitted by Robert Sloand as a part of his masters thesis [10], 1984. According to that plan, the system configuration has a loop containing two parallel main track lines, two transfer assemblies, and two track modules each of which interfaced with one of the CNC machining centers by means of using the two shuttles (Figure 4-1). Sloand explains the system operation as follows [10]:

"The AGV stops at the proper location, signals its presence to the local cart control, and transfer is initiated. When the pallet transfer is completed. the cart control directs the load to the proper machining station and signals its position as ready. The pallet is shuttled off the cart onto either the pallet shuttles on the machining center or the buffer area of the turning center.

At the machining center stations, the CNC is signalled by the cart control that a load is in position for transfer into the machine's workspace. The CNC will then initiate the pallet shuttle when it requests another workpiece for processing. When part transfer is completed, the CNC will start the proper program for that particular part. During this time, the next part to be processed at this station is brought into position by the cart control and transferred to the ready position on the pallet shuttle. This procedure is repeated for all workpieces scheduled for these situations.

Another plan was developed by research engineer John Keefe Jr. using the original system layout configuration mentioned in Section 4.2. That layout configuration is made up of a loop and carrier accumulation track section (Figure 4-2). The vertical movement against parallel main track lines in the loop is provided by two transfer assemblies. One of the parallel main track lines has three major parts; the dual shuttle, and two double interface track modules placed on both sides of the shuttle. Each of the tracks includes the same equipment; a photocell, drive motor, queue station, drive tube, and limit switch. The other main track line, on which four limit switches, three queue stations, and a photocell are mounted, involves two single interface track modules having a tube drive supplying the power needed. The carrier accumulation track section carries out a trapping queue station, limit switch, drive tube, and a reversing drive motor. Each of the transfer assemblies contains a transfer car moving on the base levels, having a drive tube, and queue station. On the other hand, a transfer assembly base level has a left and right hand side fixed control bars, drive tube, and reversing drive motor. The system is supported by 9 track supports, four of which are at the edges of the parallel main track lines holding up a limit switch and actuator for the traffic control of transfer cars. Three solenoid valve panels are installed on the track supports where they distribute the air pressure needed for system.

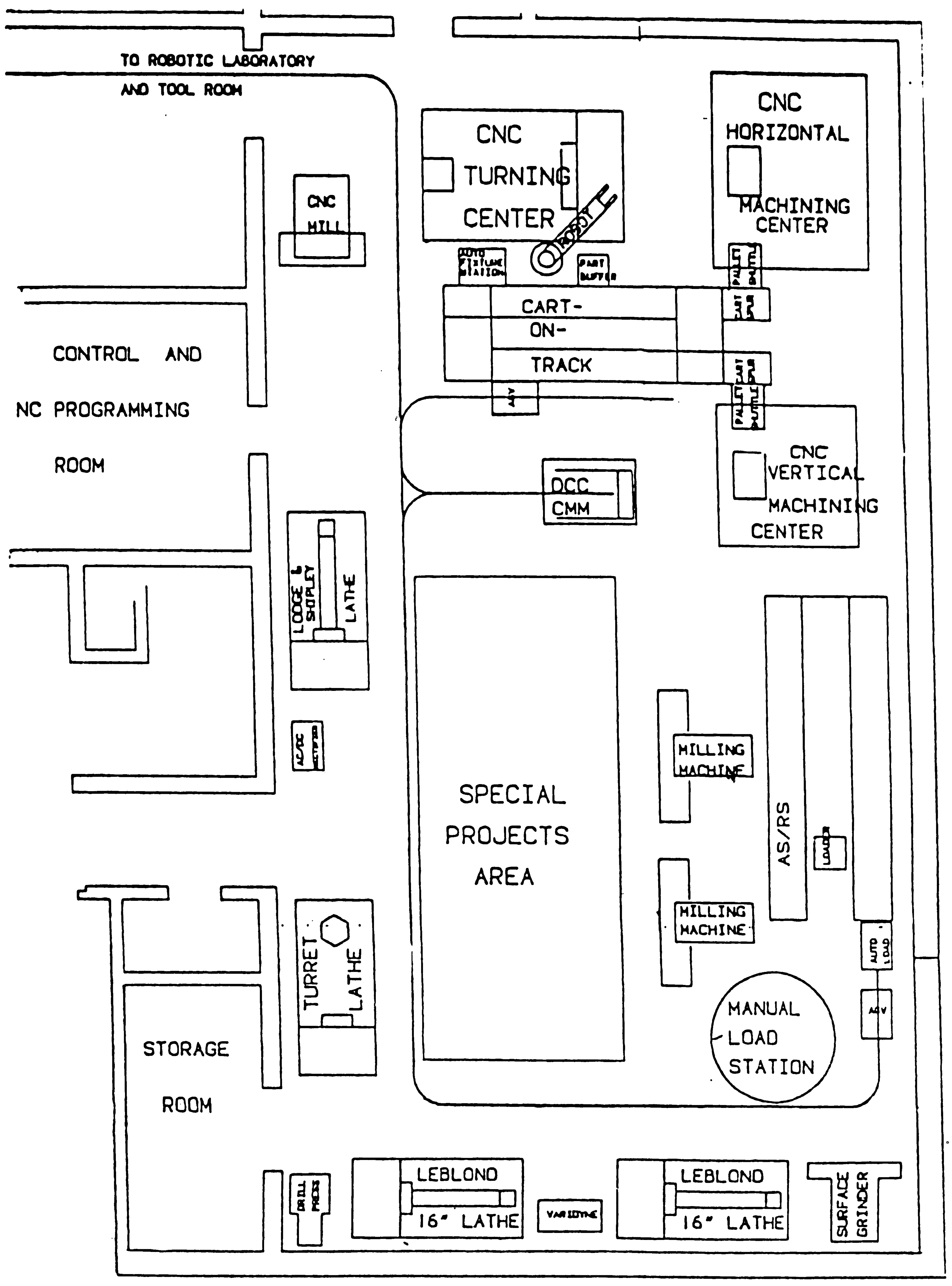

Figure 4-1: Predetermined plan-1 [10].

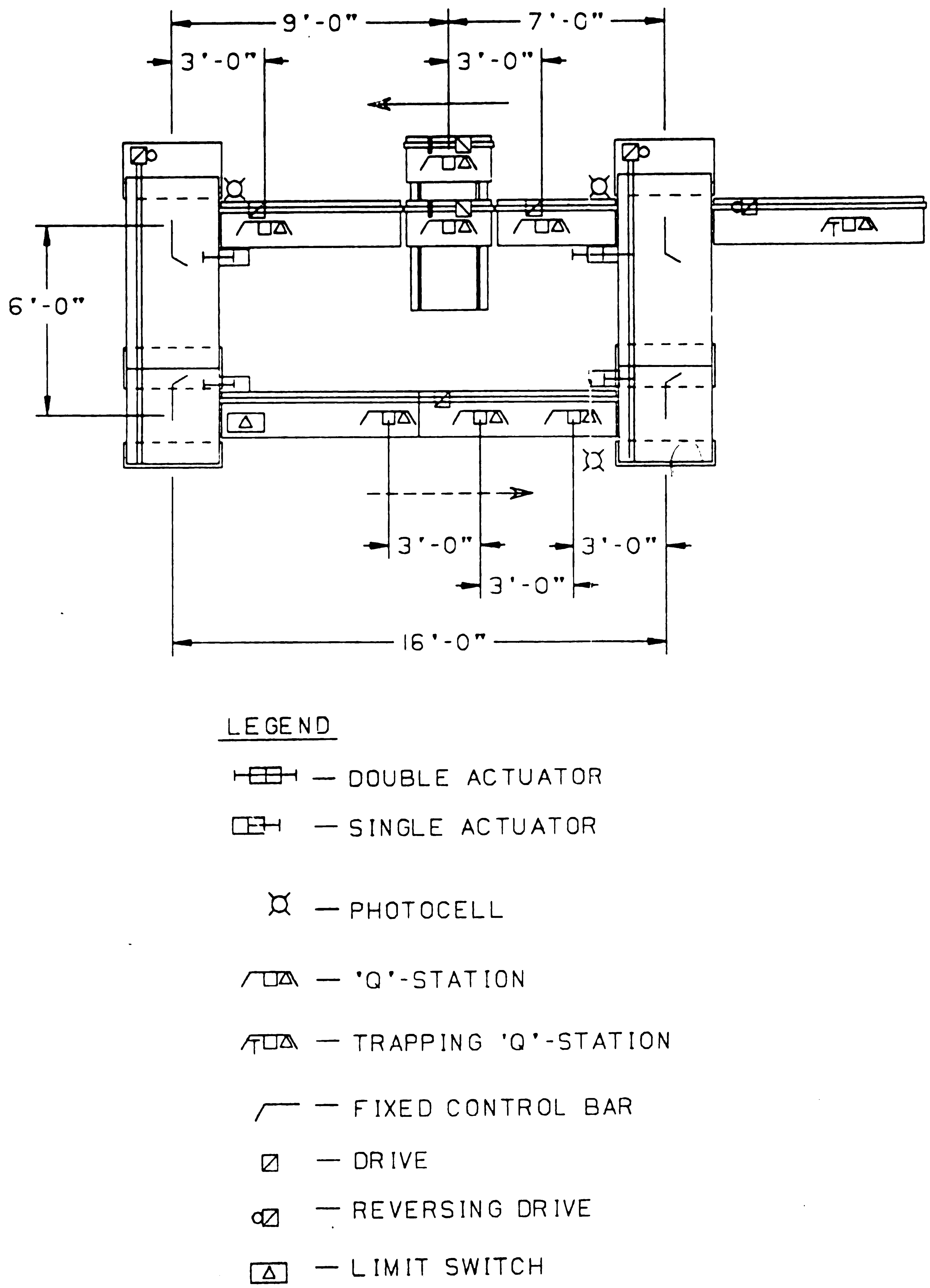

Figure 4-2: Original cartrac system layout plan [11].

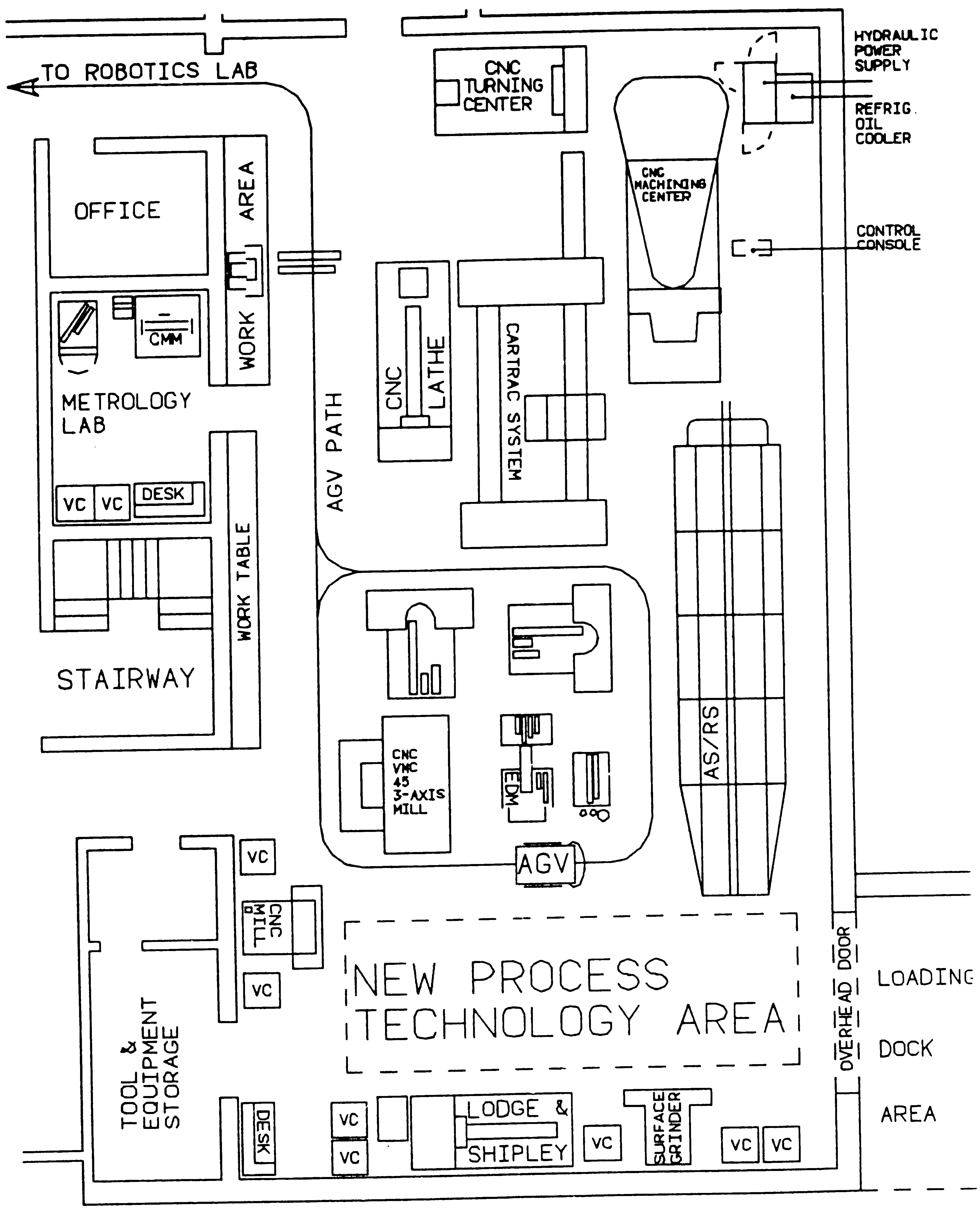

Figure 4-3: Predetermined plan-2.

4.3.2 Disadvantages of the Previous Plans

Sloand's layout plan is not feasible because of lack of required space and equipment. The plan proposes that the Cartrac system interfaces with the CNC horizontal and vertical machining centers in the same line which also includes the AS/RS, a manual load station, and a surface grinder. However, the actual dimensions of the laboratory do not allow us to have all of these systems and equipment. There is only a space for loading dock area except the installed CNC horizontal machining center and AS/RS. Another reason is that the Cartrac system involves more eouipment than we actually have. There is also no consideration to have a CNC vertical machining center in establishing the flexible manufacturing cell. The sum of these reasons shows that the first predetermined layout plan is not valid for our case.

The second plan is feasible, but it does not meet all of our objectives in planning. The system interfaces with the AGVS next to the transfer assembly, and the CNC turning center connected by a robot. Interfacing with the CNC horizontal machining center and AS/RS, however, still seems to be a problem (Figure 4-3).

4.4 Factors Considered in Designing

There are a number of factors being considered in a system layout design. some of the most important of which are as follows:

Combining Handling with Other Functions:

The system layout should permit interfacing with other material handling systems and workstations so that the system integration accommodates the utilization of high investment machinery.

Improved Flexibility:

The layout must be capable of providing future needs and handle any size of load.

Optimum Space Requirement:

The available space should be engaged by utilizing as little space as possible.

Being Compatible with Balance of Laboratory:

Since the Manufacturing Technology Laboratory will be connected to the Robotics Lab., the system must accurately work together with the speed of other equipments, machines, and systems.

4.5 Proposed Layout Design

4.5.1 Analysis

A number of different layouts were developed and revised on the IBM CADAM system in the Computer-Integrated Manufacturing (CIM) laboratory. Since the CNC Horizontal machining center has been running and the AS/RS has been installed, these systems were considered as a starting point. The use of a robot providing access between the CNC turning center and the Cartrac system seemed logical. Therefore, that part of the system might have been a carrier accumulation track module or normal track module without any carrier accumulation on it. At the same time, it should interface with the CNC Horizontal machining center. In the original layout plan, one of the parallel main track lines including the dual shuttle in the loop appeared to be an ideal section of the system. After that, the problem was how the system should be expanded to connect with the AS/RS. In order to make the loop up again, the other main track line consisting of two single interface track modules was separated and these modules could have been the parallel track modules of the loop. Of course, the two transfer assemblies are vertical at both sides of these parallel modules. The left part of the system was the carrier accumulation track module which was long enough to extend the system up to the center section of the AS/RS where the loading and unloading is possible (Figure 4-4).

At this point let's review our objectives. The system is working together with the CNC horizontal machining center and turning center, and the AS/RS in conjunction with the appropriate interfacing equipment for the systems encountered. The location for the AGVS interfacing is available in front of the AS/RS, next to the transfer assembly. As it can be understood, the system has satisfied all of our required objectives. The location of the system also permits efficient use of floor space in the laboratory and future expansion by the addition of more workstations . Figure 4-5 illustrates the final layout plan for the Mini Cartrac conveyor system. The conveyor system has been installed in the Manufacturing Technology Laboratory according to this plan.

4.5.2 Problems with the Proposed Layout Design

Many of the hardware components of the new layout plan shown in Figure 4-4 are the same as in the original plan described in Subsection 4.3.1. In comparing these two plans, the transfer assemblies and the dual shuttle have the same subassemblies on their track modules. The parallel main lines of the loop must be double interface track modules with their appropriate drive tubes. The current track modules and drive tubes, therefore, are not useful for that plan. Because of the new configuration, the system needs one more track support, photocell, and double actuator to be used on the track module located

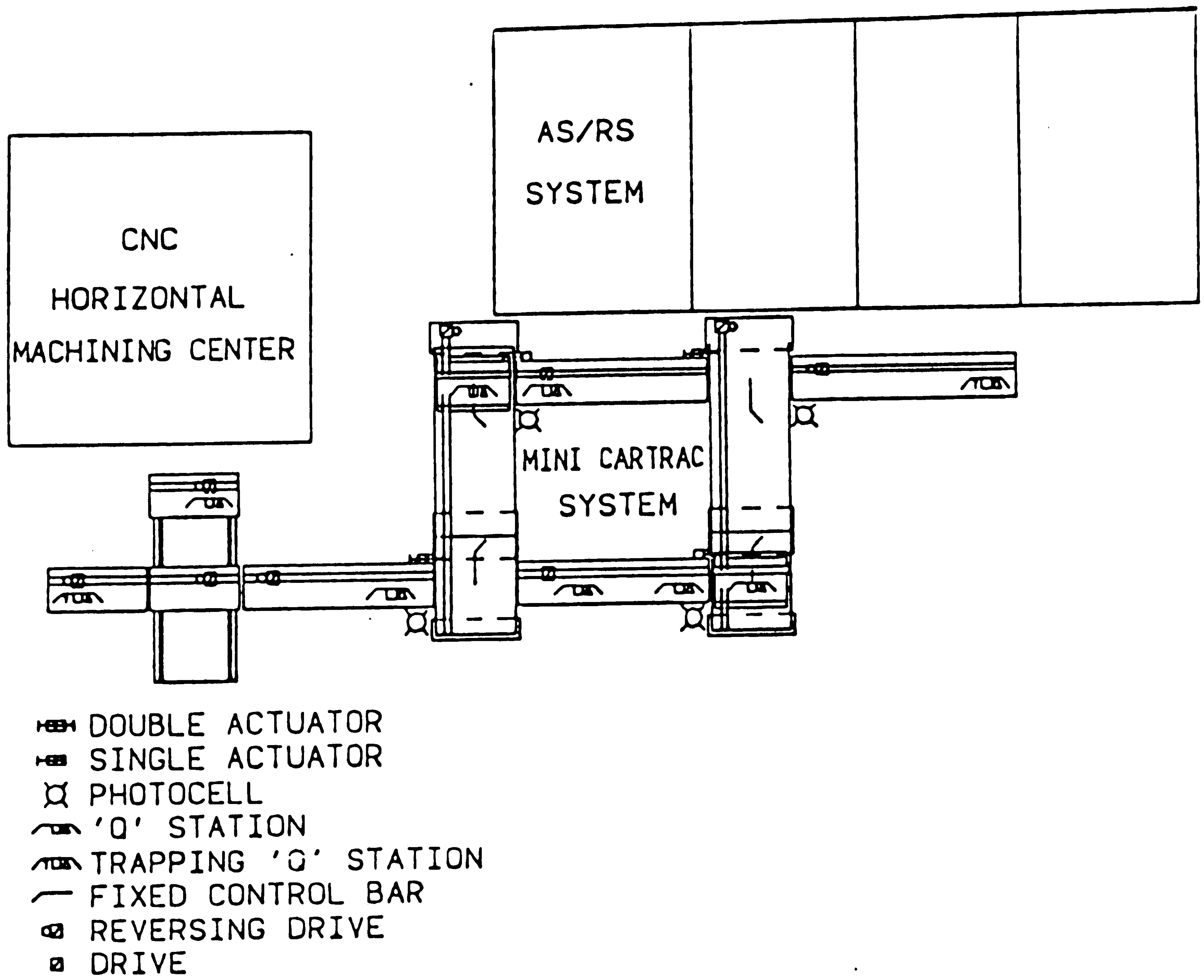

Figure 4-4: Proposed layout plan and the subassemblies.

between the dual shuttle and the transfer assembly. Another thing that the track module interfacing with the robot and the CNC turning center might be a carrier accumulation track module. As a result, one more trapping queue station will be needed.

One thing that would change in the system is that the length of parallel track lines in the loop went down from 6 ft. 3 in. to 5 ft. 10 in.. The reason was that the company had only 3 ft. 10 in., 4 ft. 10 in. ,and 5 ft. 10 in. double interface track modules in stock. 5 ft. 10 in. length was selected in order to have enough space for one or more robots or workstations to be placed next to the loop.

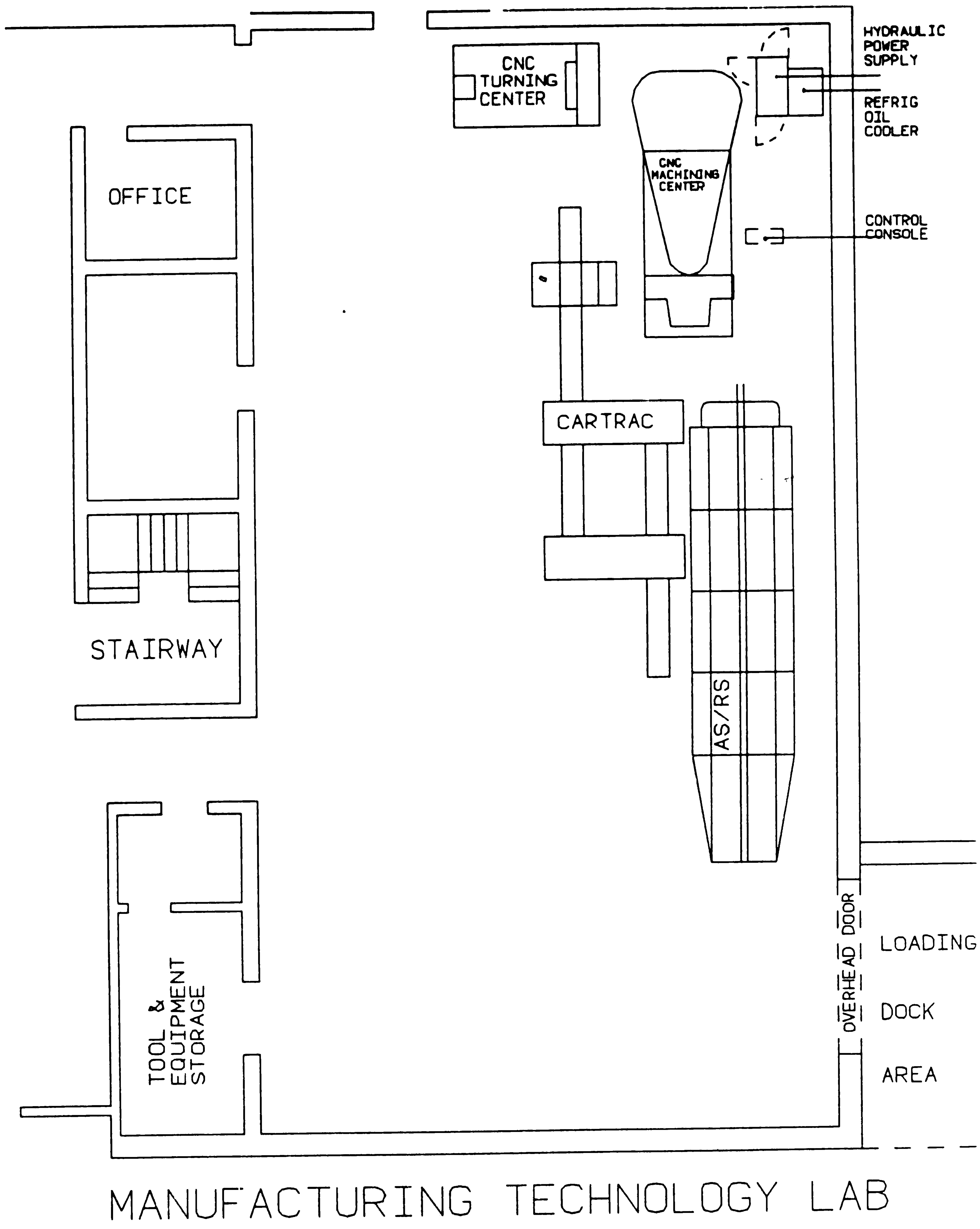

Figure 4-5: Cartrac system in the Manufacturing Technology Laboratory.

Chapter 5
Description of Installation for Cartrac Conveyor System

5.1 System Track and Peripheral Equipment

The system installation is made possible from the system layout plan and the engineering drawings. Before anchoring, all system track supports, modules, transfer assembly base levels and the shuttle must be initially placed over the installation area. Then all bolt points are marked down while the system pieces are located in position according to the layout plan.

After that, the system pieces are removed from the installation area and the floor level, which must be within + or - 1/2 inches [1], is checked out. During that operation, we can establish the high and low points of the floor where track supports are located. The next step is to drill the holes in which the anchoring bolts are inserted. At that point, we are ready for installing the system. We describe it in three procedures in which each step should be followed.

Typical Track Support and Track Module Joints:

The system height according to the high point of the floor has to be established. Then, the track supports are placed in position and rough level surface -F- (Figure 5-1). If the floor is too far out, a shim might be placed under the track support base. Anchoring may begin at this time while keeping the plane -G- and -H- at the same level (Figure 5-2).

By using a special fixture, surface -E-, -D-, -B-, -C- and -J- must be checked out if they are in line (Figure 5-3). The drive shaft is also aligned by using the fixture and maintaining surface -D-. It must contact the fixture at two surfaces as shown in Figure 5-3. The shim can be used under the friction wheel housing as required (Figure 5-4). Surface -K- must also be maintained straight (Figure 5-5). After aligning the drive shaft, the thrust block is installed (Figure 5-6).

Drive Motors, Reducers and Belt Tensioning:

The sheave and bushing should be fastened together by using the adjustment screws, before placing on the reducer shaft and the key coated with anti-seize compound. If the drive motor is located at the other end of the track, the motor disconnect switch, and the sheave and bushing locations must be reversed (Figure 5-7). After checking the oil level in the reducer which are normally shipped prelubricated, they are connected to the motor shaft as in the sheave-reducer fastening.

Then the drive motor is assembled to the track as shown in Figure 5-7 and adjusted by using the take up nuts. The reducer output shaft must be parallel to the drive shaft and the belts must be perpendicular to the drive shaft. The drive motor must also be parallel to the bottom of the track. The vent plug must be installed before operating and the vent hole must face upward (Figure 5-8). Finally the drive guard is assembled as shown in Figure 5-8.

Queue and Trapping Queue Stations, Limit Switches:

The queue station (or trapping queue station) is assembled to the track using the fixture shown in Figure 5-9. If the queue station blade is not parallel to the fixture after shimming (Figure 5-10), the blade mounting bolts and the tilt blade is made looser until the guide rollers are kept parallel against the rods as shown in Figure 5-11. Then, the blade mounting belts are fastened and checked. Figure 5-12 and Figure 5-13 indicates the trapping queue station and track joints.

Solenoid Valve Panel:

After determining the solenoid valve location from the the system layout, the valve mounting plate is assembled as shown in Figure 5-14 and Figure 5-15. Then the air lines are installed. The use of seamless steel tubing and connectors, or brass connectors, or stainless steel tubing and connectors from the F.R.L (Filter, Regulator, Lubricator) panel to the system device (Figure 5-16 and Figure 5-17) is recommended so that the contamination of the air lines are avoided from the foreign matter, such as; threading, oil residue and metal chips. Pneumatic installer must purge all air lines before connecting to individual devices (Figure 5-18).

Figure 5-19, Figure 5-20, Figure 5-21, and Figure 5-22 illustrates the subassemblies pneumatic control diagrams.

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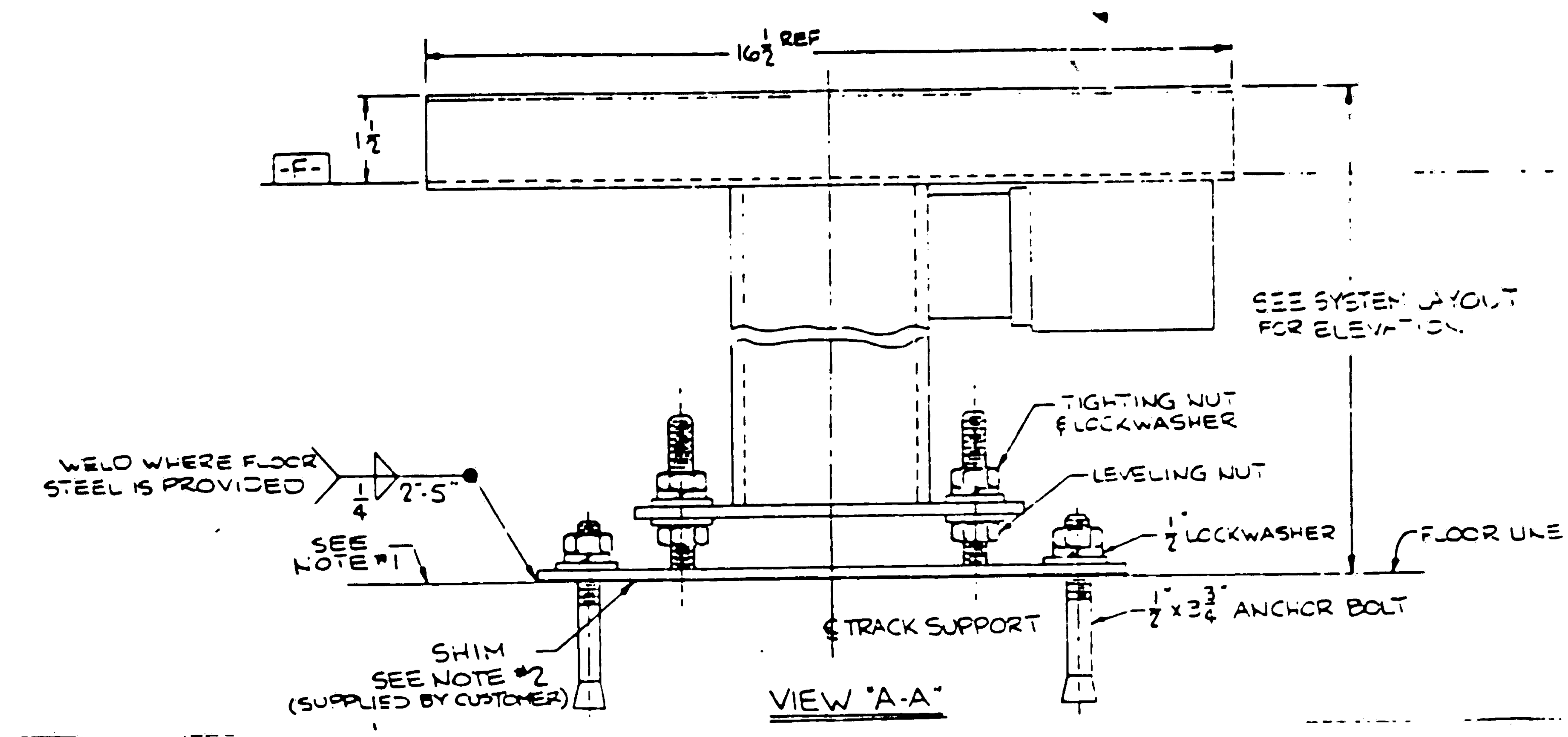

Figure 5-1: View A-A for track support [11].

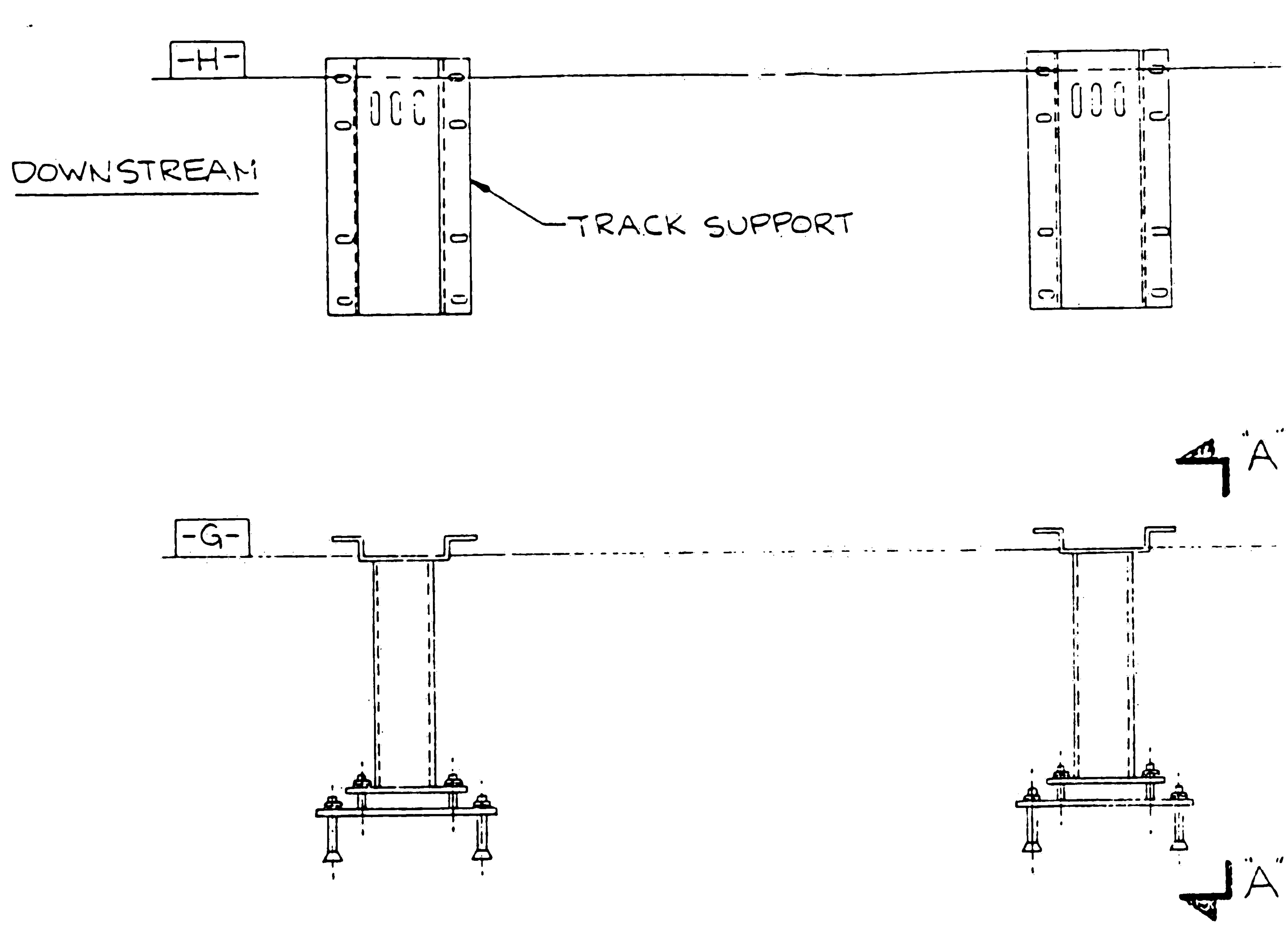

Figure 5-2: Track support [11].

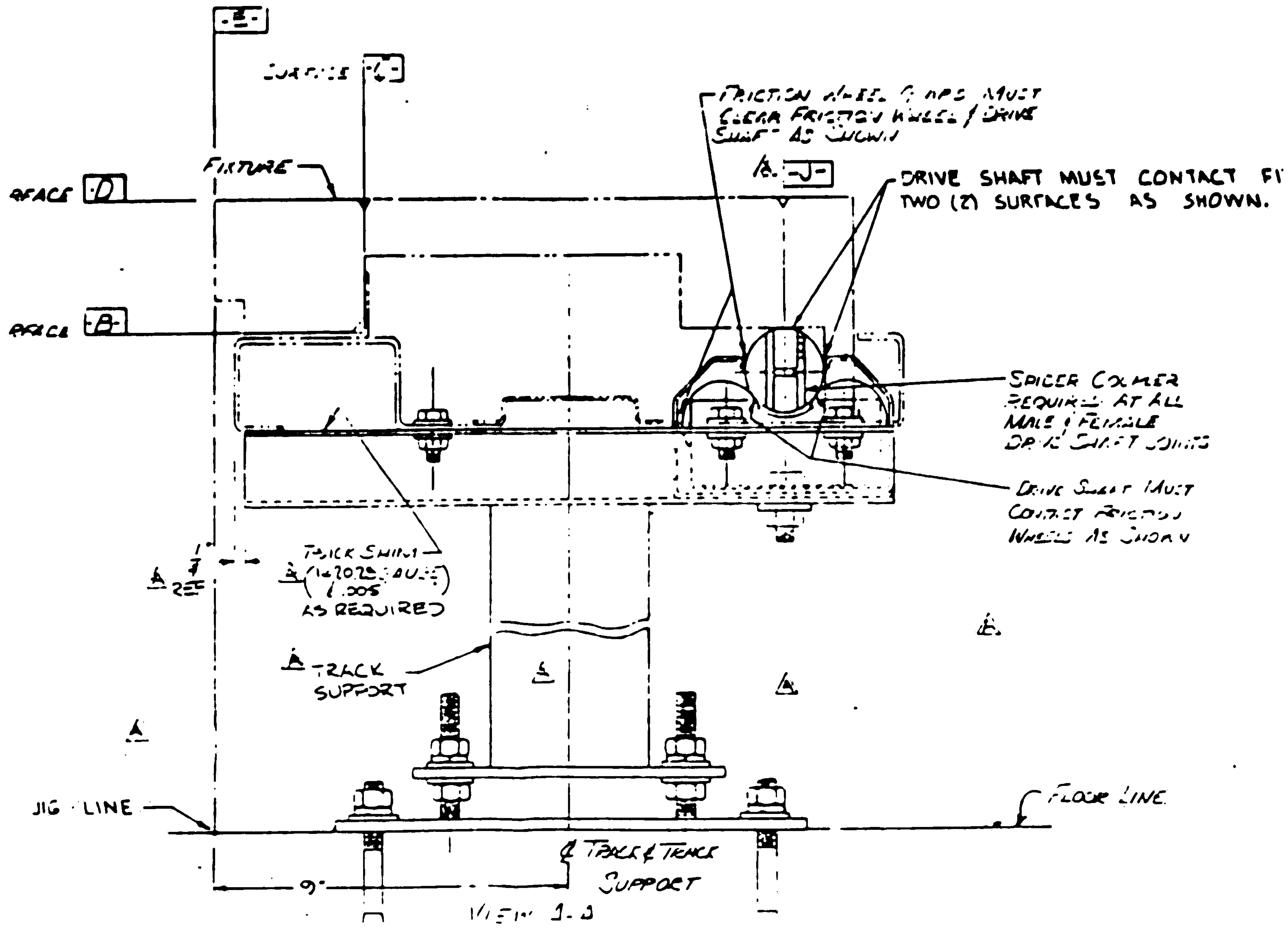

Figure 5-3: Track and track support [11].

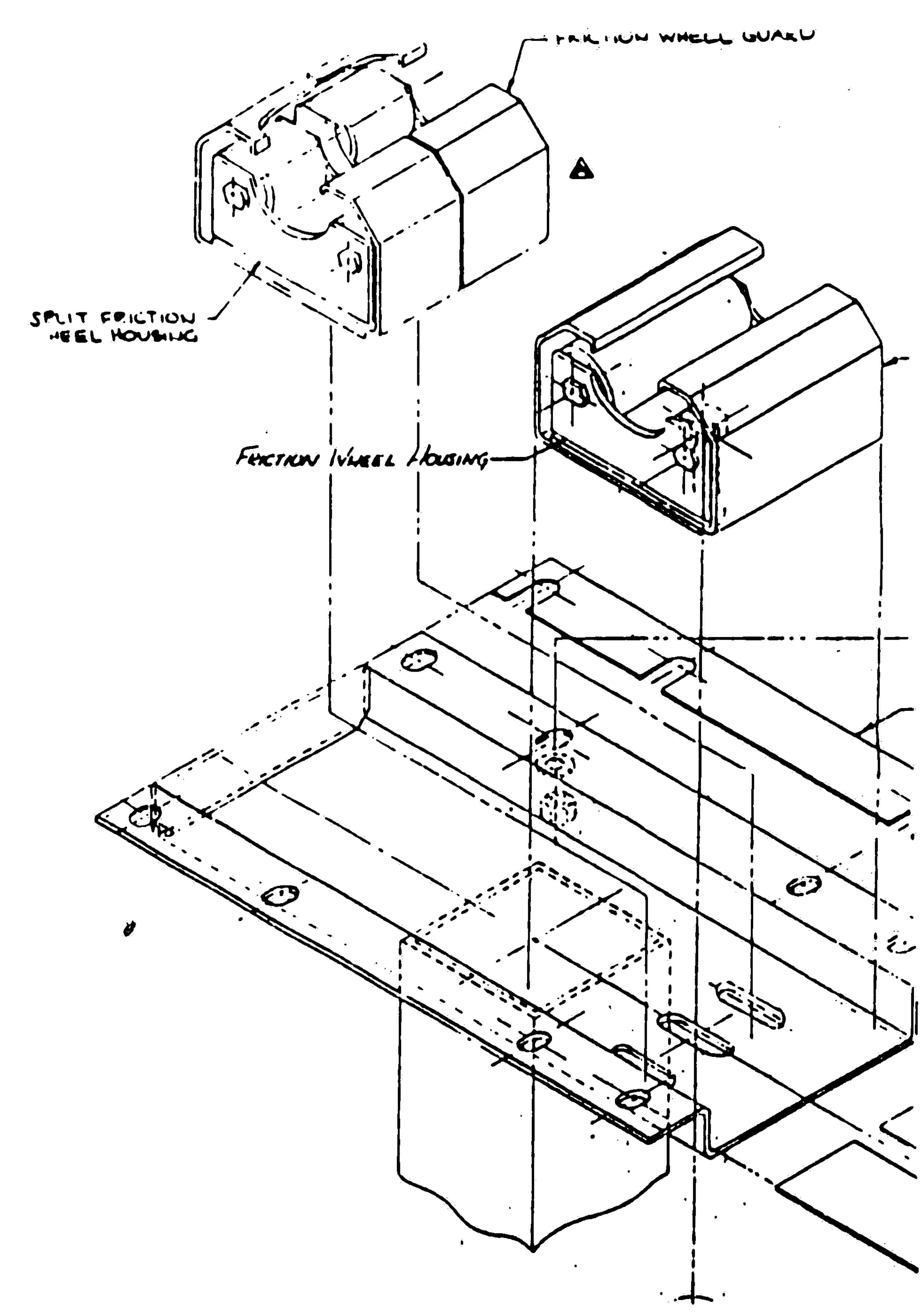

Figure 5-4: Friction wheel housing and track support [11].

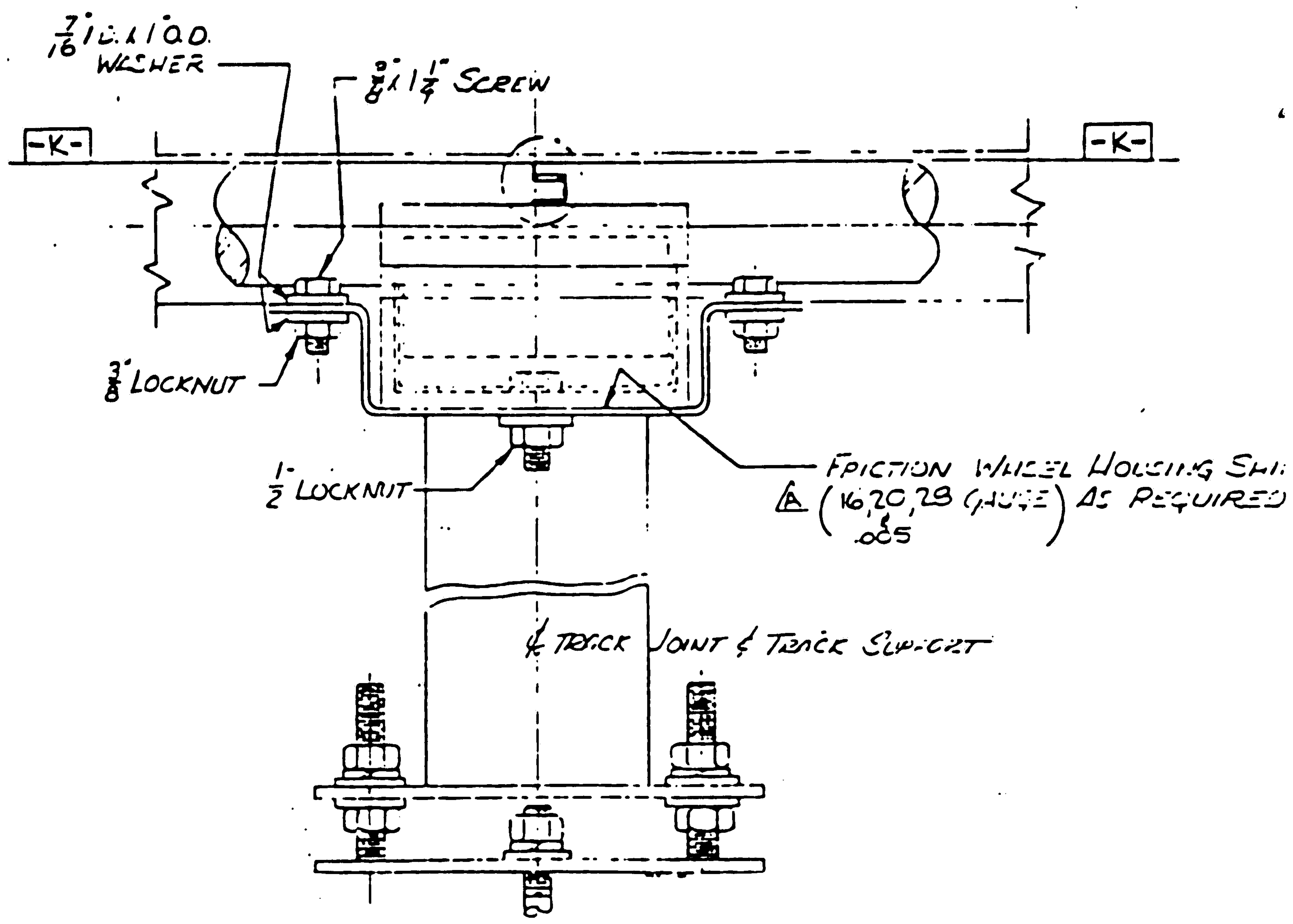

Figure 5-5: Track joint and track support [11].

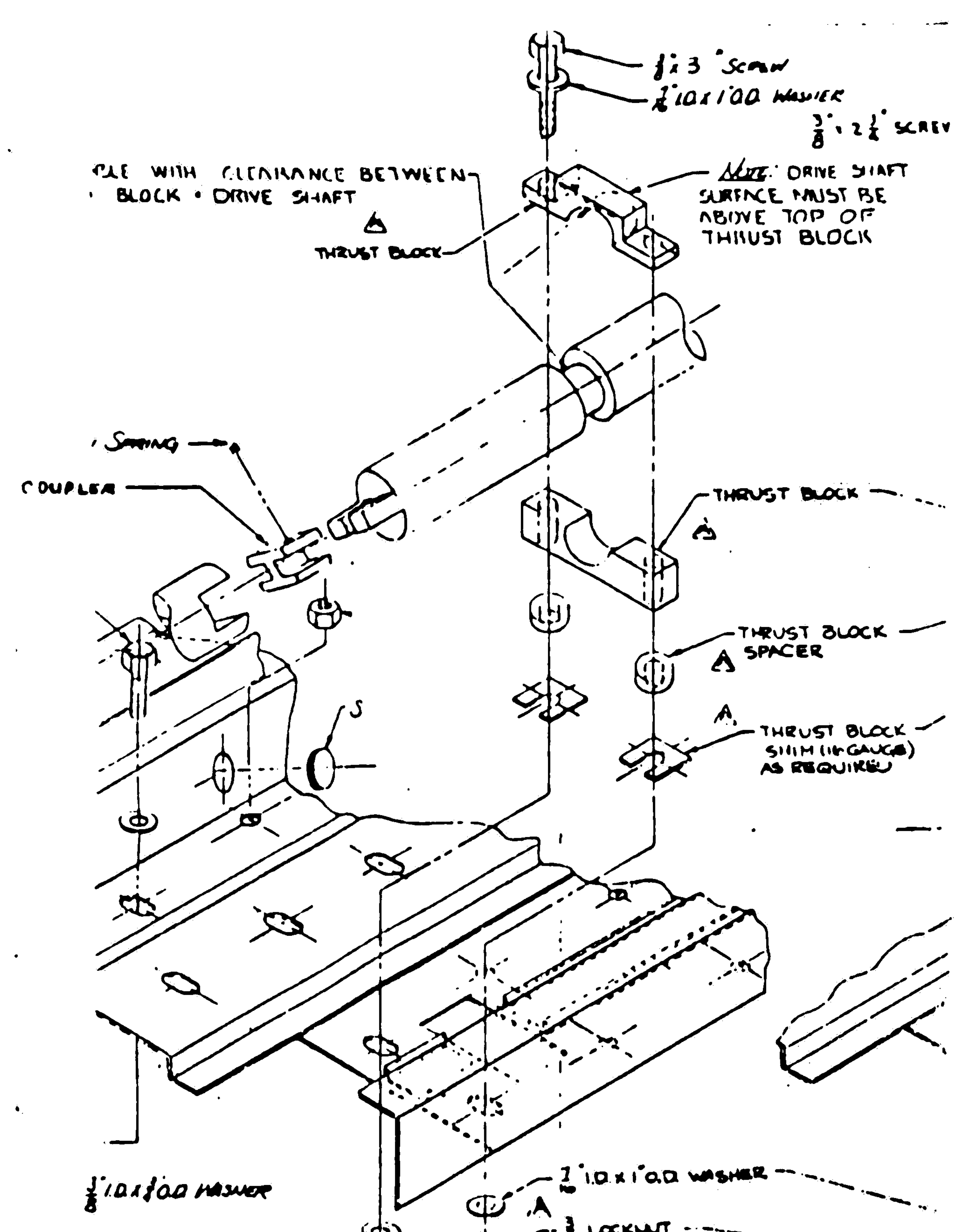

Figure 5-6: Thrust block [11].

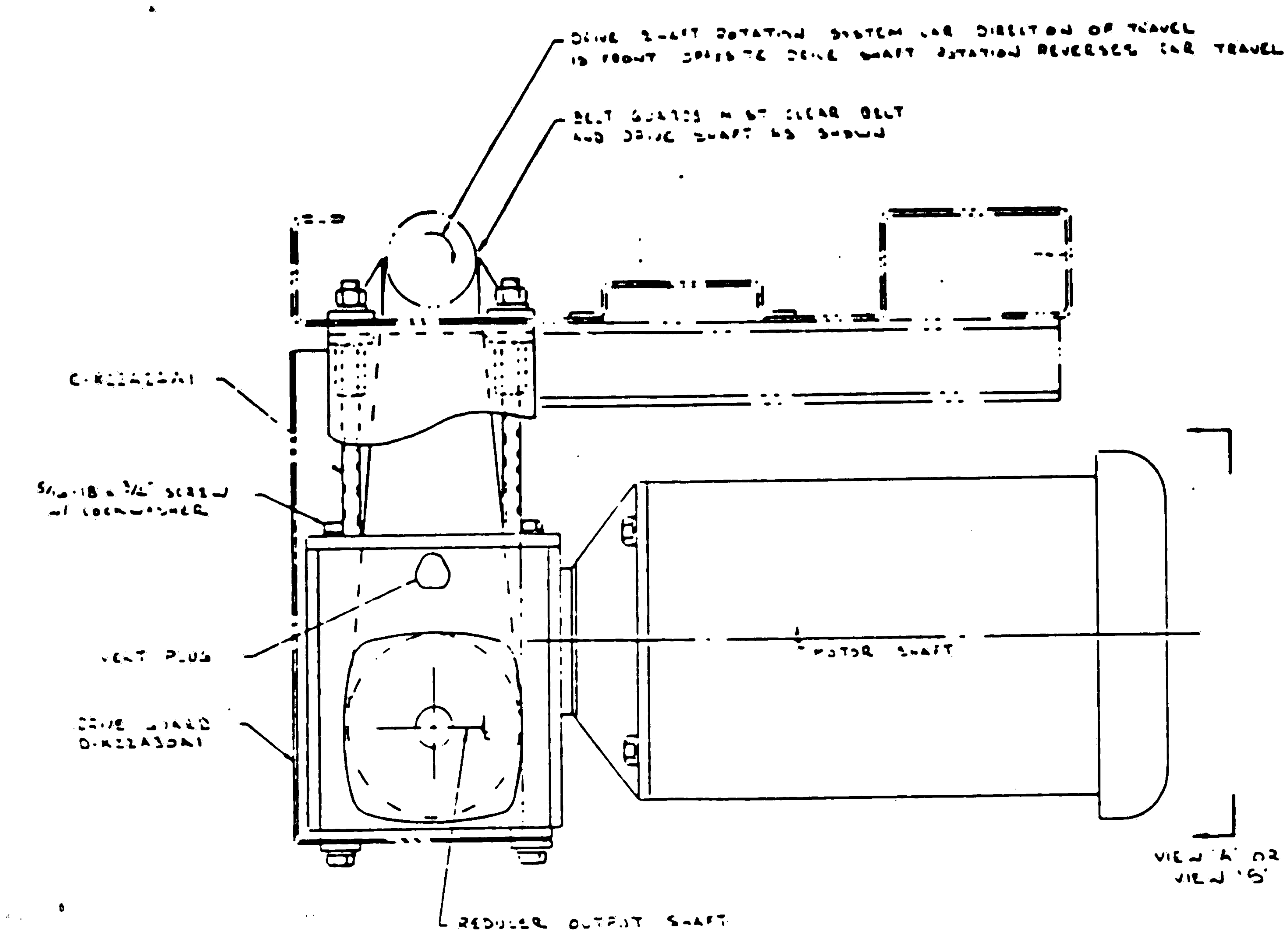

Figure 5-7: Drive assembly [11].

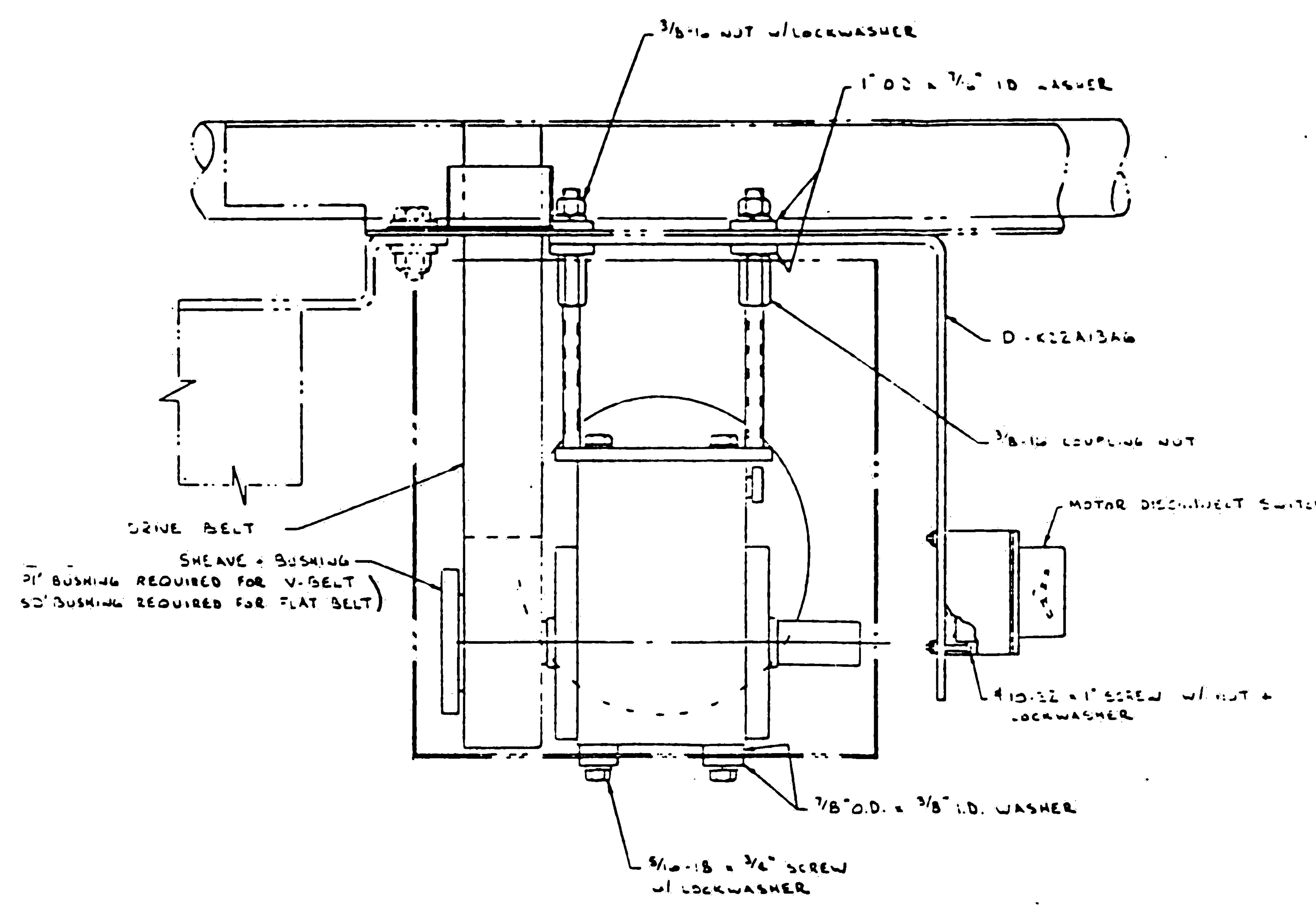

Figure 5-8: Drive and belt tensioning [11].

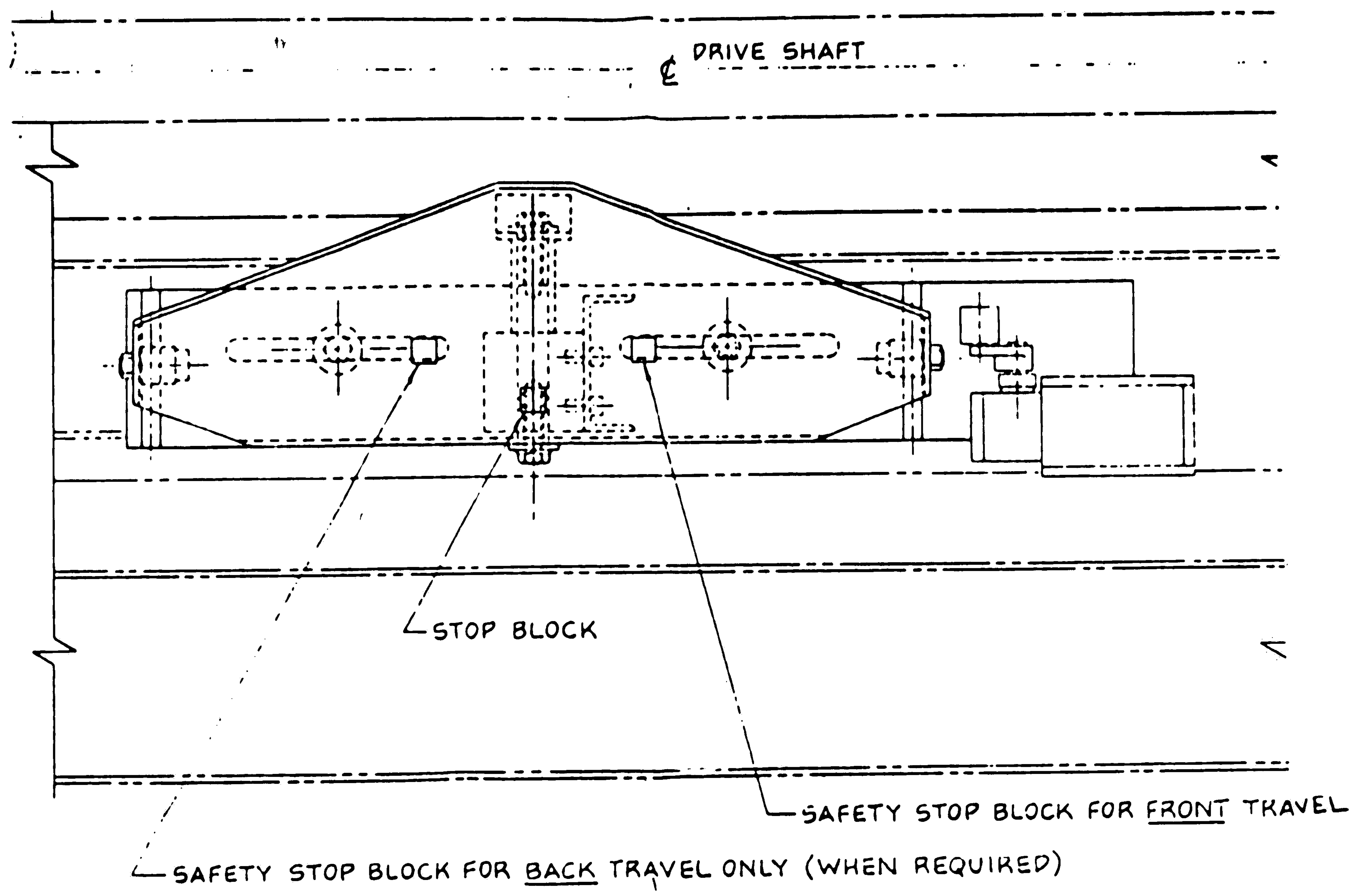

Figure 5-9: Typical queue station and limit switch [11].

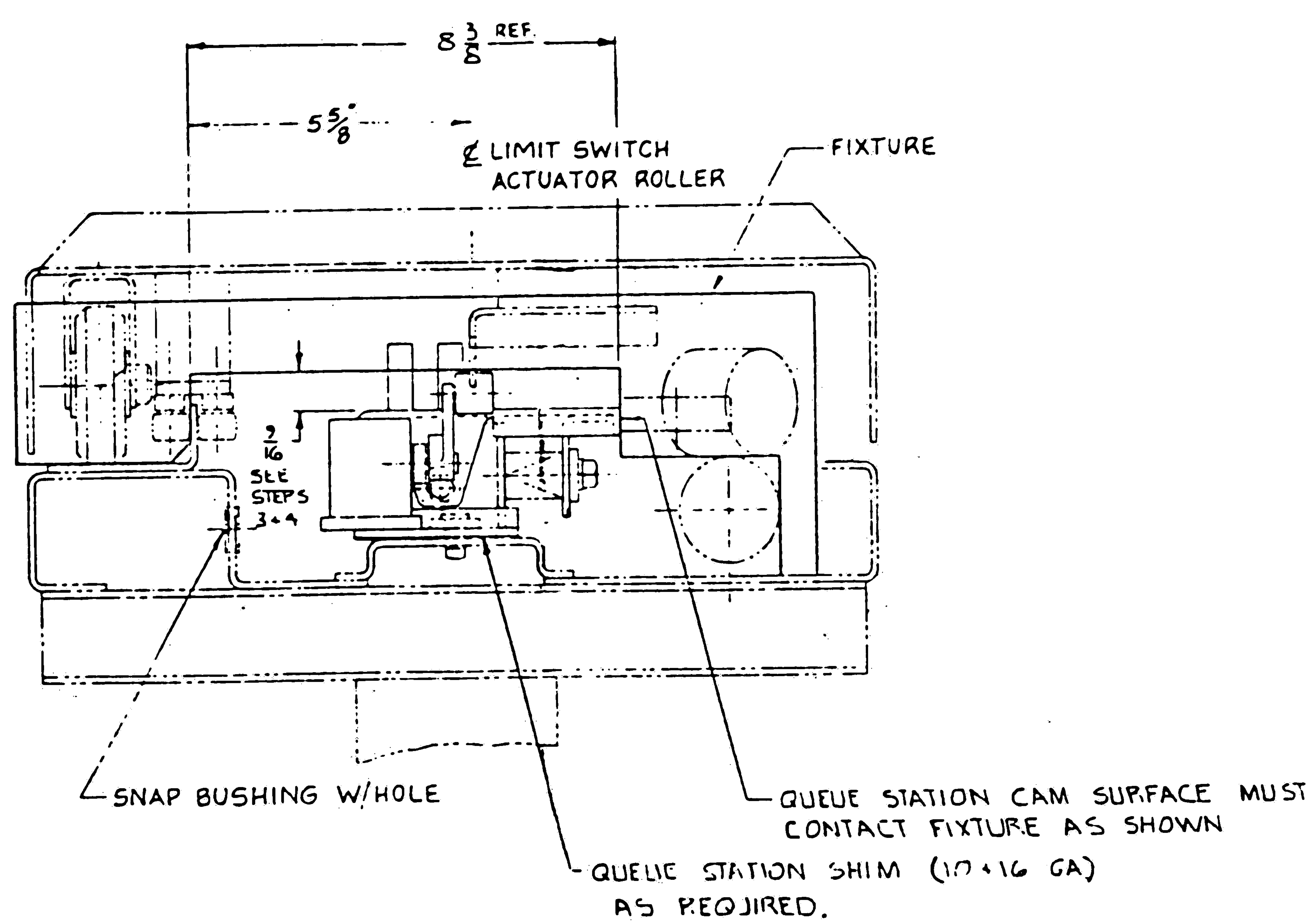

Figure 5-10: Carrier, queue station, and track joints [11].

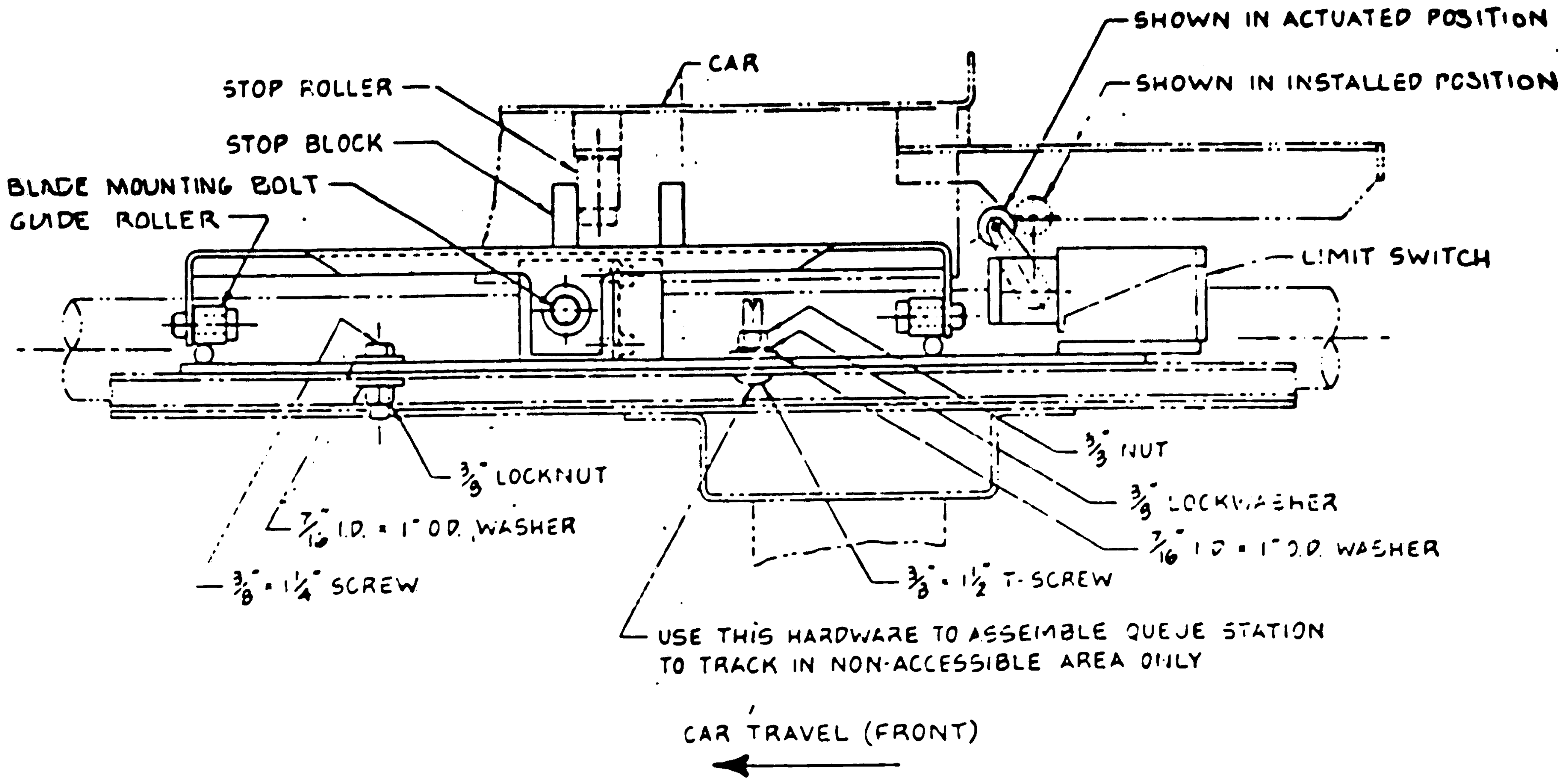

Figure 5-11: Queue station and track joint [11].

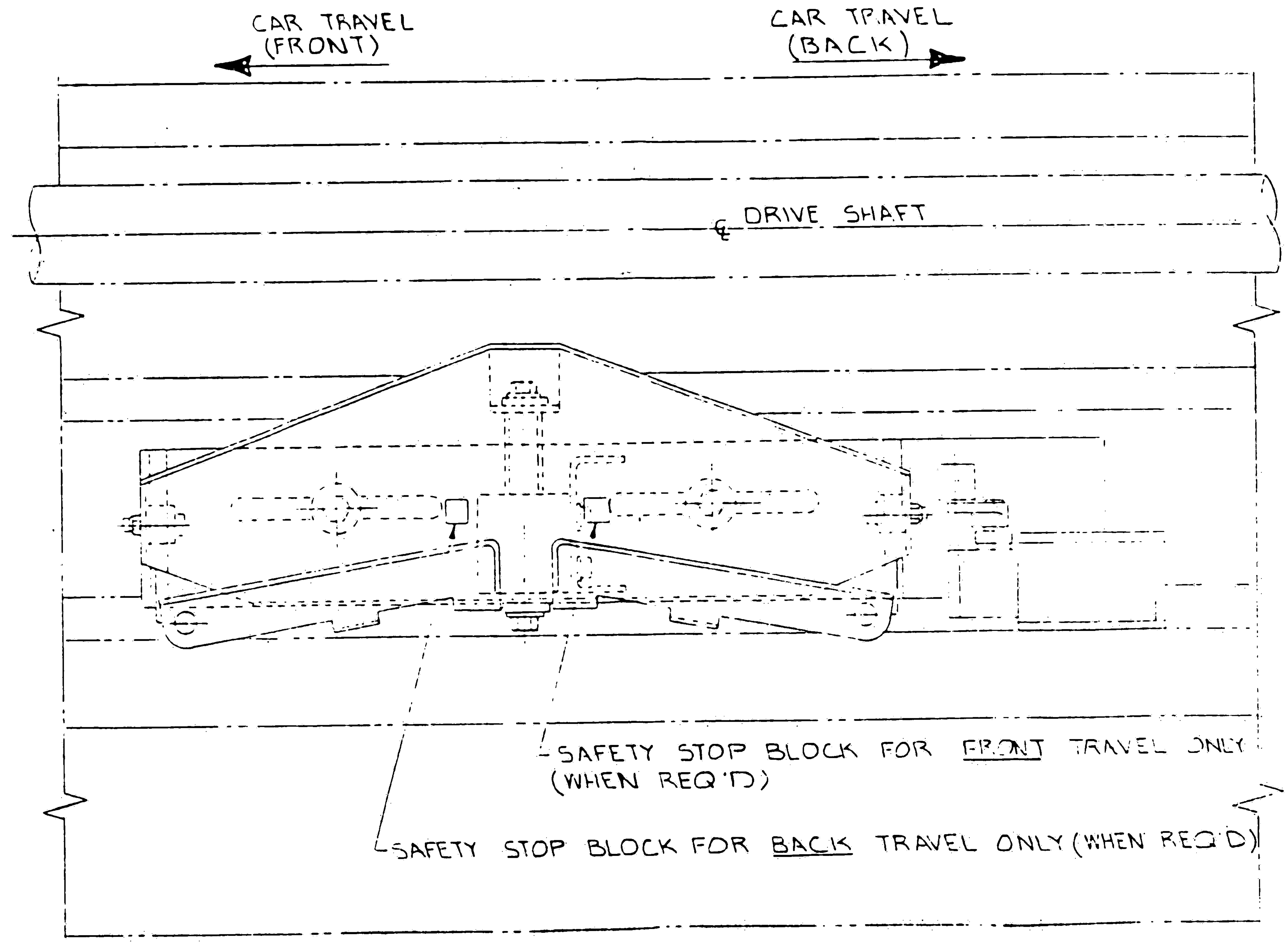

Figure 5-12: Trapping queue station [11].

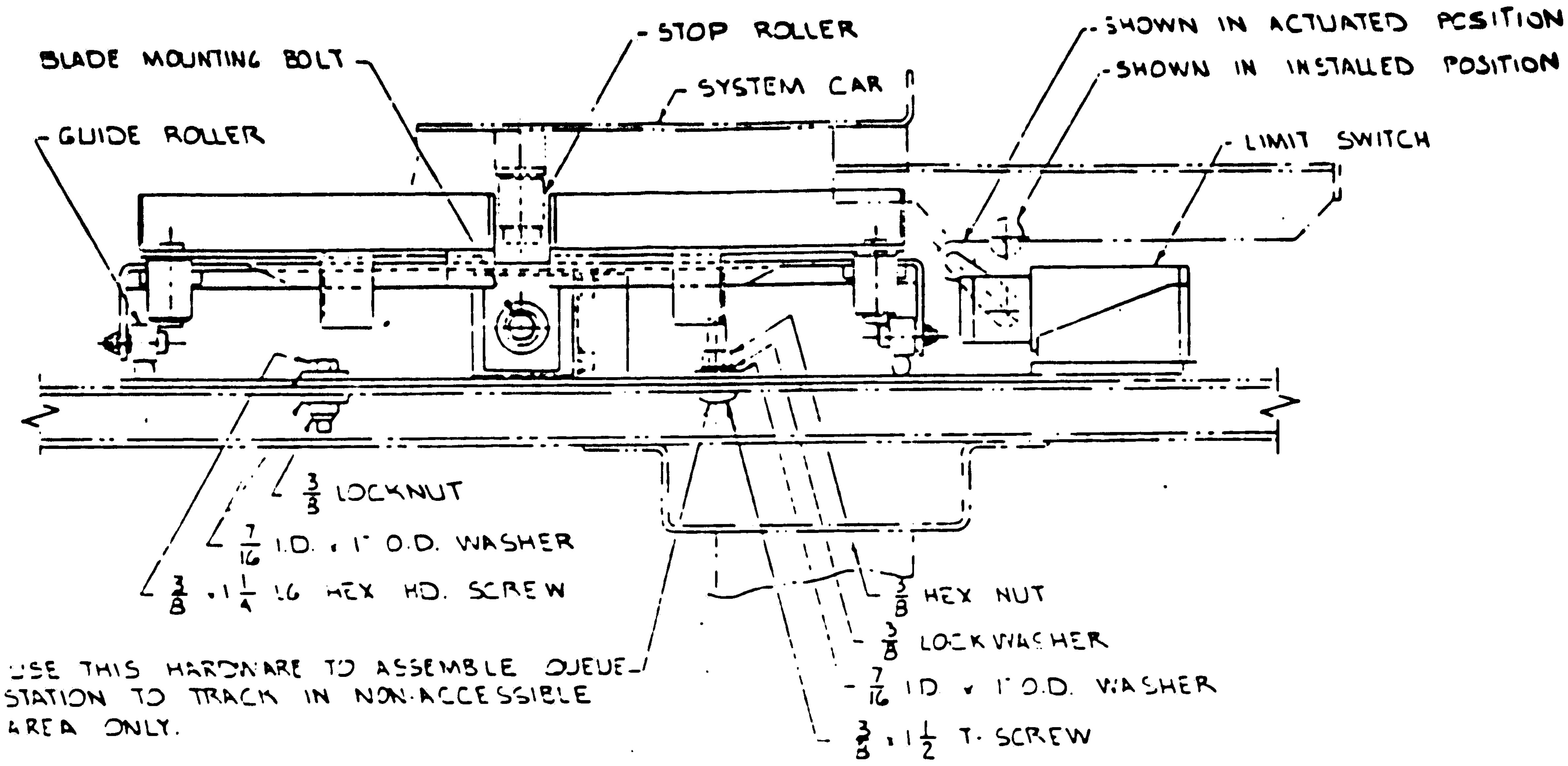

Figure 5-13: Trapping queue station and track joints [11].

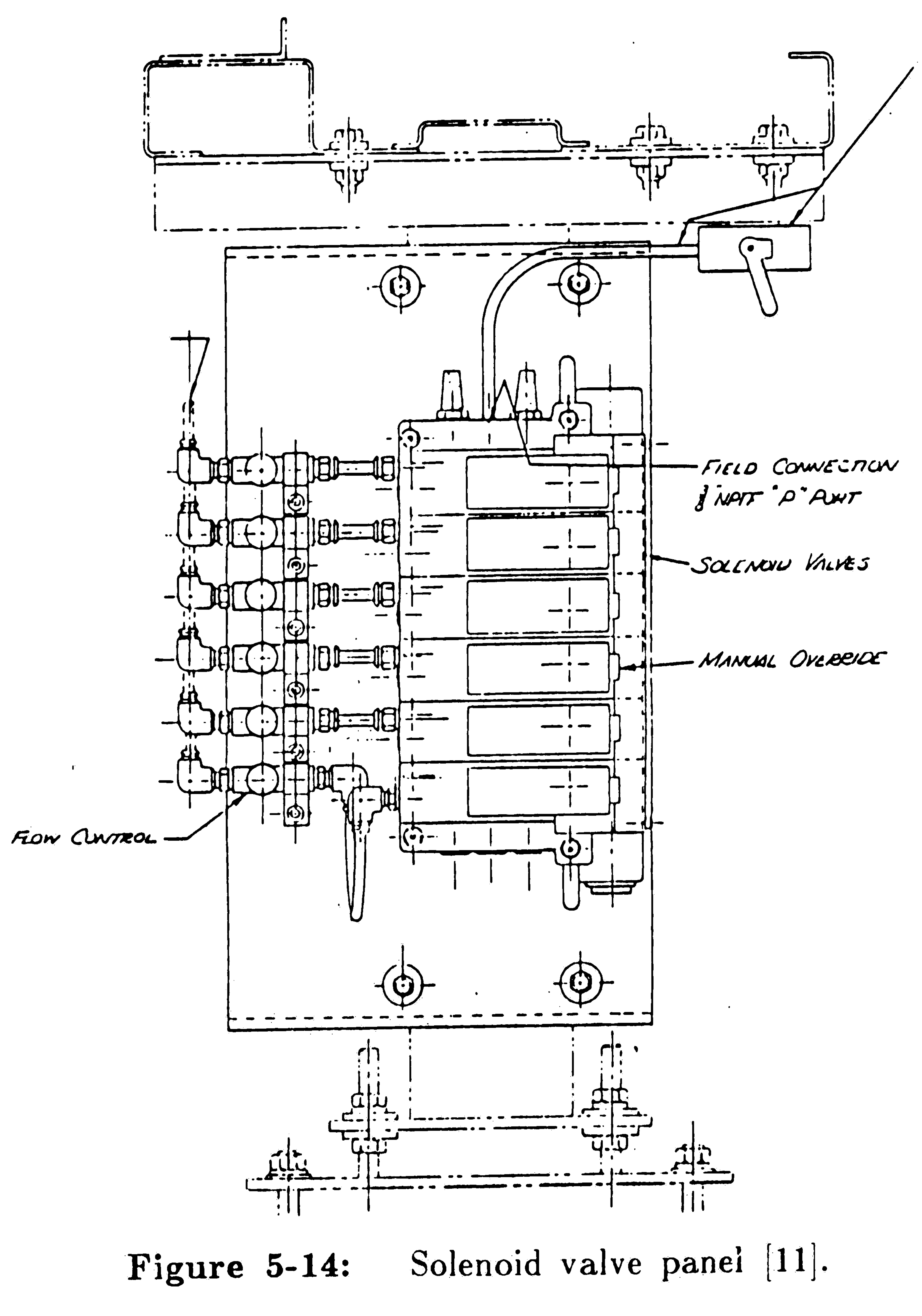

Figure 5-14: Solenoid valve panel [11].

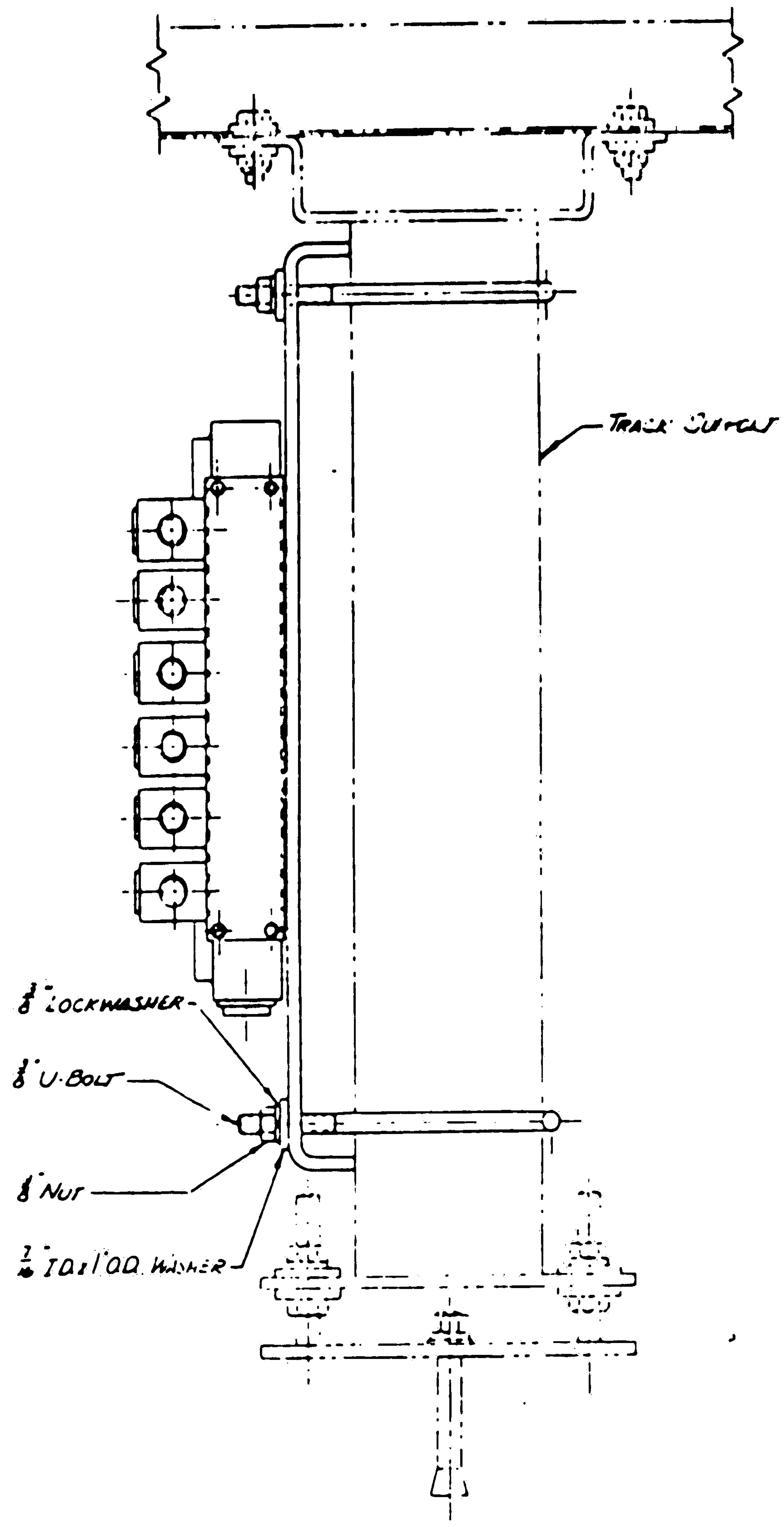

Figure 5-15: Solenoid valve panel and track support joint [11].

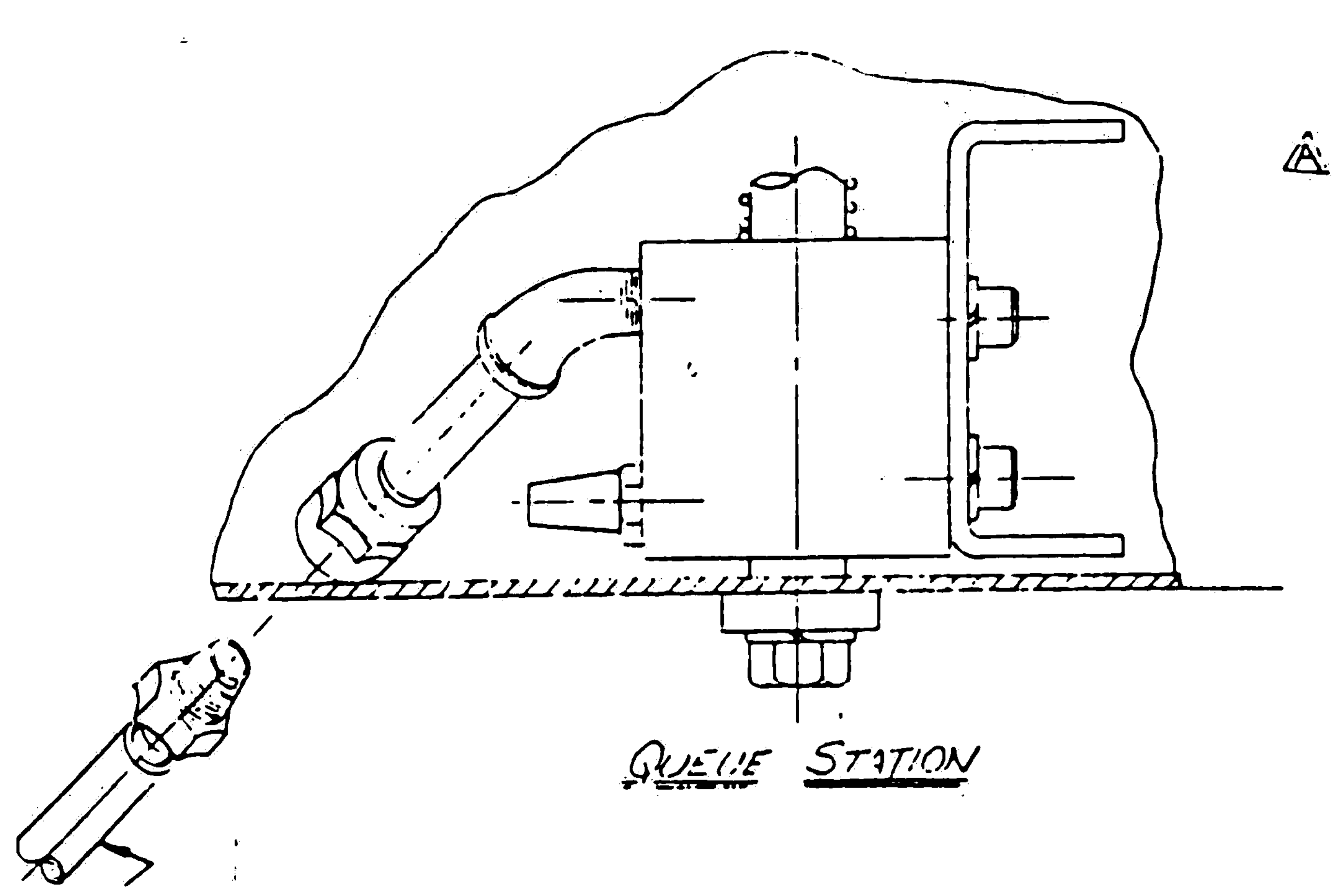

Figure 5-16: System device tubing and connectors [11].

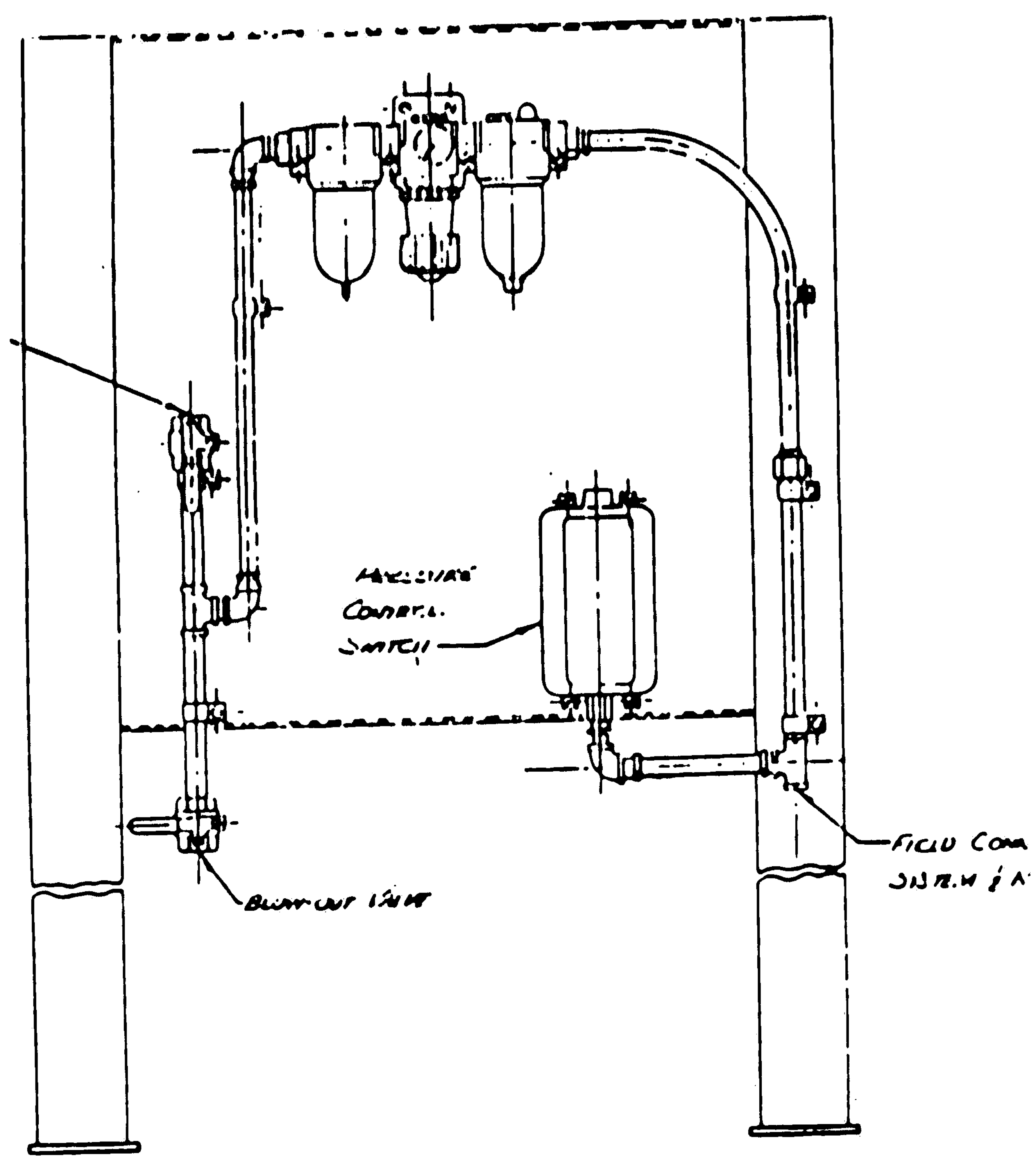

Figure 5-17: Pneumatic supply panel (F. R. L.) [11].

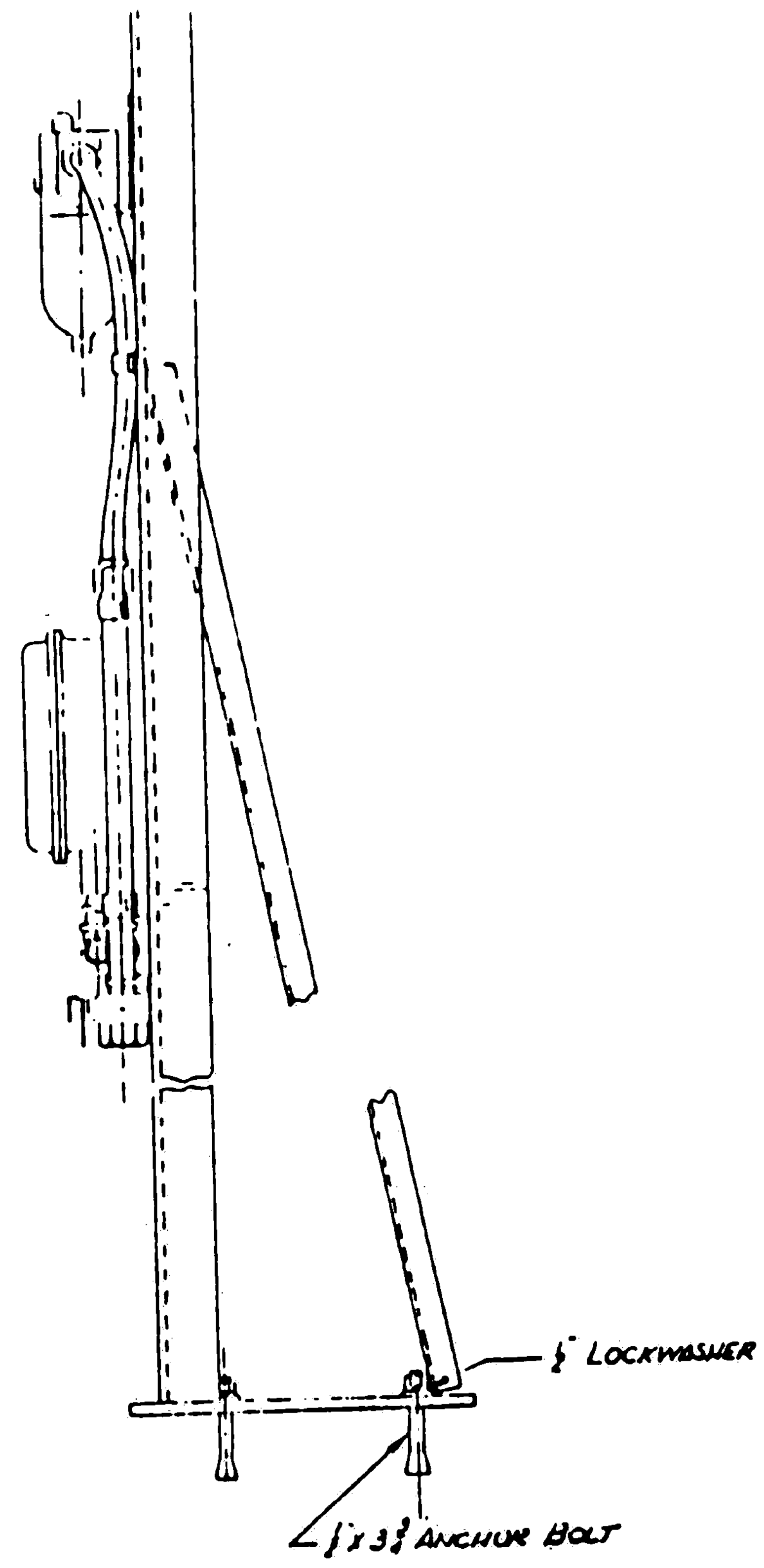

Figure 5-18: Penumatic supply panel joint [11].

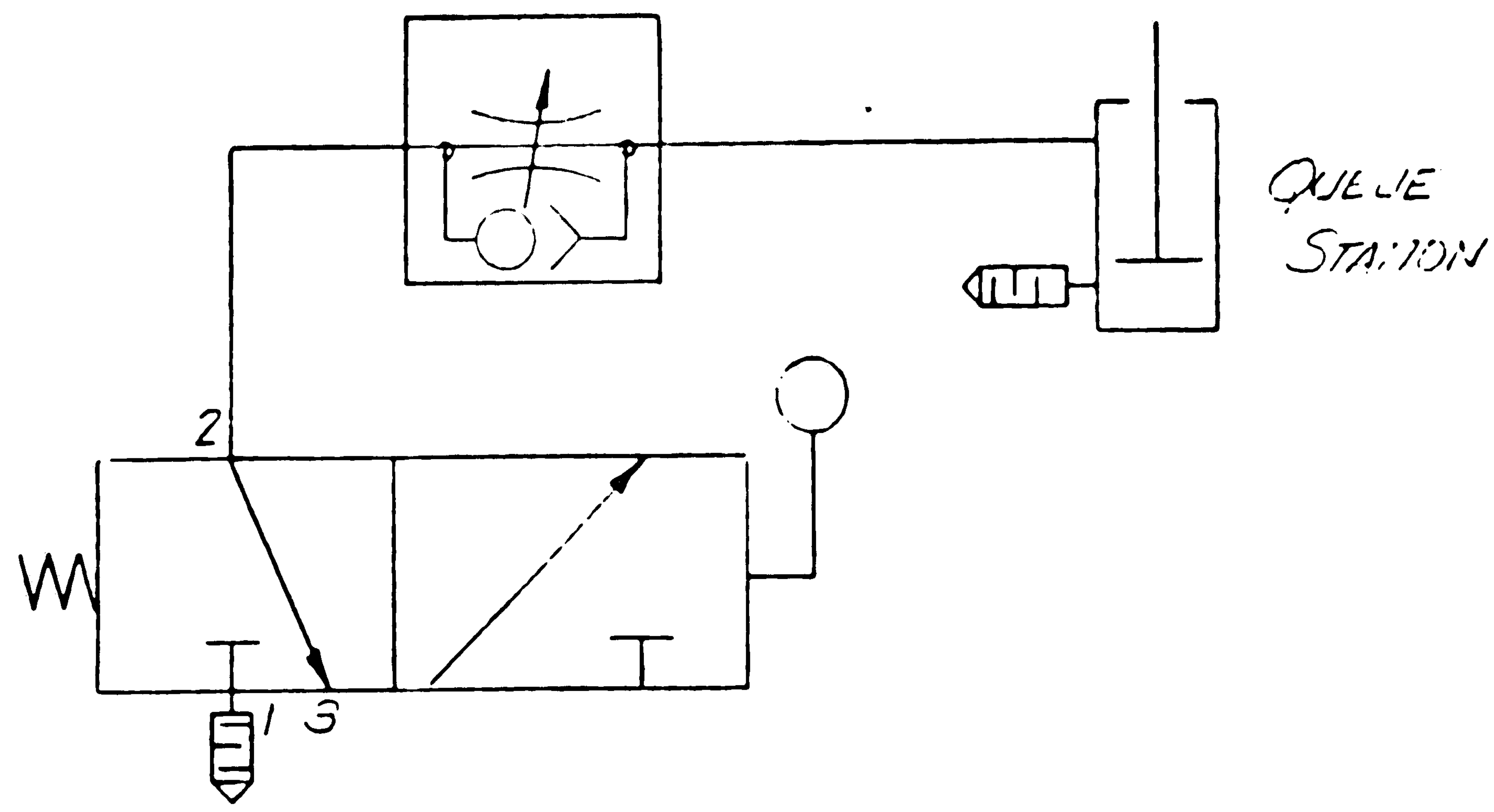

Figure 5-19: Queue station pneumatic control diagram [11].

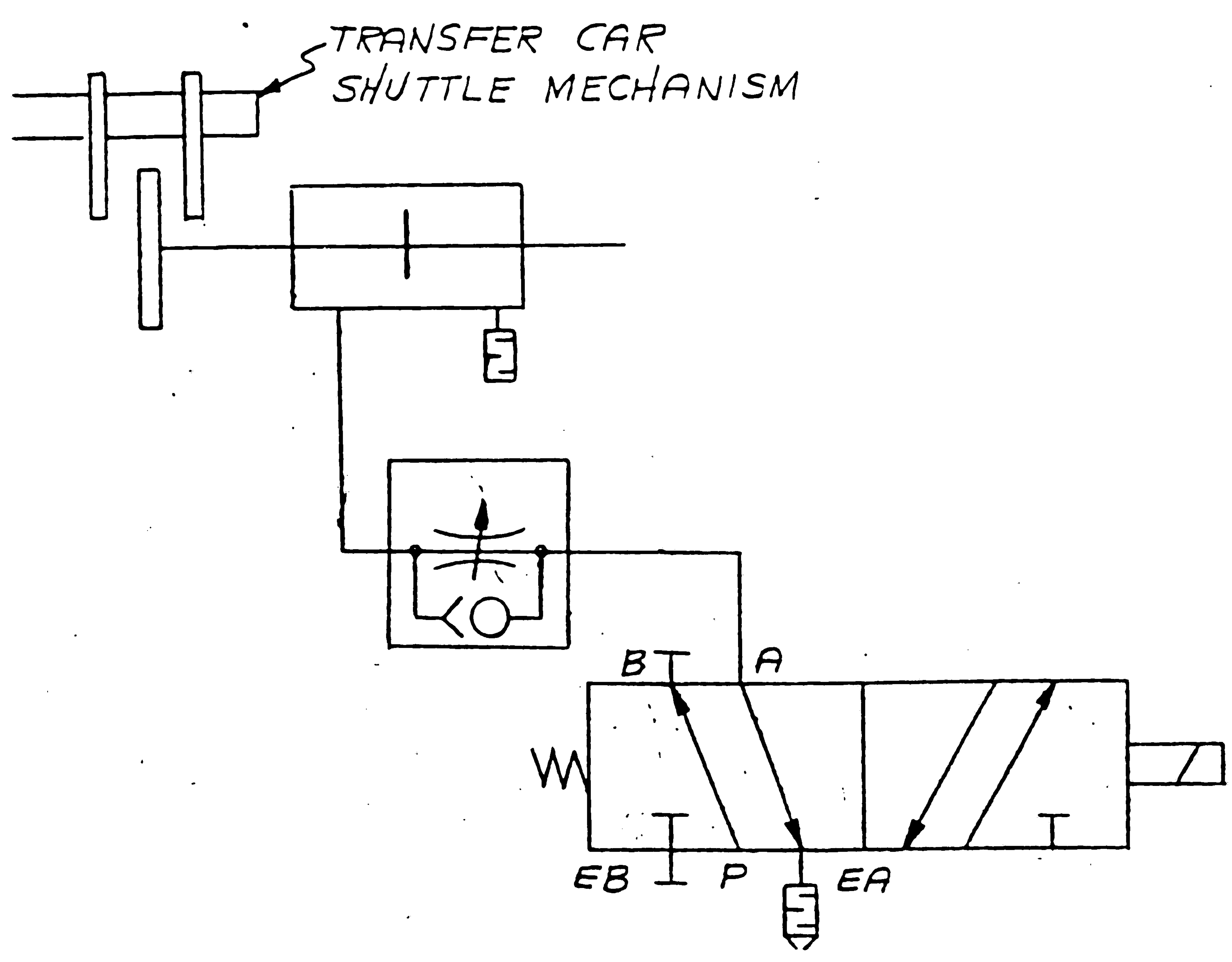

Figure 5-20: Single actuator pneumatic control diagram [11].

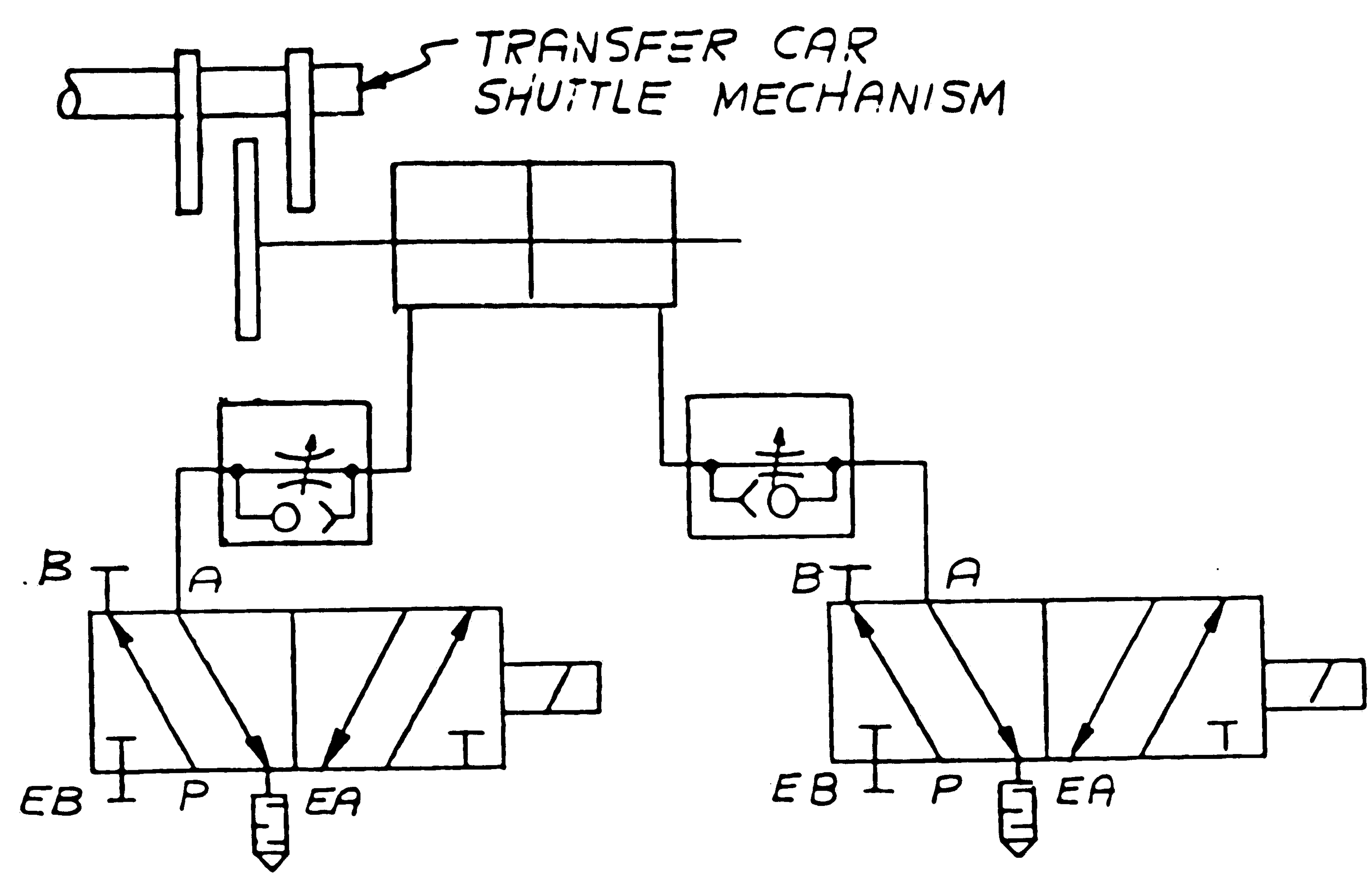

Figure 5-21: Double actuator pneumatic control diagram [11].

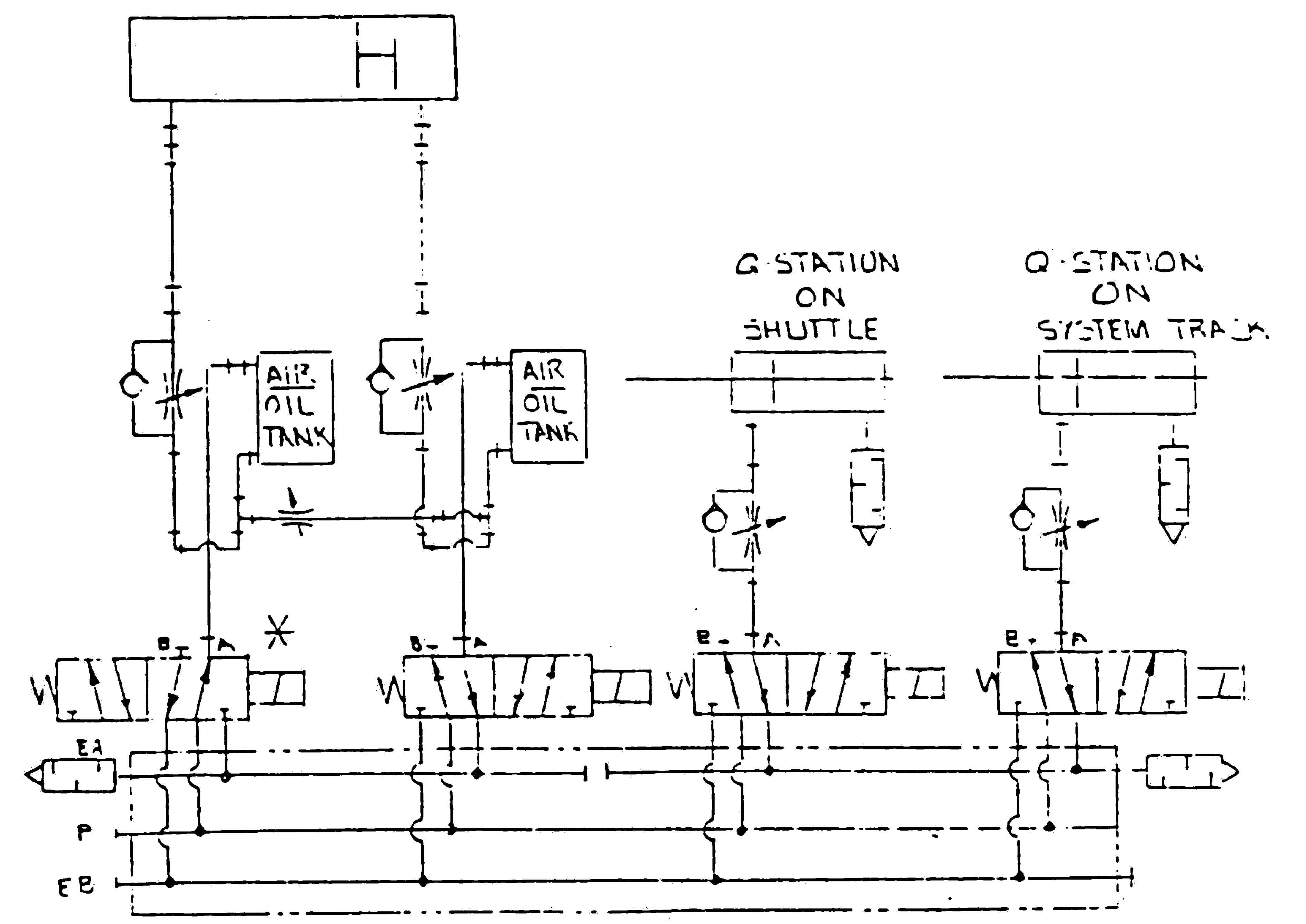

Figure 5-22: Shuttle pnuematic contol diagram [11].

5.2 Transfer Assembly and Peripheral Equipment

Transfer Cars, Photocells, and Push-Pull Buttons:

The locations of transfer assembly and the interface track are established from the system layout. The bottom of the track or surface -A- must be adjusted to the system elevation (Figure 5-23). Surface -B- and the guidance surface -C- must be maintained straight with all interface tracks. When the carrier is in position on the transfer car, the photocell should be adjusted to operate off the reflector on the carrier (Figure 5-24). Then, the tapping arm is adjusted to clear the stop on the carrier as the transfer car is pushed or pulled against the interface track (Figure 5-25).

Transfer Assembly Base Levels, Transfer Tracks, Tube Drives and Reducers, Fixed Control Bars:

The high and low points of the floor where base plates are located is defined before installing. After that, the transfer base plates are placed. Surface -A- (Figure 5-26) and surface -C- (Figure 5-27) must be in line and anchoring may begin at this time.

The drive shaft is aligned by maintaining surface -B- and -D- (Figure 5-28). The reducer output shaft is also adjusted with the transfer drive shaft by using the shims as shown in Figure 5-29. The locations of the left and right hand side fixed control bars depend on the transfer car interfacing position with the system tracks. After adjustment, they are fastened by using two screws (Figure 5-30 and Figure 5-31).

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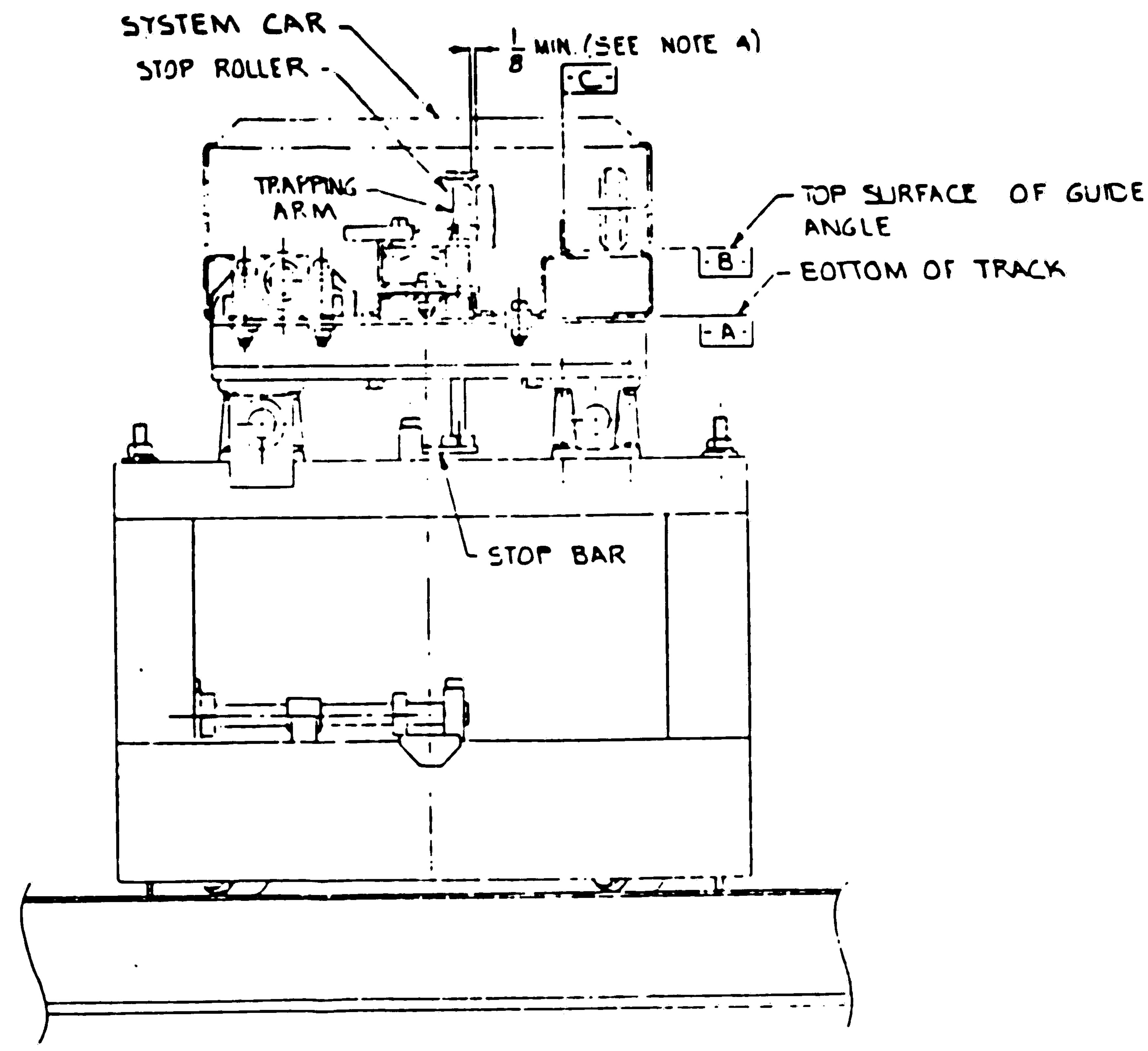

Figure 5-23: Transfer car [11].

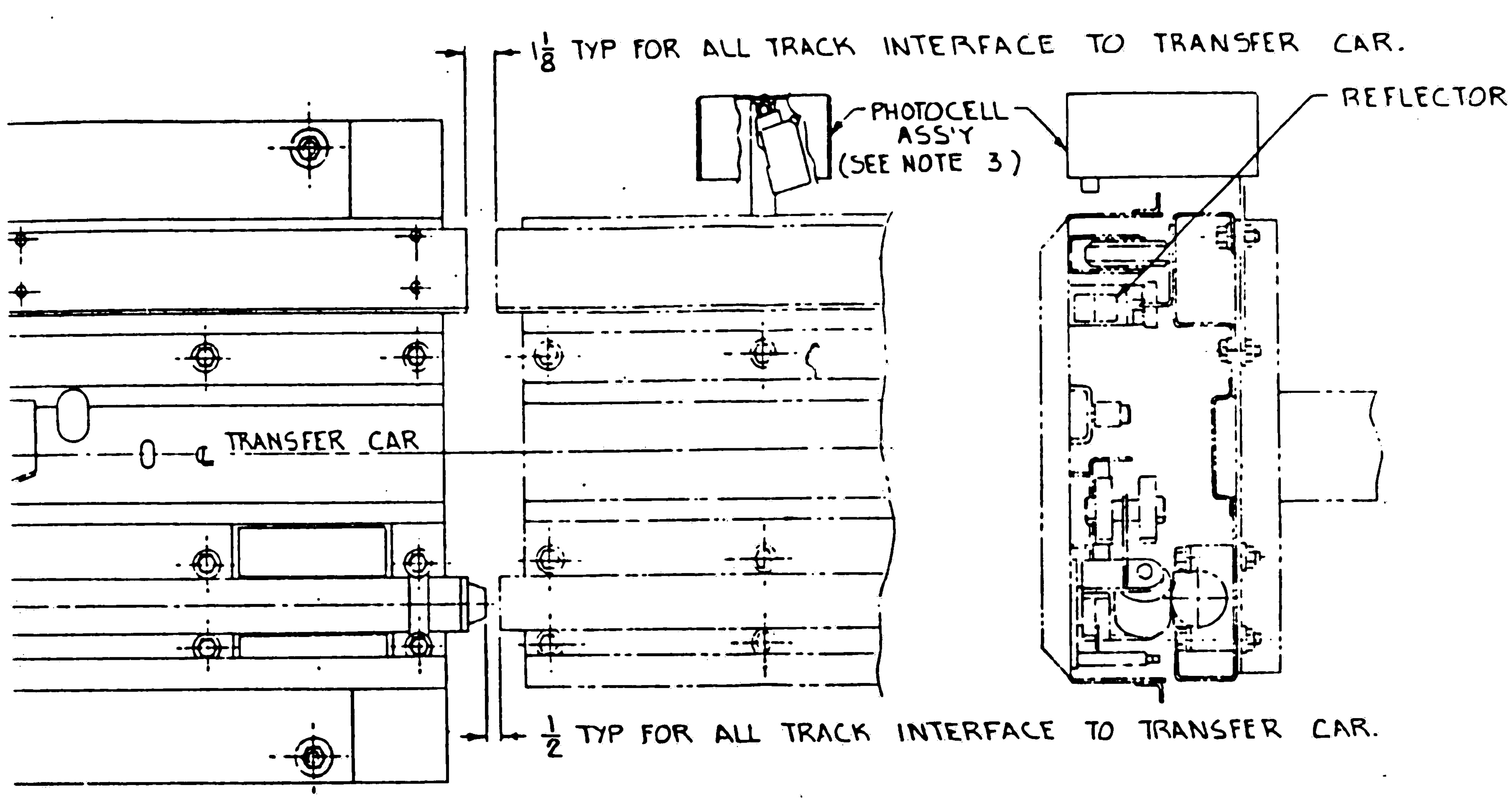

Figure 5-24: Photocell, carrier, and track joint [11].

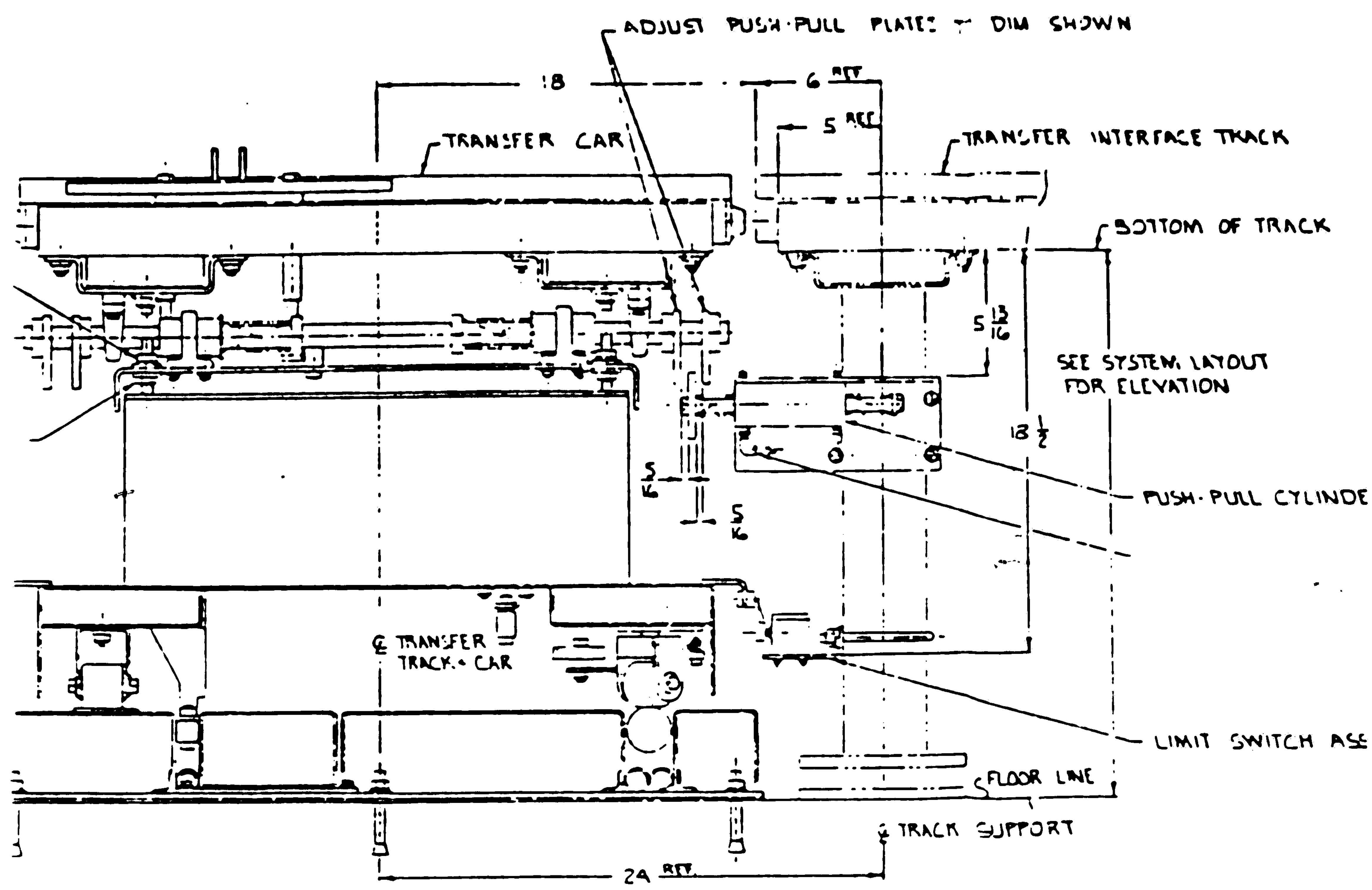

Figure 5-25: Transfer car, limit switch, actuator, and track joints [11].

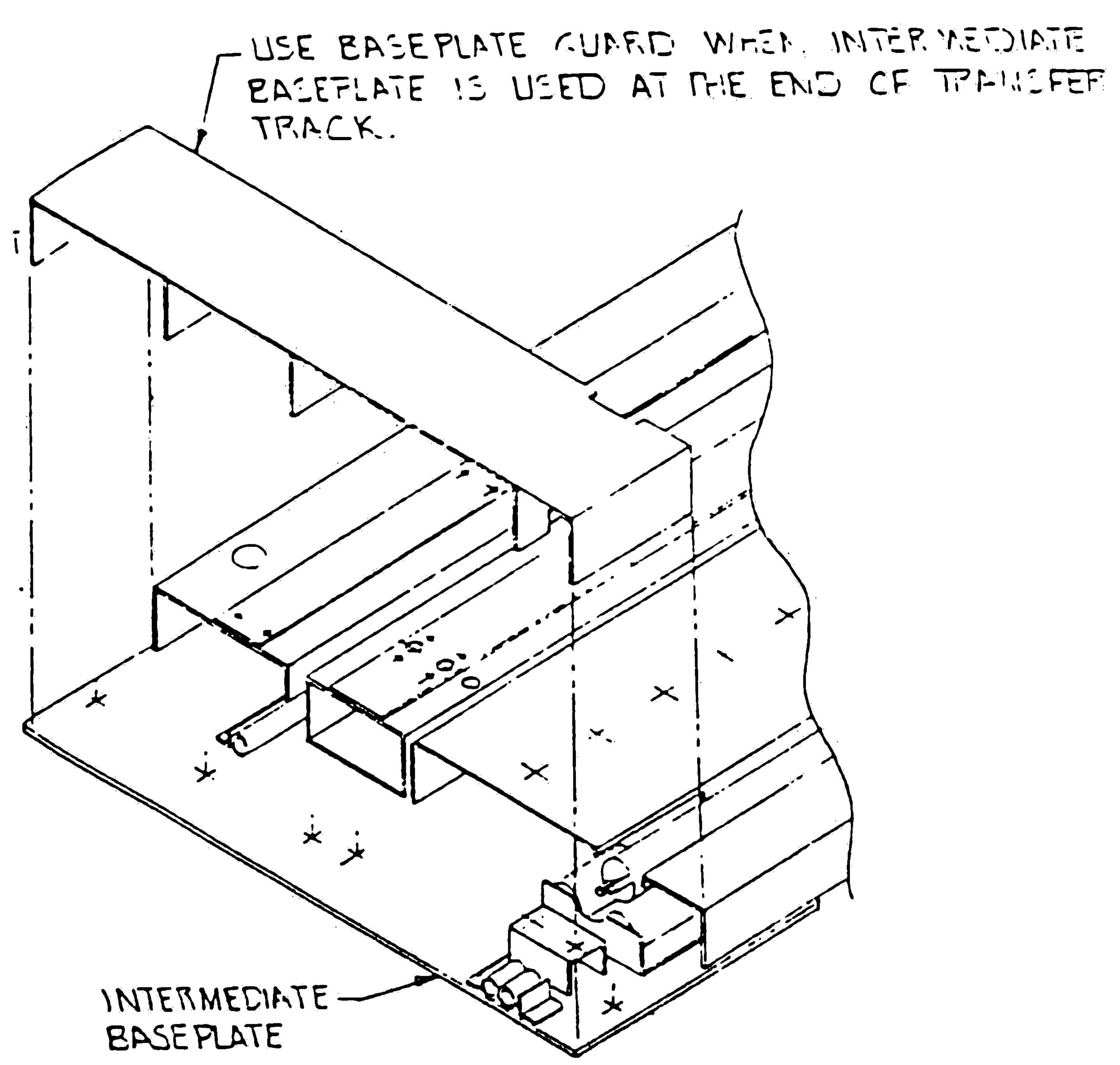

Figure 5-26: Transfer tracks and base plate [11].

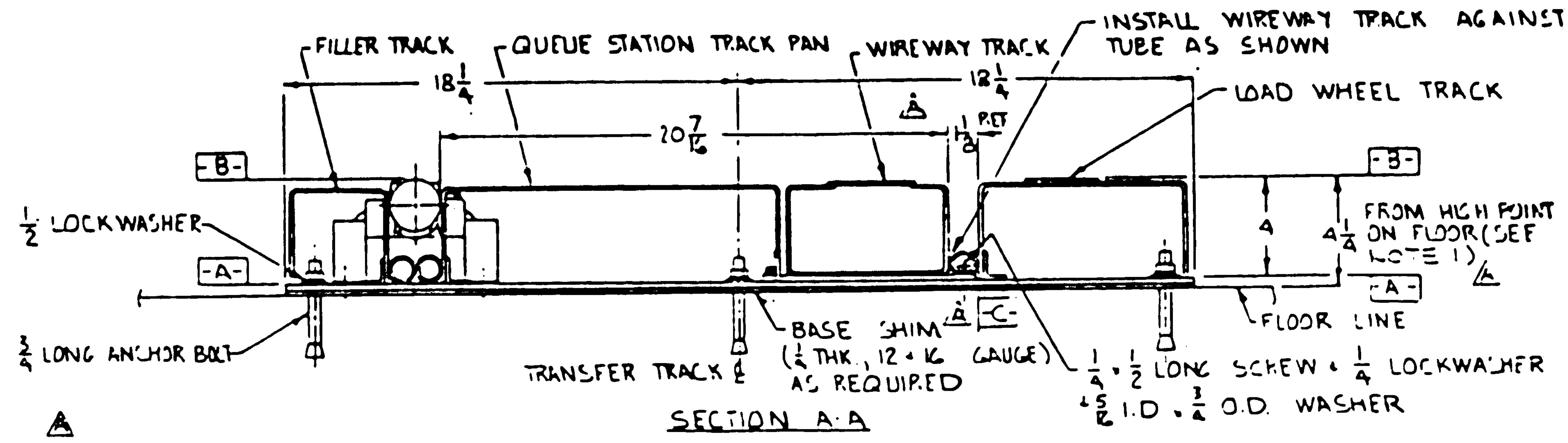

Figure 5-27: Transfer tracks and base plate joint [11].

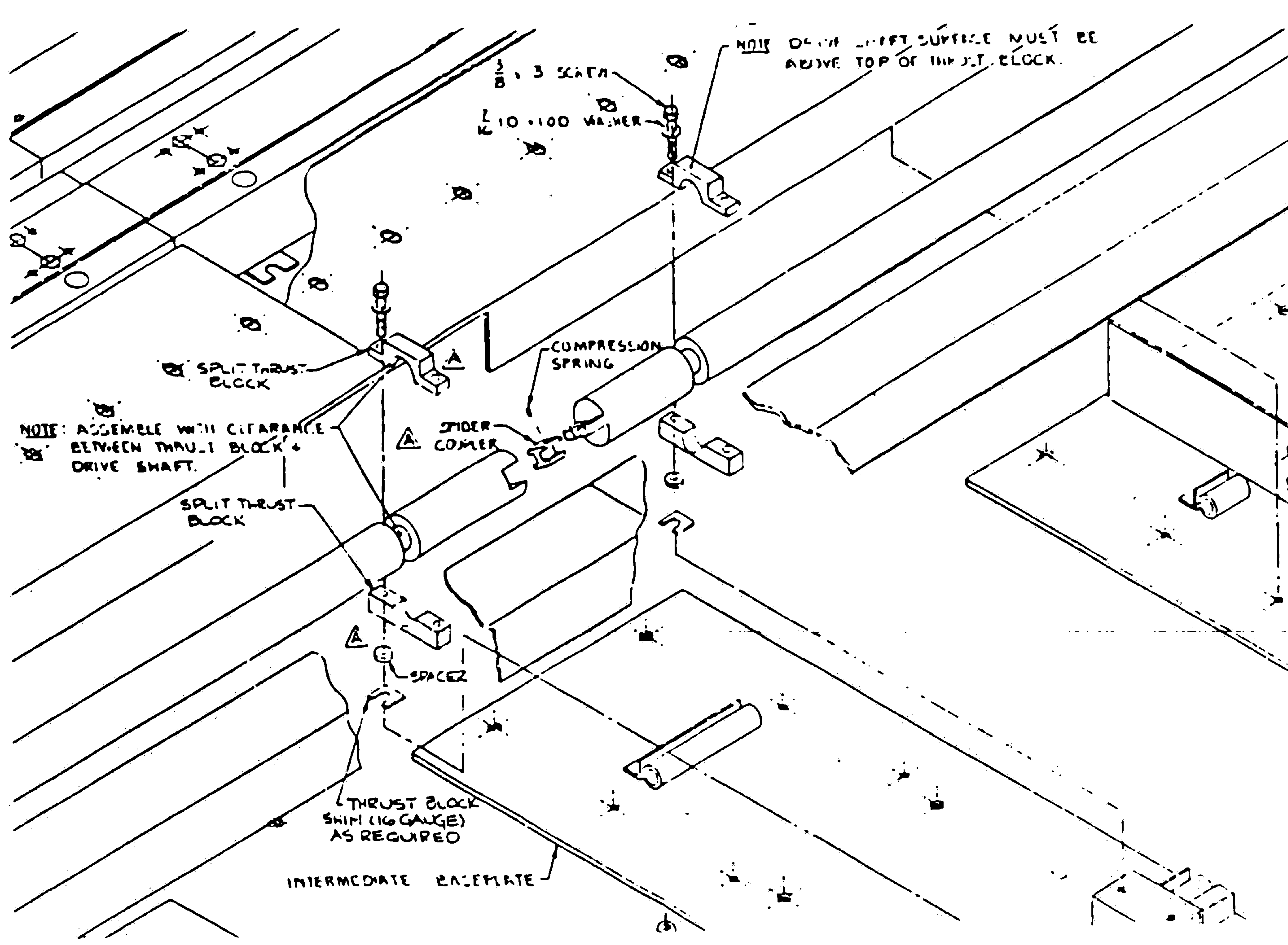

Figure 5-28: Drive tube, coupler, thrust block, and track joint [11].

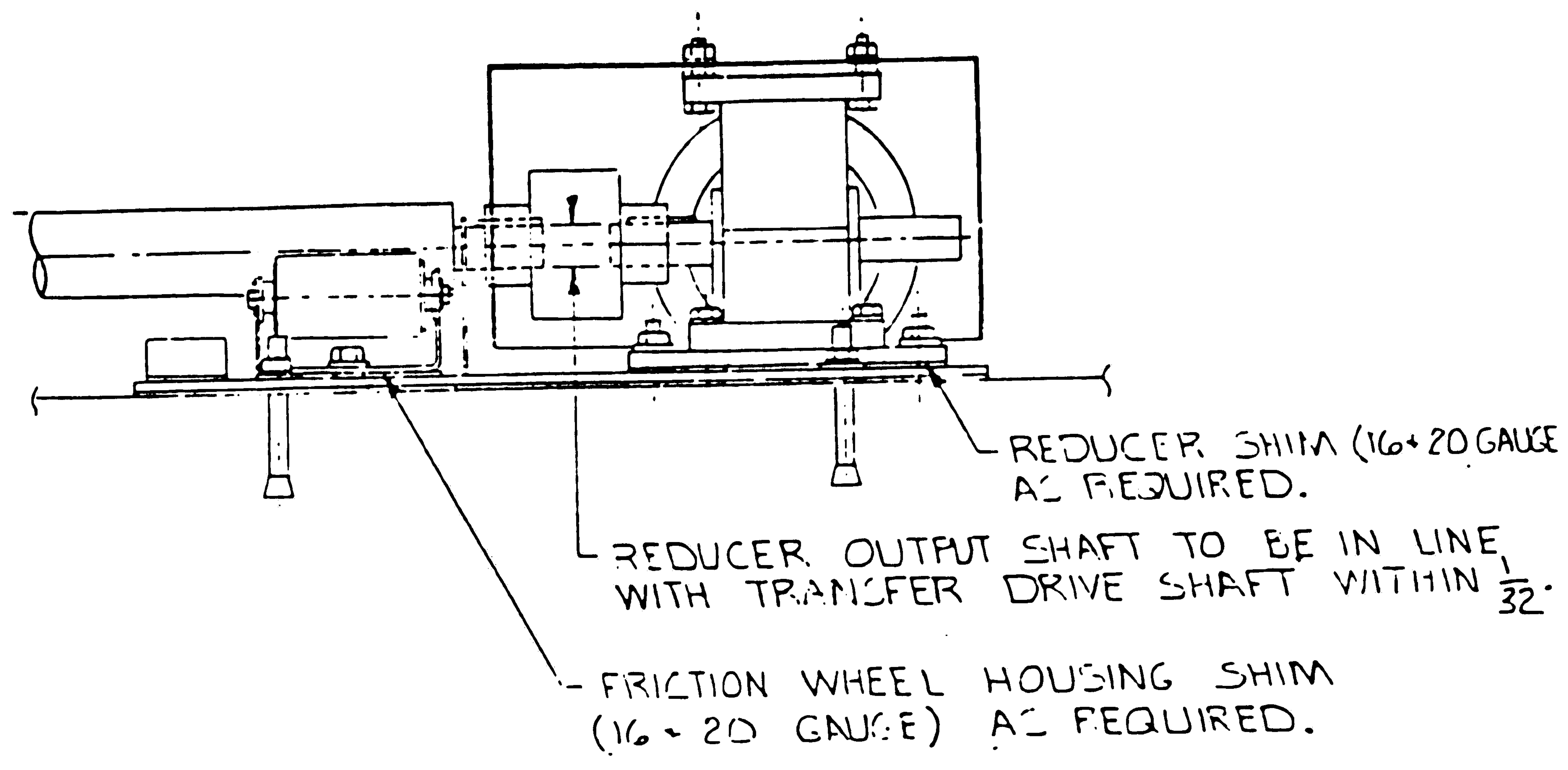

Figure 5-29: Transfer assembly drive [11].

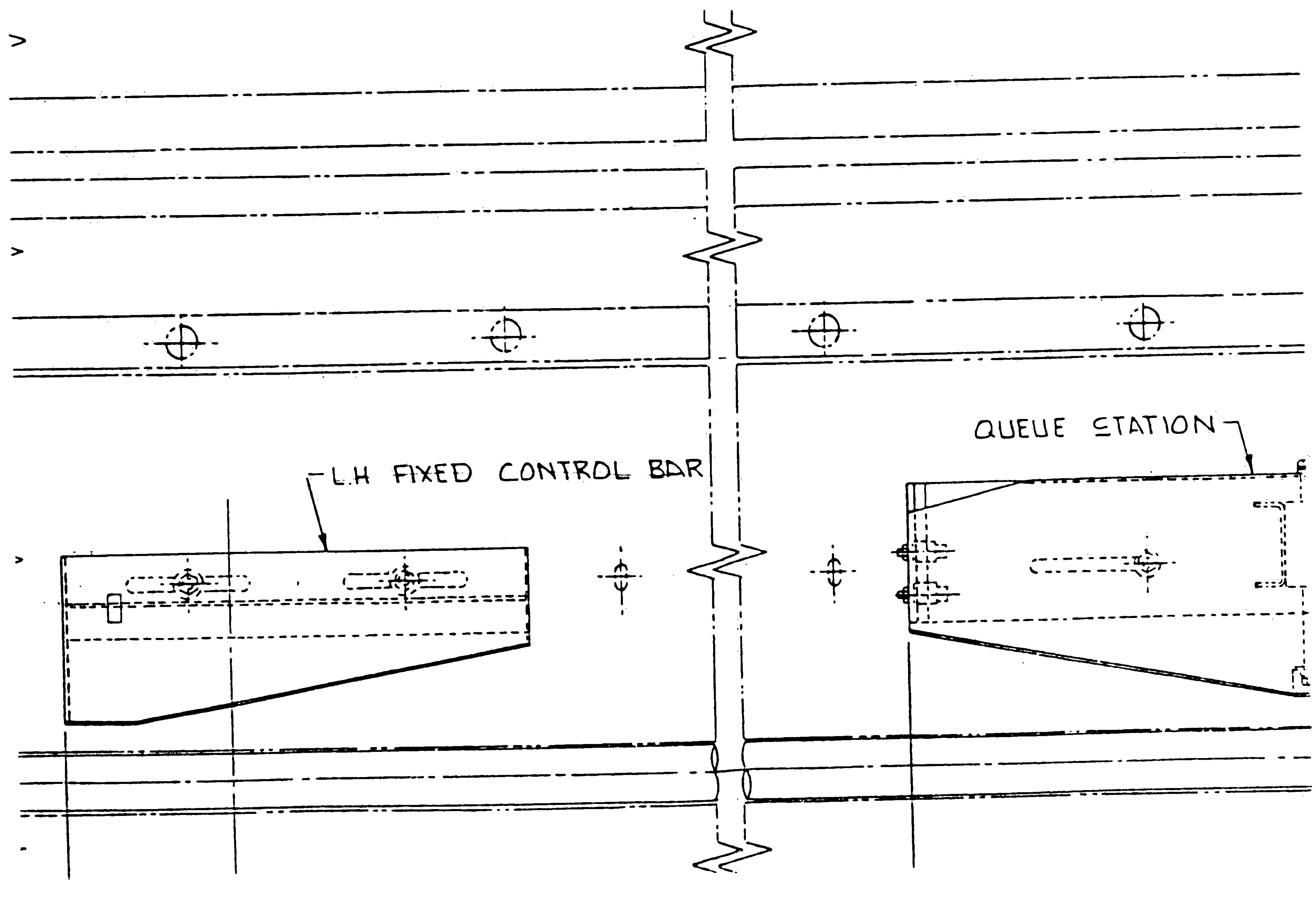

Figure 5-30: Left hand side fixed control bar and track joint [11].

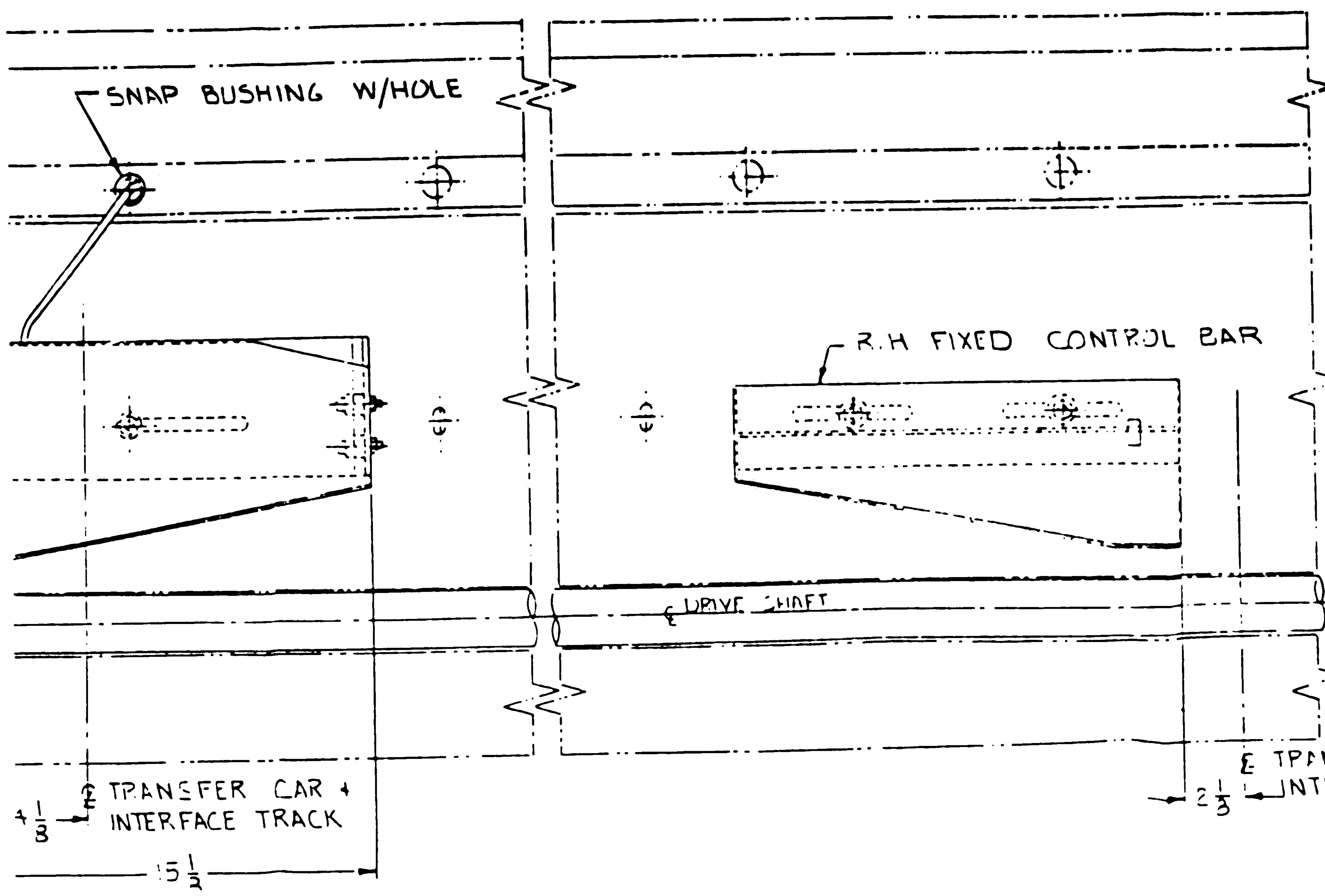

Figure 5-31: Right hand side fixed control bar and track joint [11].

5.3 Dual Shuttle and Peripheral Equipment

After determining the shuttle and interface track location from the system layout, the shuttle stop bolt may be adjusted to align the shuttle track module sides with other track modules (Figure 5-32). The top surface height of the shuttle should be equal to the height of the other track modules (Figure 5-33). Then the leveling plates must be secured to the floor with anchor bolts. The air/oil tanks are filled to proper levels at the factory. With the shuttle at the end of stroke, one tank should be full and the opposite tank should be near empty. The shuttle should not be moved manually with the flow control valves closed. This may cause a vacuum forcing oil to exhaust through the solenoid valves.

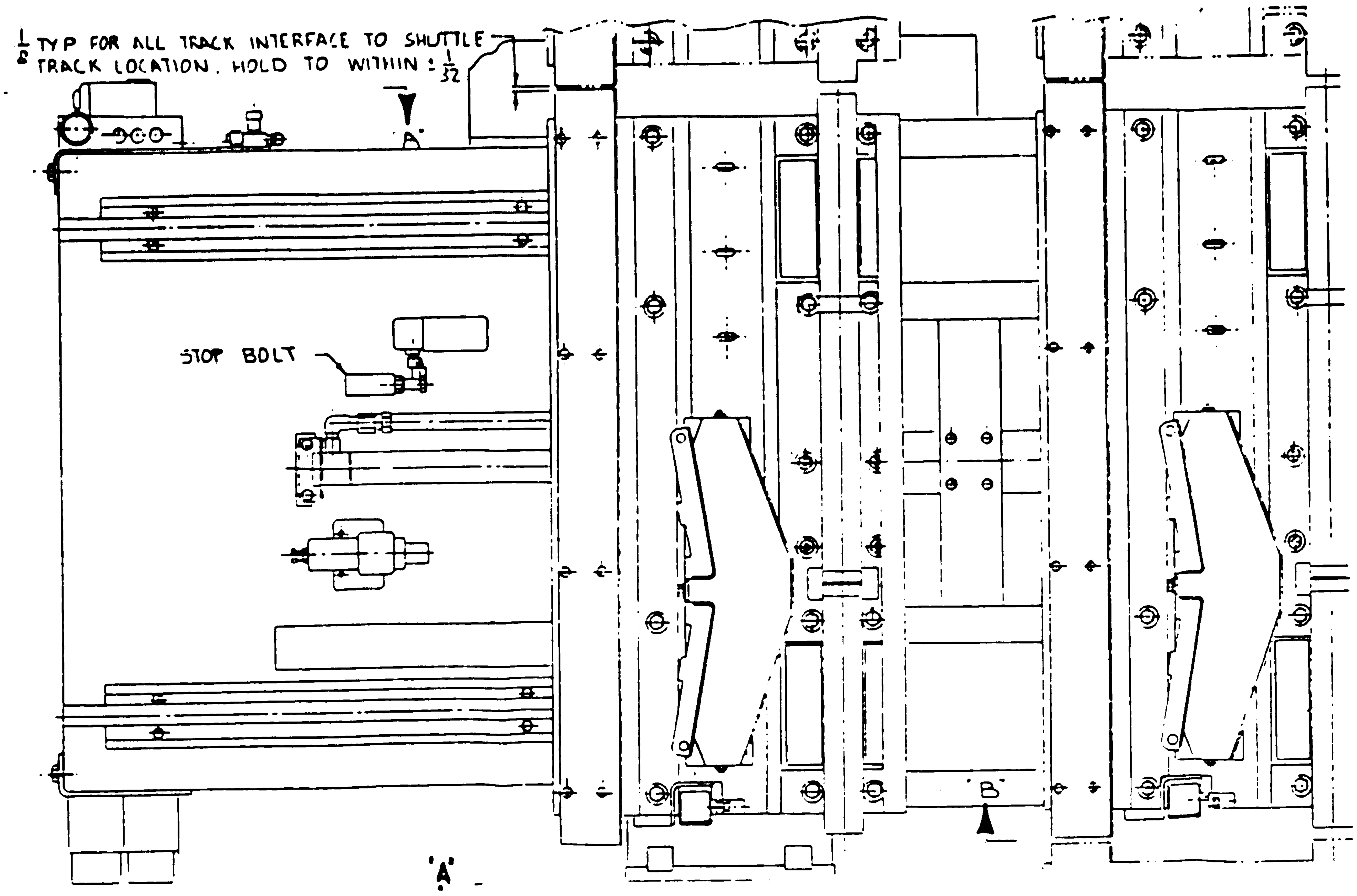

Figure 5-32: Dual shuttle interfacing with track modules [11].

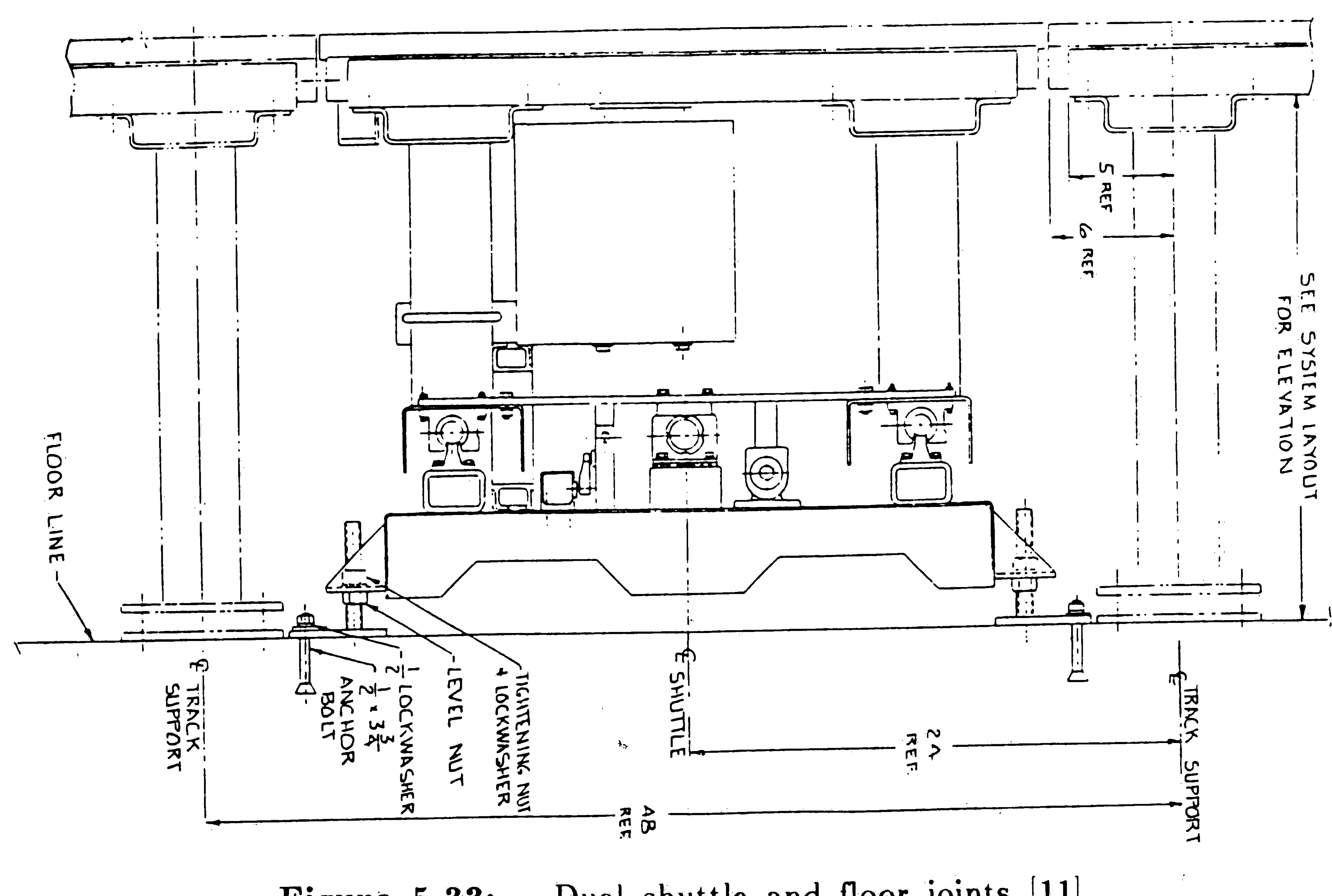

Figure 5-33: Dual shuttle and floor joints [11].

Chapter 6
System Interfacing

6.1 Interfacing with other Materials Handling Systems

Consideration was given in this thesis project to the desirability of interfacing the Mini Cartrac conveyor system with other material handling systems in the Manufacturing Technology Laboratory. The other handling systems in the lab include an automated storage and retrieval system (AS/RS), an automated guided vehicle system, and one or more industrial robots. The layout plan for the Mini Cartrac is designed to permit interfacing with these other systems. This chapter describes the issues and plans relative to system interfacing.

6.1.1 AS/RS

An AS/RS can be defined to be "a combination of equipment and controls which handles, stores, and retrieves materials with precision, accuracy, and speed under a defined degree of automation" [5]. Such systems range from relatively simple manually controlled order picking machines operating in small storage structures to relatively complex, computer-controlled storage/retrievel (S/R) systems that are totally integrated into the manufacturing and distribution process.

An automated storage and retrieval system was donated to the Manufacturing Technology Laboratory by SI Handling Systems as part of its matching contribution to a Ben Franklin project at Lehigh. The AS/RS is approximately 32 ft. 6 in. long, 7 ft. 1/2 in. wide and 16 ft. 5 in. high. It consists of a single aisle with storage racks on both sides of the aisle. The length of the AS/RS is divided into eight sections (four sections on each side of the aisle), only four of which contain storage shelves (two sections on each side). These storage sections are located at either end of the AS/RS, thus leaving the middle sections empty of shelves. There are 15 storage shelves vertically in each of the four sections, thus providing a total of 60 storage compartments in the AS/RS. Each storage compartment can accommadate one tote pan or pallet fixture. A double masted storage/retrieval (S/R) machine is used to perform the storage and retrieval transactions.

The operation of the system is typical of an AS/RS: the S/R machine is controlled to move horizontally and vertically to position its extraction mechanism at any of the storage compartments. When positioned, the extraction mechanism pulls the tote pan (or pallet) from the compartment in the case of a retrieval transaction, or pushes the tote pan into the compartment in the case of a storage transaction.

To interface with the Mini Cartrac conveyor, the S/R machine positions its extraction mechanism at a location near the middle of the storage racks (in one of the empty sections of the AS/RS) corresponding to the position of the loading and unloading station of the Mini Cartrac. A specially designed transfer mechanism will be used to move the tote pan between the AS/RS and the conveyor cart.

6.1.2 AGVS Docking

An AGVS can be defined as follows [5]: "An automated guided vehicle system is a materials handling system that uses independently operated, self-propelled vehicles that are guided along defined pathways in the floor. The vehicles are powered by means of on-board batteries that allow operation for several hours (eight to 16 hours is typical) between recharging. The definition of the pathways is generally accomplished using wires imbedded in the floor or reflective paint on the floor surface. Guidance is achieved by sensors on the vehicles that can follow the guide wires or paint."

Since the AGV in the laboratory is a unit load carrier, it may be equipped for automatic loading and unloading by means of powered rollers, moving belts, mechanized lift platforms or other devices. In our case, the unit load carrier could be equipped with a Cartrac module section that contains a trapping queue station, limit switch, drive tube, and drive motor. The location for interfacing might be next to the transfer assembly, and in front of the AS/RS. It would work in conjunction with the transfer car that transports the carrier from the Cartrac system to the AGVS (Figure 6-1). Basically, the operation is as follows:

As soon as the AGV-unit load carrier gets the predetermined destination point, it tells an activation device that it is ready to be loaded. When the transfer car is in position with the Cartrac track module which is one of the main track lines of the loop and the AGV-unit load carrier, a double actuator pulls the transfer car toward the track module and the queue station lets the Cartrac carrier move forward. Then, the carrier approaches the transfer assembly and its wheels move onto the adjacent track rails of the transfer car and a queue station stops the carrier's motion. At this time, the transfer car waits to be pushed toward the AGV via a double actuator which is activated by the carrier presence. After being pushed, the queue station control bar is pivoted and the carrier accelerates forward. As the carrier gets the AGV on which a trapping queue station stops the carrier's motion precisely and a limit switch senses that the loading operation has been completed and allows the AGV to move to its next predetermined destination point. The unloading operation is the reverse of the procedure described above.

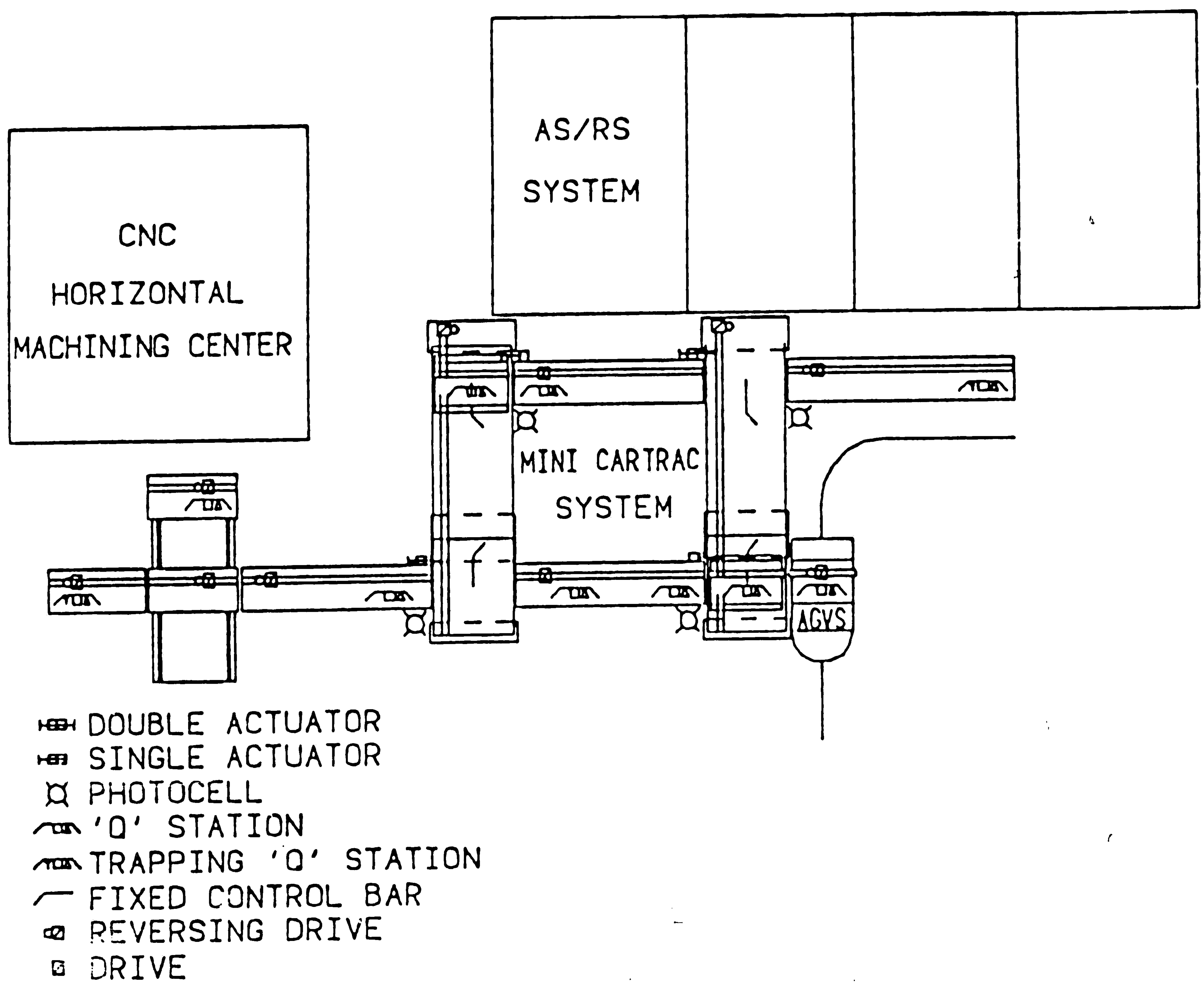

Figure 6-1: AGVS-Docking.

6.2 Interfacing with Robot or other Work Stations

6.2.1 Robots

As we mentioned in earlier sections, a Cincinnati Milacron T^3 robot coordinates between the CNC turning center and the Cartrac system in transferring materials. Another possible use of a robot is in front of the loop, between transfer assemblies (Figure 6-2). The operation done by that robot could be one of the following manufacturing operations.

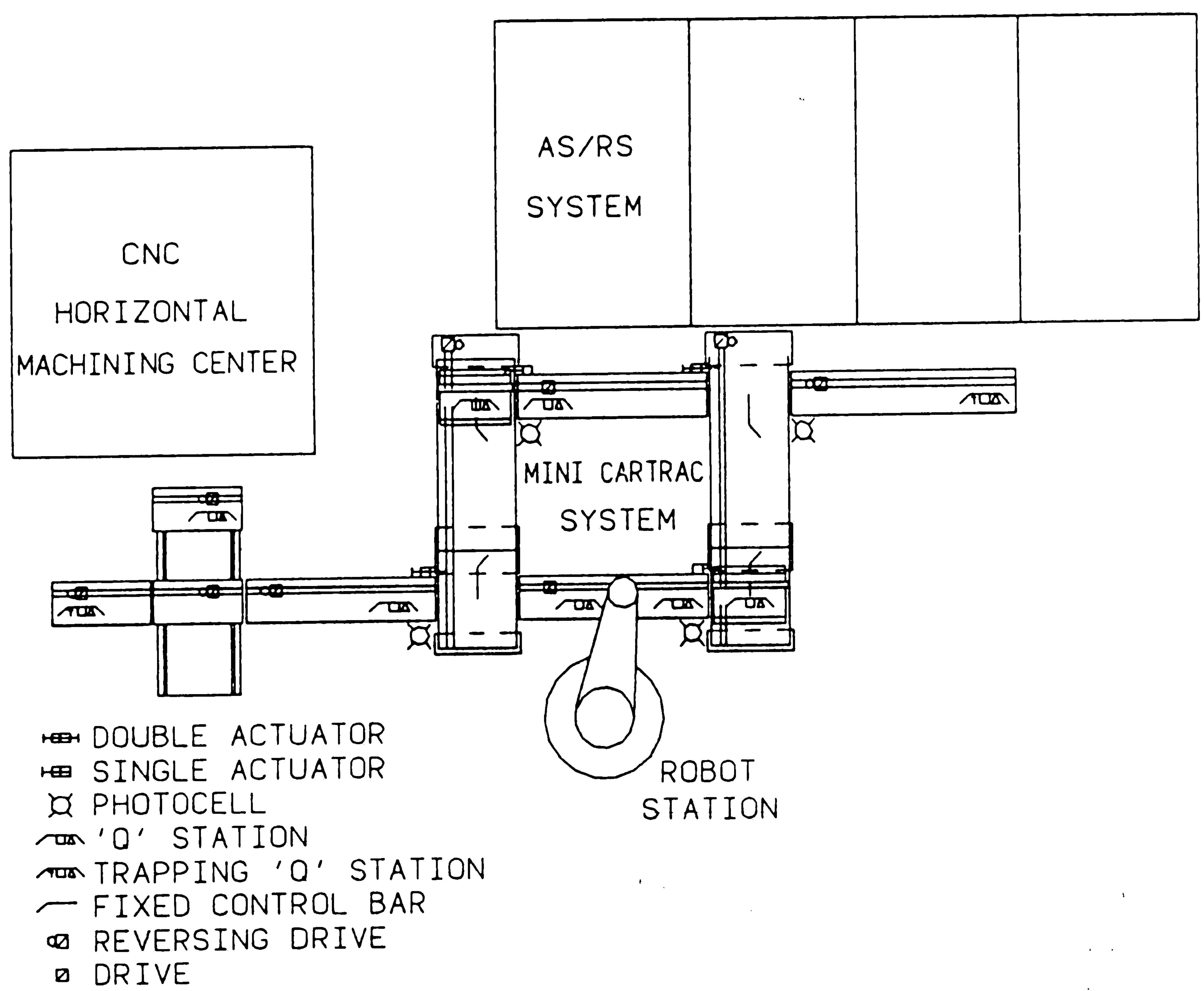

Figure 6-2: Interfacing with a robot station.

Welding: Welding processes are a very important application area for industrial robots. The applications logically divide into two basic categories, spot welding and arc welding. There are several advantages attributed to a robot welding station compared with its manually operated counterpart. Among these are the following [7]:

----Higher productivity.

----Improved safety.

----More consistent welds.

Processing Operations: The processing operation is performed by a specialized tool attached to the robot's wrist as its end effector. The end effector is typically a powered spindle which holds and rotates a tool such as a drill. The robot would be used to bring the tool into contact with a stationary workpart during processing.

Assembly: Since there are variations in products and the demand for each product is significantly lower than in mass production, batch type assembly operations seem to offer the most promise for using robots. The robot would pick a part or subassembly stored in the assembly area and place it in the base unit, the fundamental building block which originates at the first assembly station.

Inspection: Robots equipped with mechanical probes, optical sensing capabilities, or other measuring devices can be programmed to perform dimensional checking and other forms of inspection operations.

6.2.2 Workstations

The Cartrac system may be interfaced with another workstation in front of the loop, between transfer assemblies (Figure 6-3). That workstation could be a CNC lathe. The interfacing equipment which transfers the workparts between the Cartrac system and the CNC lathe might be a roller or belt conveyor system.

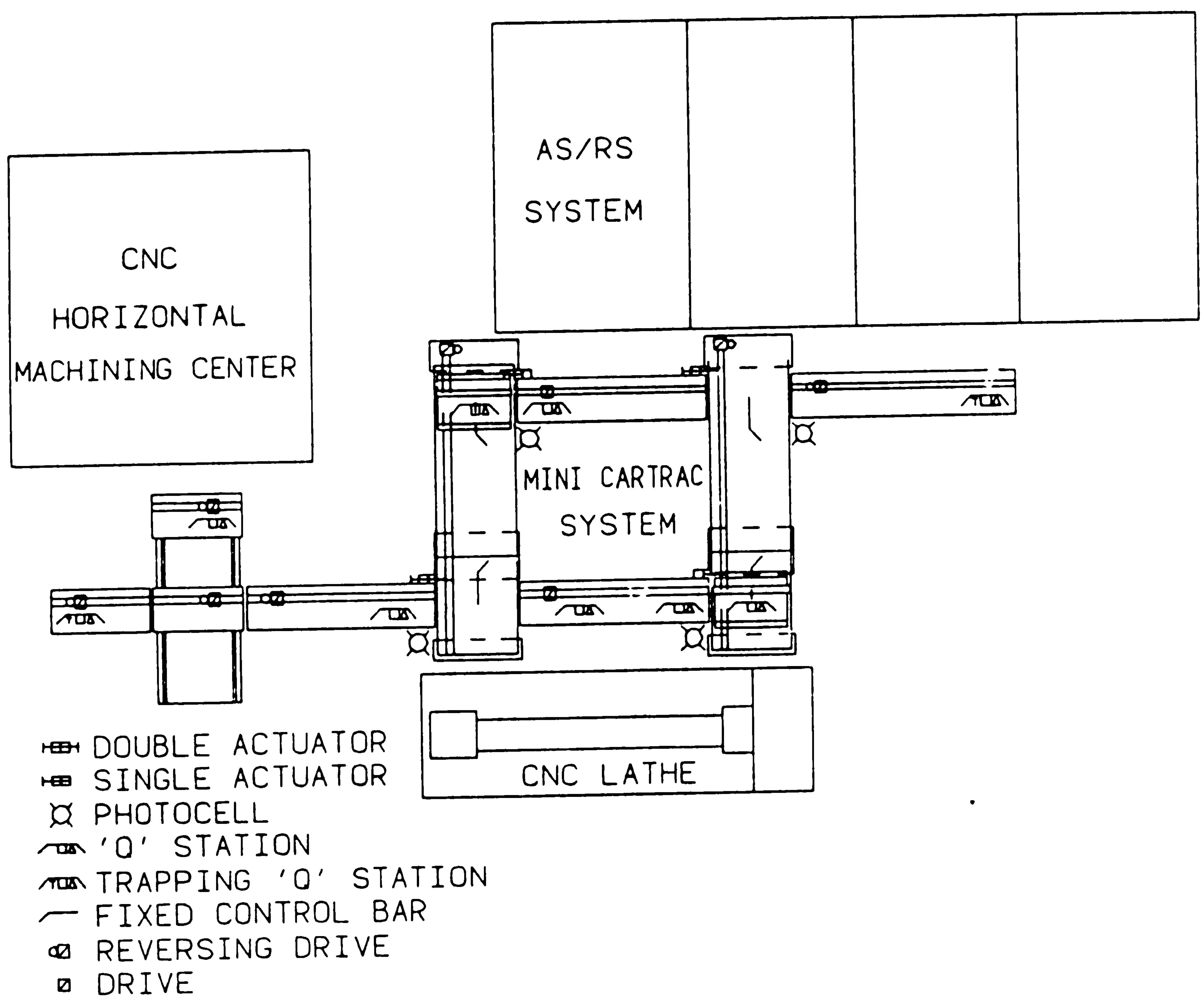

Figure 6-3: Interfacing with a CNC Lathe.

Interfacing with the CNC horizantal machining center can be made possible by operating the dual shuttle in conjunction with a mechanical interface fixture designed by Richard Jiranek who explains the ideal interfacing operation as follows [8]: "The cart will perform normally during transport to the workstation. However, the cart will arrive at its destination point; four solenoids will control the carrier height and the roller rotation (Figure 6-4). All of the power transmission is from the drive tube while the controls are located offboard of the cart-on-track and on the workstation. Lever 2 is engaged to raise the carrier top while lever 3 lowers it. Lever 1 powers the rollers forward and lever 4 powers the roller backwards. When the levers are not engaged, chain brakes prevent the load from slipping. A sample part delivery routine will perform the following steps: The cart will arrive at the workstation with its load in the low position (for stability and safety during travel). Lever 1 will be engaged to raise the load. A limit switch changes state when the rollers reach the proper height. The solenoid engaging lever 2 is disabled thus engaging the chain break to prevent slippage. Lever 1 is then engaged to drive the pallet off the cart-on-track carrier bed until another limit switch senses that the pallet is off. Lever 3 is then engaged to lower the rollers for departure."

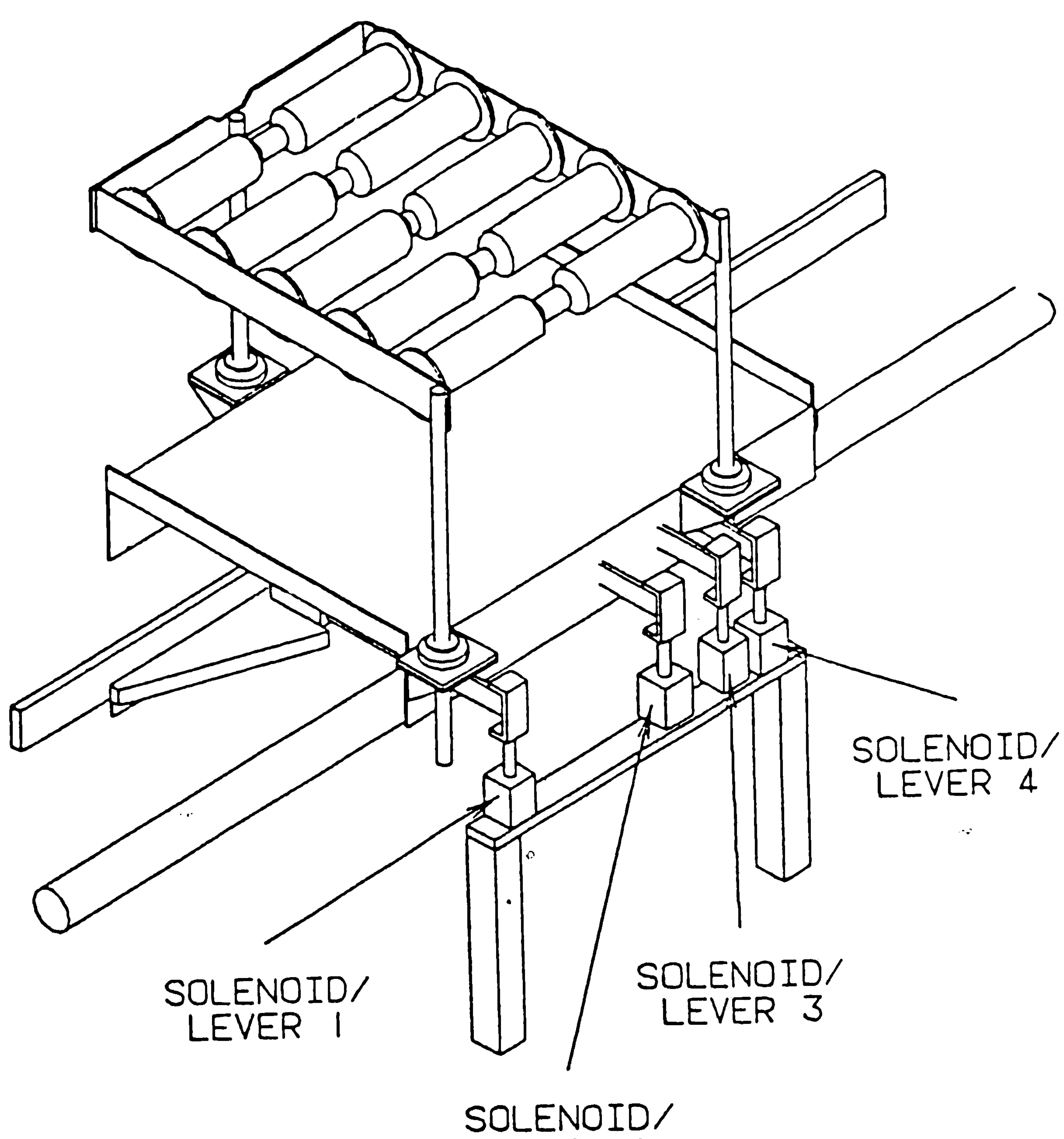

Figure 6-4: Solenoid activators [13].

Chapter 7
Conclusion and Areas for Future Study

A layout plan has been developed for a Mini Cartrac conveyor system, contributed by SI Handling System Inc., that would permit it to serve as the central material handling system for a flexible manufacturing system (FMS) in the Manufacturing Technology Laboratory. This layout plan is illustrated in Figure 7-1. The handling system is designed to permit parts to be moved between the two machine tools in the FMS to accommodate variations in processing. These two machine tools are a CNC horizontal machining center and a CNC turning center. At the horizontal machining center, a pallet fixture holding the work part will be transferred back and forth between the Mini Cartrac conveyor cart and the machine tool table. At the turning center, an industrial robot will be used to pick parts from the conveyor cart to place them into the machine chuck.

In addition to its function as the central handling system for the FMS, the Mini Cartrac system has also been planned so that it can be interfaced with the automated guided vehicle system (AGVS) and the automated storage and retrieval system (AS/RS) in the lab. Accordingly, it will be possible to transfer pallets (on which the single workparts are attached) and tote pans (in which more than one part can be contained) between the three systems (Mini Cartrac, AGVS, and AS/RS).

Further research and development is required in the following areas related to the Mini Cartrac system and other material handling systems in the Manufacturing Technology Laboratory:

----Design of the peripheral equipment for interfacing the Mini Cartrac conveyor system with the CNC horizontal machining center, the robot, the CNC turning center, the AS/RS and the AGVS.

----Development of the appropriate controls for coordinating the transfers of parts and loads between the various systems.

----Design of a pallet fixture that can be used to hold parts to be processed in the FMS and can also be moved by the various handling systems in the laboratory and transferred between these systems.

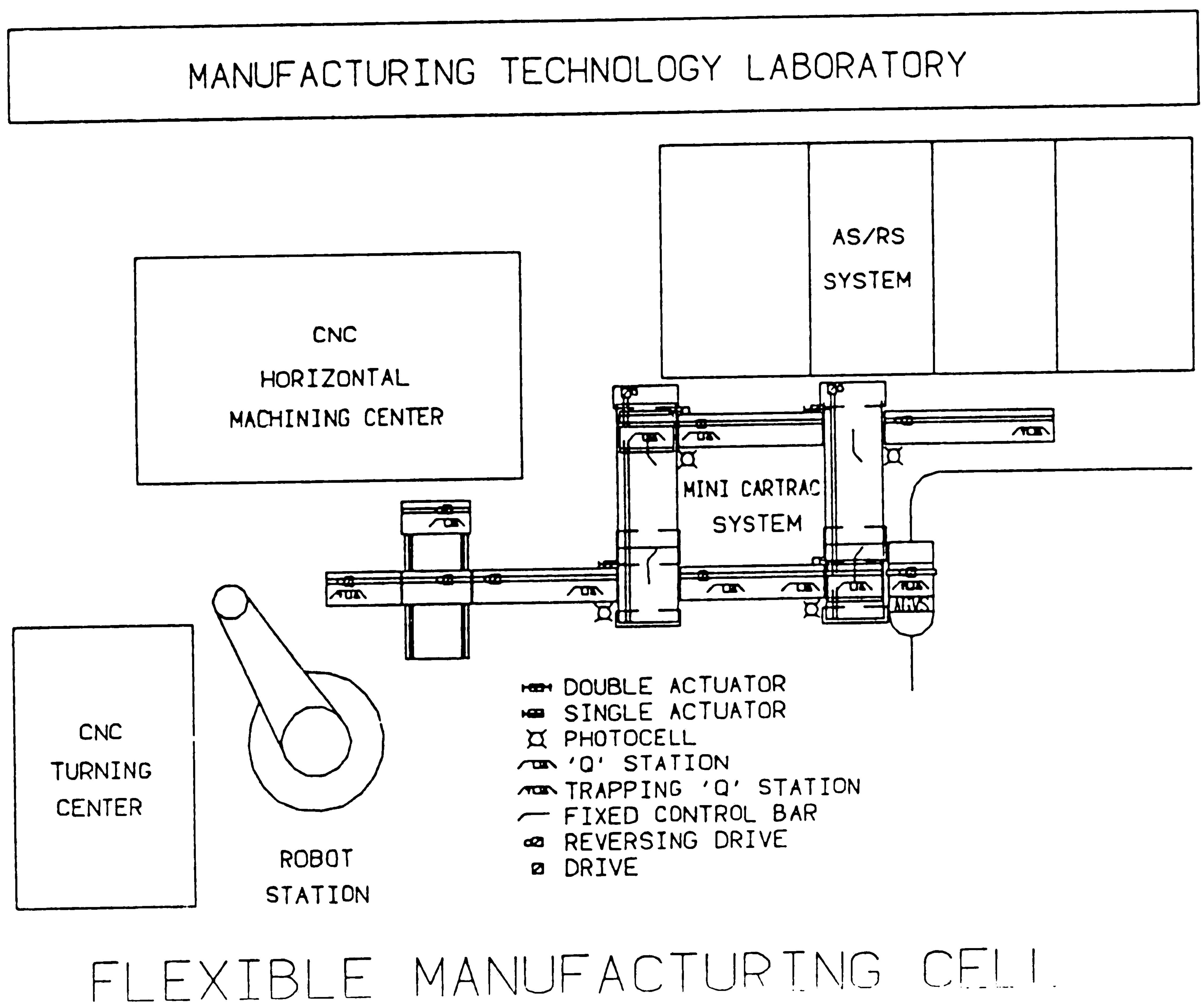

Figure 7-1: FMS in the Manufacturing Technology Laboratory

References

[1]- Announcement, "Conveyor Systems". Modern Materials Handling. August 5, 1983, pp 50-57.

[2]- J. G. Dorrance. "Spinning-Tube Conveyors", Materials Handling Handbook, 2nd edition (R. A. Kulwiec, editor), John Wiley & Sons, New York, 1985, pp 346-353.

[3]- R. L. Dunn, "Systems Integration: The Creative Side of Material Handling", Plant Engineering, February 13, 1986, pp 44-47.

[4]- N. Glenney, "Modular Integrated Material Handling System Facilitates Automation Process", Industrial Engineering, November 1981, pp 118-124.

[5]- M. P. Groover, Automation, Production Systems and Computer Integrated Manufacturing, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1987, Chapter 14.

[6]- M. P. Groover, Automation, Production Systems and Computer Integrated Manufacturing, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1980, Chapter 19.

[7]- M. P. Groover and E. W. Zimmers, Jr., "Robot Applications", CAD/CAM Computer-Aided Design and Manufacturing, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1984, pp 257-273.

[8]- R. D. Jiranek, "Design Principles For Mechanical Interfacing Production Equipment To Material Handling Systems", Masters Thesis, Manufacturing Systems Engineering Program, Lehigh University, Bethlehem, PA, 1986, pp 13-22.

[9]- ME Staff Report, "Automated Materials Handling", Mechanical Engineering, September 1983, pp 38-43.

[10]- R. Sloand, "Design and Development of the Manufacturing Technology Laboratory at Lehigh University", Masters Thesis, Industrial Engineering Department, Lehigh University, Bethlehem, PA, 1984, pp 86-89.

[11]- SI Handling Systems Inc., "Engineering Drawings", Engineering Service, Easton, PA, 1986, Drawing sheet 1-20 of D-K 34A15.

[12]- SI Handling Systems, Inc., "Cartrac Systems", Bulletin No. 1178, Easton, PA, 1984.

[13]- SI Handling Systems, Inc., "SI Cartrac", Bulletin No. CT5M, Easton, PA, 1985.

[14]- Staff Report, "Integrated Manufacturing", Production Engineering, February 1986, pp IM1-32

[15]- J. A. Tompkins and J. D. Smith, "Keys to Developing Material Handling System For Automated Factory Are Listed", Industrial Engineering, September 1983, pp 48-54.

[16]- J. A. Tompkins and J. A. White, "Automated Storage/Retrievel Systems", Facilities Planning, John Wiley & Sons, New York, 1984, pp 167-181.

[17]- J. A. White, P.E., "Factory Of Future Will Need Bridges Between Its Islands Of Automation", Industrial Engineering, April 1982, pp 61-68.

[18]- B. I. Zisk, "Flexibility Is Key To Automated Material Transport System For Manufacturing Cells", Industrial Engineering, November 1983, pp 58-62.

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