MFG: ARROW DYNAMICS, INC.
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CIRCUS WORLD LOOP

OWNER'S MANUAL

ARROW DEVELOPMENT CO., INC.
1555 Plymouth Street
Mountain View, Calif.

CIRCUS WORLD LOOP OWNER'S MANUAL

C O N T E N T S

I. INTRODUCTION

Arrow Development Company's Loop is very much like a roller coaster with some major new features not found in any other amusement ride.

To begin with, the loading station is about 50 feet in the air and the ride is in a long straight line with a real upside-down loop in the middle. It may look like a rather unexciting ride but don't be fooled. A ride on the Loop will start as you choose a car and climb into the seat. After you have adjusted the shoulder restraint bar you are ready to be "launched". The launcher is very similar, though smaller, to the catapult used to launch the airplanes off of an aircraft carrier deck and you will feel yourself going faster and faster out of the station until suddenly you are plummeting down a steep hill to a top speed of more than 45 miles per hour. Then it is up and over the Loop, down the other side and you are climbing up a steep hill to arrive at a high spot just like the loading station. Here the train will slow down and come to a stop. No, the ride isn't over - there is another launcher and another trip through the Loop but this time you will travel backwards, which is another kind of thrill altogether.

The train will come to a final stop in the loading station where you will raise the restraint bar and step out of the coach.

A lot of thought and engineering has gone into the development of the Loop to insure the safety and reliability of the ride and its many component parts, but the overall success of any modern amusement ride is highly dependent on the quality of the operation and the maintenance of the device.

The Loop is an electro-mechanical system in which various subsystems function with one another to make the ride work properly. Some of these systems, such as the solid state controller for the drive motors, are quite complex at the design level, but they can be understood, diagnosed and repaired in a straightforward manner when required.

We will attempt, in this manual, to describe the ride and its various subsystems so that you can get a general idea of how and why things happen if you are an operator or, if you are concerned with maintenance, you can go far enough to learn about the more complex technical details related to the maintenance, trouble-shooting and repair of any part of the system.

As you read through the several sections of the manual you will find that the information gets more detailed and more technical in nature as you get further along. You will find that many things appear in more than one place in the manual and you may feel that it is unnecessary to say things over again. The items that are repeated are all aiming toward the safe operation of the ride, and are felt to be important factors that must be remembered.

The Loop, like any amusement ride, has been designed and built with safety as the foremost consideration, but safety is a people problem as well as a machinery problem. It is extremely important to closely observe all safety rules and use common sense when operating or working around machinery of any kind.

II. GENERAL INFORMATION

The Loop system is made up of several subsystems that work together to provide a safe thrilling ride experienced. We will try to describe the various subsystems in a way that will make it easy to understand what is going on, what the function of some of the more obvious items is and how each subsystem fits into the overall ride program.

A. Track and Supporting Structure

The first thing that you see as you approach the Loop is the major supporting structure that holds the tracks up. The basic support is a braced frame network that holds up the station and all of the track except the Loop portion. Major areas of concern regarding this type of structure are associated with periodic inspection of anchor bolts and tie rod turnbuckles to be sure that they remain tight. A braced frame structure is made up of a series of relatively small members tied together in such a way to make the entire system very stable and able to support large loads applied in several directions.

The most outstanding part of the support structure is of course the arch that supports the Loop portion of the track. This arch is far from being a simple frame structure even though it too is made up of small members tied together in such a way as to gain a lot of strength and stability. The arch is subjected to loads in many directions as the train moves through it and is therefore a very difficult engineering problem.

The arch structure and its attachments to the track were studied by using a complex computer program in a large computer. The computer is able to look at many conditions in a short period and come up with information regarding the loads applied to all of the members in the arch and their connections to each other.

You may notice that when the Loop train runs back and forth there is some movement of the supporting structure. This movement is normal and should not be cause for alarm. Any excessive movement should be reported to the maintenance department.

B. The Train

As you arrive on top of the loading platform you will first notice the train. The train is made up of four to six coaches each seating four passengers. Other than the number of coaches in the train all trains are the same so that we do not have to talk about four car trains and six car trains.

You will notice that there is a set of wheels at the front, a set between each pair of coaches and a set at the rear of each train. A closer look at the wheels will show you that there are two wheels on top of the track, two wheels inside of the track and one wheel underneath the track at each end of each axle assembly. The two wheels on top of the track are called road wheels, the two inside are called guide wheels and the one underneath is called the upstop wheel.

All of the wheels are covered with a rubber like material called polyurethane. The polyurethane is very tough, helps absorb bumps, and quiets the ride. The polyurethane is molded onto the wheels and will normally last for a long time. Sometimes, however, the polyurethane does not bond properly to the aluminum wheel and it will come off after some period of operation. Ride operators, loaders, etc., should get into the habit of checking the train each time it comes into the loading area and one thing to check is the wheels. If a tread seems to be loose, or if it comes off the wheel, report it to the maintenance department right away. They can put a new wheel on in a few minutes.

Under normal conditions the tread material will show some checks and small cracks after the wheels have been used for awhile. This is a normal process and does not effect the usefullness of the wheel. Wheels should be replaced only when the tread shows signs of loosening on the wheel or if large chunks are torn off.

Another important part of the train that should be observed is the connections or couplings between the coaches. The couplings are found ahead of the axle assembly between the coaches.

The couplings are very much like a universal joint in that they have three axis freedom. They are able to move up and down, side to side and to twist to allow for the various angles that develop between the coaches. The coupling is made up of a large yoke with a rotating stem on one end that fits into the rear of the chassis frame. The open end of the yoke receives a block that has two pins through it at right angles to each other to allow for vertical and lateral movement. The two large pins are held in place by threaded fasteners which should always be tight. On each side of the coupling yoke you will see a safety cable that has one end attached to each chassis frame. The fasteners that hold the safety cables to the chassis must be in place with a cotter pin to lock them.

It is a good idea to develop a standard picture in your mind that shows the relationships between the various parts and fasteners so that, if something isn't quite right, you will be able to recognize it and notify the maintenance department. The maintenance people will be checking all of these parts on a daily basis so it will be a very rare occurrence to find something out of place.

Underneath each chassis, mounted on the bottom of the main chassis beam there is a brake fin. The brake fins run between shoes on the brakes that squeeze them much like disc brakes on a car. We will talk about the brakes in more detail later.

The passenger restraint system is one of the most important parts of an upside-down ride and it is important that you understand something about its operation.

The restraint bar (one for each seat) is locked and unlocked by the foot pedal at the right rear of each coach. With the pedal in the down position the bar can be moved freely up or down. When the pedal is in the upper position the restraint bar will move down but will not move up. The bar may be pulled down to any position that is comfortable to an individual rider and it will be locked in that position.

The restraint bars are locked by trapping hydraulic fluid in a cylinder that is attached to a pivot arm at the top of the seat. When the pedal is moved, a hydraulic valve is actuated which allows fluid to move from one end of the cylinder to the other. Occasionally some of the hydraulic fluid may leak out of the system and leave an air space at the end of the cylinder. This will show up as free play after the bar is locked in position. This condition should be reported to the maintenance department.

If one or more of the foot pedals is not placed in the locked position and the train is dispatched, it will move forward about 2 feet and come to a stop. A discussion of how to restart the system if this happens appears under the ride operating section of this manual.

The train has many more parts than those we have discussed but these will fall more in the pure maintenance area. The parts and systems we have talked about with regard to the train are those major easy to see items that the operators of the ride should try to understand and be aware of.

C. The Launch System

As the train leaves the station you will notice that it is being pushed along by another vehicle that rides on top of the track just like the train. This is the launch vehicle and you will notice that it is fastened to a steel cable that pulls it either way along the track.

If you were to follow the cable you would see that it follows a path along a channel between the rails then goes over a large pulley and returns below the track over a series of smaller pulleys that guide it onto a drum.

The cable drum is divided into two halves with one end of the cable fastened to each end of the drum. As the drum turns to pull the launcher along the track, the cable winds on one side of the drum as it unwinds from the other.

The cable drum is driven by a 100 HP direct current motor through a heavy duty belt drive system. The motors are programmed to run at 100% overload (this is alright for DC motors on a short duty cycle such as found on the Loop) thereby delivering 200 HP to the launch system.

The motors are controlled by a complex solid state system that changes the incoming alternating current to direct current and delivers the DC power as required to launch the train. The controller is able to control the acceleration rate and the speed within its design range and to run the motor either direction to launch the train and then retrieve the launch vehicle.

When the train is launched, the motor is programmed to provide a uniform acceleration up to the final launch velocity of approximately 38 ft/sec. (26 MPH).

At about the time the train reaches its top speed, the launcher stops and the train continues on down the track towards the Loop (more about the train later). As we have seen there are certain events that take place to get the launcher moving and you might wonder how it all stops so quickly. As the train is started there is a rotary switch on the cable drum that counts the revolutions as the drum turns. After so many turns the switch signals the controller and several things happen. The fin on the launcher runs into a set of brakes that has just been energized, a disc brake on the drive unit is energized and the controller puts reverse current into the motor. Each of these events is necessary to absorb the kinetic (moving) energy that is stored in all of the moving parts of the launch vehicle. All of this happens in a small part of one second as the launcher stops over an approximate 5 foot distance.

After the launcher stops it will restart and move slowly backwards until it once more stops at the rear of the station in its original position.

The train meanwhile has gone down the dip leading to the Loop reaching a maximum speed of approximately 66 feet per second (45 mph) before rising and moving through the top of the Loop. The speed of the train through the Loop has been programmed so that the forces that are applied to the passengers are high enough to hold them up against the seat while in the upside down position. Because of this it is not possible to fall out of the seat as the train turns upside down. The shoulder restraint bars are there as a safety feature and will hold passengers safely in place even if the train were to slow down due to a mechanical problem.

After completing the trip through the Loop, the train will proceed up the hill and onto the high flat portion of track at the end opposite the loading station. The train will come to a stop and dwell for a few seconds, then it will be launched backwards by a launcher just like that in the station.

After the returning train has gone through the Loop and up the hill it will come rolling smoothly towards the station platform. You will notice that there are two brakes on the track next to the loading area and that just before the brakes there are two wheels mounted at about the same level as the brakes. As the train approaches the brakes they are closed so that as the brake fins on the train enter them the train will be slowed down. Before entering the brake, the fin will contact the two wheels and start them turning. As the wheels start turning they take over the control of the station brake and check on the speed of the incoming train. When the train is slowed to the desired pre-set speed, the first brake will be released and the train will continue to be slowed by the one remaining brake. When a second pre-set speed level is reached, the remaining brake will be released allowing the train, which is now moving very slow, to proceed to the end of the station area and come to a complete stop against the launch vehicle.

You will notice that behind the launch vehicle there are two large shock absorbers. These are capable of absorbing the energy from a train that is moving much faster than the normal speed but they are not able to be continually hit by trains that are moving too fast. If you notice that the trains are hitting the launcher too hard when they come to a stop, notify the maintenance department so that they can make an adjustment on either the brakes or the speed control devices.

We have talked about the major parts of the system in rather simplified terms so that you will be able to understand what is happening as you operate the Loop on an everyday basis. If you wish, or need, to know more, the remaining sections of the manual go further into the detail of the ride.

The most important consideration in any ride operation is safety. Safety is mainly a people problem. No matter how many safety devices are installed, it is only through the proper maintenance and the alertness and attention to detail of those people who maintain and operate the ride that safety can be assured.

Safety will be stressed over and over as you read through this manual and also by those who are in charge of maintaining and operating the ride. There will be a check list of things that must be done each day before opening the ride and each item on the list is important and requires strict attention.

III. DAILY PRE-OPENING AND OPERATING PROCEDURES

Each morning before opening the Loop for public operation there are a number of things that must be done to assure that the ride is in safe operating condition. We will describe the daily inspection and testing procedures in detail and then discuss the normal operation of the Loop.

A. Daily Inspection and Testing by the Maintenance Department

Each morning prior to opening the ride, the maintenance department will perform the various inspections and test procedures as described fully in sections IV and V of this manual. It is important for each item to be completed as specified with no shortcuts or omissions.

The proper daily inspection of a major amusement device like the Loop is critical to the safety of passengers and park employees alike and the importance of such an inspection cannot be overemphasized.

We highly recommend that the inspection be performed under the direct supervision of a responsible individual who will sign a log book after each inspection stating when the inspection was performed, by whom and carefully noting any observed discrepancies.

B. Pre-Opening Operational Check

After the maintenance department has made the daily inspections as required in section V, the following operational check must be made each day before turning the ride over to operations for opening to the public.

1. One person should be located at the control panel at the station end and one person should be located at the control panel on the run-out end of the ride.

2. Place the key in the switch marked power at the top left side of the station console panel and turn it to the "on" position.

3. Pull on the head of the large button marked Power just below and to the right of the keyswitch. The head of this button will light indicating that the system power is on.

4. Put the key in the switch marked "exit brakes reset", turn it and press the button. This will make the system ready to operate in the manual mode.

5. Locate the manual forward-reverse switch at the lower left corner of the control panel. This switch is spring loaded to the center. Move the switch to

the forward position and the launcher and train will move slowly out of the station. Release the switch and the train and launcher will stop. Move the switch to reverse and the train and launcher will move back into the station. Move the train in and out of the station 2 or 3 times being careful not to move out so far that the train drops over the edge of the hill and is lost at the bottom. If when moving the train back into the station the launcher leaves the train behind and arrives home first then the station brakes will close and stop the train away from the launcher. Moving the launcher back to contact the train will open the brakes and the train can be kept closer to the launcher. If you wish, you can put the key in the switch marked station brake release and press this button to allow the train to roll back to the launcher.

6. The operator on the run-out end should now use the key to actuate the "reset exit brake" button on his console. Press the button and the "manual on" light should come on. The run-out side is now ready to run in the manual mode.

7. Use the "manual forward and reverse" switch on the run-out end to run the launcher back and forth 2 or

3 times. On the last run out of the station, allow the launcher to go forward as far as it can until it stops automatically at the extreme position at the top of the hill. To bring the launcher back you must hold down on the exit brake release button and actuate the switch to the reverse side. After the launcher moves back 2 or 3 feet you can release the exit brake button and bring the launcher all the way until it stops at the rear of the run-out section.

8. When both sides are "home", the "dispatch position" light on the station console will come on.

9. Push the "automatic" button on the station panel and if the launchers have been home for 20 seconds or more the "dispatch OK" light will come on.

10. The system is now ready to dispatch the train.

11. The train must be empty and everyone must stand clear.

12. Push the "dispatch" button and the train will quickly accelerate and leave the station.

13. The train will go through the loop up the other side, slow down, and stop against the launcher at the

run-out end. Leave the train in this position.

14. At the station end push the "manual" button so that the "manual" light comes on again. Use the manual switch in the forward position and run the launcher all the way out to the end of its travel where it will stop automatically. This tests the ability of the system to detect and stop an overrun situation. Hold the "reset exit brakes" button and return the launcher to the home position.

15. Push "automatic" button.

16. When the operator at the runout end is ready, he pushes the "return OK" button and the "return OK" light at the station panel will come on.

17. The operator now pushes the "return" button and the train will leave the runout end, return, slow down and stop in the loading station.

18. The train should be cycled back and forth 2 or 3 times prior to opening the ride to the public. It is not necessary to check the automatic stop on the launcher more than once each morning.

If during the operational check anything at all does not seem right, it must be checked and repaired or adjusted as necessary.

After the operational check has been completed by the maintenance crew the ride should be turned over to the operators for the daily operation.

C. How to Operate the Loop

The daily operation of the Loop is not difficult because most of what happens to make the train go back and forth is automatically controlled. The major function of the ride operators is; always be aware of what is going on. The Loop, like all other high speed rides can be hazardous to those around it if anyone falls down on his or her job.

The people who are responsible for loading and unloading must be alert at all times to what the guests in the cars and on the platform are doing. There is no time for fooling around or horseplay. It only takes a few seconds for someone to do the wrong thing and cause an accident. When loading people in the train, be certain that each person is in a seat with the shoulder bar down over his shoulders prior to signalling that the train is ready to launch. Do not allow passengers to carry objects that may fall out and hit someone either in the train or on the ground.

We feel that a minimum size should be placed on those who ride the Loop. We find that most parks set this limit between 42" and 48" tall.

The operator at the control console must always watch the train and must stay at the console. It is not the operator's job to load and unload the train or to talk to people on the platform. Here again a few seconds relaxation of attention can cause a serious problem.

The following discussion will describe a sequence for normal operation of the Loop after the ride has been checked by the maintenance department and the operational check has been made as described in section III.B.

1. The train is in the station with the shoulder bars all the way open in the up position.

2. Load <u>one</u> passenger in each seat and ask them to pull the shoulder bar down to a comfortable position. Passengers should be pre-positioned on the loading platform to save time when the train arrives.

3. After everyone is seated and the shoulder bars are down, check to see that the shoulder bar locking pedal is in the raised (locked) position. If all is ready signal the operator that the train is ready

to launch.

4. The operator at the console is now ready to dispatch the train. The "dispatch OK" light on the panel should be on. This should have been checked before loading the first passengers. If all is ready, press the "dispatch" button and the train will leave the station. The loaders on the platform must keep everyone away from the train as it is launched. The launcher will return to the back of the station and stop automatically.

5. Meanwhile, the train will go through the Loop up to the run-out end and will slow down and stop against the launcher. When the operator at the run-out end decides that all is clear he will press the "return OK" button on his panel and the "return OK" light on the station console will come on.

6. The operator at the station console now presses the "return" button which causes the train to be dispatched from the run-out end back to the station.

7. The train will come into the station, be slowed by the brakes, and will come to a stop against the launcher.

8. As soon as the train stops, the loading attendants should unlock the shoulder bars by stepping on the pedal at the rear of each coach. As you do this ask the passengers to push the bars up and step out on the unload side of the platform. The passengers waiting to load should be encouraged to get in quickly and the process is repeated.

Maintaining the capacity of the ride depends on seconds being saved wherever possible and being sure that all of the seats are filled each time the train is dispatched. An orderly operating sequence that runs smoothly can only be developed through actual practice, and ride capacity will increase as the system is worked out and the operators become proficient at their jobs.

It is not necessary for the train to dwell very long at the run-out end of the ride. As soon as the operator at the run-out end knows that the train is against the launcher he should press the "return OK" button.

If one or more of the shoulder bar pedals is left down in the unlocked position, the train will not leave the station. It will start to go, move 2 or 3 feet and stop. If this happens, the station operator must press the "exit brake reset" button to clear the system. This will put the ride in the manual mode. Move the "manual" switch at the lower left corner of the station panel to the "reverse" direction. The launcher and train will return to the starting position. Check the pedals and move the open ones to the upper (locked) position. Now the operator must press the "automatic" button and wait 20 seconds for the "dispatch OK" light to come on before pressing the "dispatch" button to dispatch the train.

If anything does not seem right or if the ride sounds different it is best to call the maintenance department to check things out.

IV. THE ELECTRICAL SYSTEM

A. Technical Description

When the launch vehicle pushes the train out of one of the stations, the necessary force comes from a direct current (DC) motor, which drives the cable drum. A DC motor (in this particular case, a "shunt wound" motor) was chosen instead of the more familiar AC motor because it has two characteristics which help make the drive system both simple and efficient. First, a DC motor can be operated at any speed below its design or "rated" speed, in either direction. Second, the amount of torque developed by a DC motor can also be controlled.

It may prove helpful to discuss these characteristics in more detail, especially as they relate to the operation of the Loop. Each DC motor on the Loop is rated 100 HP, 1750 RPM, 240 volts DC (armature voltage). (At this point, you should remember that only one motor is running at a time.) Let us assume that we can test one of these in a facility that has sources of DC power (one with adjustable voltage), a method of "loading" the motor (such as a dynamometer), and devices to measure voltage, current, speed, and torque.

In order to operate the motor, its "shunt" field must be permanently connected to 300 volts DC, which provides the necessary fixed amount of DC current to flow in the field.

With the motor unloaded and zero volts applied to the armature connections, the motor will remain at a stand-still (zero speed). As the armature voltage is increased from zero to 240 volts, the motor speed will increase to slightly over 1800 RPM. If the motor is then loaded so that it is developing full torque (approximately 300 ft/lbs.), the speed will drop slightly to about 1750 RPM, the "rated" speed of the motor. If the polarity of the armature voltage is reversed, the motor rotation will reverse. Both the speed and rotation direction of the motor, then, can be controlled by adjusting the magnitude and polarity of its armature voltage.

When the motor is being loaded, you will notice that the torque developed by the motor, regardless of speed, is almost exactly proportional to the armature current. For the Loop motor, for every 10 amperes, the motor develops about 8.8 ft./lbs.

If we can arrange to reverse the load on the motor so that the load drives the motor (overhauling load), we find that the motor current reverses direction and the motor tends to act as a generator. If that generated energy can be dissipated, the motor acts as an electrical brake. Electrically, this is called "regeneration" and a control system that has the ability to return power to the distribution system during this braking action is called a "regenerative" system. At one point in the Loop sequence of operation, this feature is actually used to return some of the drive system energy to the power company.

In the sample "tests" we made above, we assumed a source of DC power, current and voltage sensing devices, and other circuits. In practice, and specifically for the Loop, we have a bridge rectifier system using SCR's (silcon controlled rectifiers), which converts 3 phase, 60 cycle 480 volt AC power to DC power. This system also can vary the DC voltage from (-) 240 volts to 0 volts to (+) 240 volts, and has the ability to handle current flow in both directions to provide the "regeneration" described above. It also rectifies the AC power to provide 300 volts DC for the motor fields, and contains the other current and voltage sensing circuits necessary to complete the speed and torque control scheme. This system is alternately connected to the two DC motors, by means of a separate DC contactor for each motor. Thus, for one direction of travel, one motor is "on line", and the other is on "standby". For the other direction of travel, the roles are reversed.

For convenience, we say this group of rectifiers and other circuits "controls" the motors and we call it the "controller". The controller is manufactured to Arrow's requirements by Randtronics, a firm that specializes in the design and production of such equipment. Detailed descriptions and data on this equipment is included in the Instruction Manual and drawings furnished by Randtronics. Additional features of this "controller" are discussed below.

Whenever a DC motor is commanded to change speed quickly or there is a sudden application of load, the motor tries to produce a large amount of torque (and therefore current) to satisfy the new requirement. However, excessive currents (for the Loop motors, in the range of 300% of rated current) may damage the motor commutator or armature windings. Therefore, the controller includes a circuit which senses motor current, compares it with a level which has been pre-set as a maximum, and acts to adjust the armature voltage so that the current is limited to that maximum value. This "current limit" circuit, then effectively limits the current drawn by the motor regardless of other demands of the control system. For the Loop, this maximum is set for approximately 210% of rated current to allow the motor to develop about 200% rated torque during the few seconds it is used to push the train from the station.

We have seen that the speed of the DC motor is proportional to its armature voltage, but the load on the motor also has some effect on its speed. For this reason, and also to make the motor more responsive to speed commands, a "tachometer feedback" system is used to control speed. A tachometer mounted on the motor shaft "feeds back" a voltage signal which is an exact representation of motor speed. This signal is compared to a "command" signal in the controller and any difference is used to adjust the armature voltage in the proper direction to make the motor speed correspond to the "command" signal.

The controller also includes circuits which adjust the rate at which a change in speed is made. That is, it is possible to set the rates at which the motor is asked to accelerate or decelerate. However, the "current limit" setting will always take precedence; it may cause slower acceleration or deceleration rates by limiting the amount of torque (current) the motor can produce.

For the Loop, the controller provides the ability to select four individually adjustable speeds:

1. Fast - the maximum speed of the motor, which represents the speed of the train as it leaves the station.

2. Intermediate - the speed at which the launch vehicle returns to its starting or "home" position.

3. Creep - the speed to which the launch vehicle slows just before it stops in its home position.

4. Slow - the speed which the launch vehicle travels at during manual operation.

Although the controller has the ability to control the speed of the DC motors, it needs the information to do so in the proper sequence. Also, the controller-DC motor combination is not concerned with stopping the train once it has left the station(s), since that is a function performed by the air operated brakes.

Therefore, in addition to the controller, the overall Loop control system consists of the following elements:

1. Limit switches which sense the position of the launch vehicle and train; pressure switches which sense pressure on the brakes; and rotary speed switches which sense train speed as it returns to the station(s).

2. Solenoid valves which control the air pressure to the brakes.

3. Operators' devices (in the console and control station) and relays (in the relay cabinet) which

translate operators' commands and information from the limit, pressure, and rotary limit switches into the proper instructions for the controller and brake solenoid valves.

These elements are discussed in more detail below.

For each station (loading and run-out), there are three track mounted limit switches to sense the presence of the train and launch vehicle. One senses the launch vehicle in its "home" position, one senses the train in its "home" position, and one senses an abnormal overtravel of the launch vehicle toward the Loop. (There is one additional limit switch in the loading station which is associated with the restraint release check system, described later.)

Coupled to the cable drum in each drive assembly is a rotary limit switch with four cam and switch combinations to sense the position of the launch vehicle (by counting drum revolutions) in four different locations:

1. <u>Point "D"</u> - the spot where the launch vehicle stops pushing the train and starts to decelerate.

2. <u>Point "L"</u> - the maximum forward travel of the launch vehicle, where it reverses direction and starts "home".

3. Point "E" - an abnormal overtravel position of the launch vehicle toward the Loop.

4. Point "C" - the point where the launch vehicle drops to "creep" speed as it approaches its "home" position.

Pressure switches are located at the output of each solenoid valve for each station brake to tell the control system when these brakes are set. (The brakes are set with high pressure, which closes the pressure switches.)

For each station, there are also two rotary speed switches in front of the station brakes (toward the Loop). These are actuated by the brake fins on the train as it approaches and passes through the brakes. They sense train speed and operate the brakes (through the solenoid valves) to slow the train down to "coasting" speed as it approaches its "home" position.

The operators' devices and control relays in the relay cabinet round out the Loop control system, providing the necessary logic for the proper sequence of operation. This sequence is described briefly here and then in greater detail in the next section, Control Circuit Description.

In Manual Operation (used for warm-up, testing, etc.), the operator can run the launch vehicle in both directions at fixed low speed by operating the Manual Forward-Reverse (spring return to off) selector switch. The vehicle will stop automatically at both ends of travel. The reset pushbutton must be pushed to allow manual return from the far (Loop) end of travel. The manual controls for each station are located at that station; it is not possible to run the run-out station vehicle from the loading station or vice-versa. If there is a malfunction during Automatic operation, the system will revert to Manual operation. Once the system is placed in Automatic operation, it can be returned to Manual by either operator. The loading station operator can push the Manual push-button or the run-out station operator can put the Man-Auto OK selector switch in "Man".

In Automatic Operation, the following sequence takes place, assuming the train is in the loading station.

1. The system checks the following conditions, through limit switches and pressure switches:

   a. Both launch vehicles are "home".

   b. The train is "home", and has been there for at least 20 seconds.

c. The run-out station brake solenoid valves are de-energized (indicating "set" brakes).

d. There is high air pressure on the same brakes (a double check that the brakes are "set").

e. The system is in the Automatic mode. (The Manual-Auto OK selector switch is in the "Auto OK" position, the loading station operator has pushed the Automatic pushbutton, and the Automatic pilot light is on). The system will remain in the Automatic mode until an operator places it in Manual or there is a malfunction of some type.

2. If the above conditions are confirmed, the Dispatch OK light comes on, and Loading Station operator pushes the dispatch button and the launch vehicle starts to accelerate the train.

3. The restraint release pedal sensors check the position of the pedals as the train passes them. If one or more pedals are down, the train stops. If all are up, the launch vehicle continues to accelerate the train.

4. At point "D", about 90 feet down the track, the launch vehicle stops pushing, comes to a stop, and returns "home".

5. In the meantime, the train has traveled through the Loop and up into the run-out station.

6. As it approaches the run-out station brakes, it actuates the two rotary speed switches, one controlling each brake. The first combination trims the train speed to 5 feet per second, and the second combination trims it down to a coasting speed of 2 feet per second.

7. The train then coasts to its starting position in the run-out station where it is stopped and held by the station brakes.

8. The system then checks on the following conditions through limit switches and pressure switches.

   a. Both launch vehicles are "home".

   b. The train is "home".

   c. The loading station brake solenoid valves are de-energized (indicating "set" brakes).

   d. There is high pressure on the same brakes (a double check that the brakes are "set").

e. The operator at the run-out station is pushing the Return OK pushbutton.

9. If all the above conditions are met, the Return OK light comes on in the console, the loading station operator pushes the Return pushbutton, and the launch vehicle pushes the train out of the run-out station.

10. The launch vehicle returns to its starting position in the run-out station and the train is trimmed to coasting speed by the loading station brakes (similarly to #6 and #7 above) and stops in its "home" position.

11. The unloading and loading of passengers is completed and the sequence is repeated.

Control Circuit Description

The Loop electrical drawings are listed below. The first three (Control Schematic Diagram) will be referred to in detail during the control description that follows. The remaining drawings cover primarily assembly and internal wiring details.

D-37567 Control Schematic Diagram (Sheet 1 of 3)
D-37568 Control Schematic Diagram (Sheet 2 of 3)
D-37569 Control Schematic Diagram (Sheet 3 of 3)

D-37562 Wiring Diagram, Relay Cabinet

D-37563 Wiring Diagrams, Operator's Console and Control Station

D-37564 Assembly and Wiring, Power Cabinet

D-37565 Field Wiring Details, Loading Station End

D-37566 Field Wiring Details, Run-Out Station End

D-37560 Assembly, Relay Cabinet

D-37561 Assemblies, Operator's Console and Control Station

(Randtronics drawings included in Randtronics instruction manual.)

The Control Schematic Diagram consists of three drawings: D-37567 (Sheet 1), D-37568 (Sheet 2), and D-37569 (Sheet 3). Sheet 1 includes legend information and description of the identification symbols which show the physical location of the various devices.

The schematic diagram is in "ladder" form, with numbers assigned to the lines (or "rungs") listed down the left side of the ladder. On the right side, opposite each relay coil, there are numbers showing the lines on which the contacts of that relay are used.

Sheet 1 covers that portion of the control system associated with the loading station. Sheet 2 covers that portion of the system associated with the run-out station.

It is almost a duplicate of Sheet 1 (except for relay designations) since the operating sequence is essentially the same for both directions of train travel. Sheet 3 includes circuits common to both sides. It also includes portions of the controller equipment in order to better represent the overall system in one drawing set; and makes a good starting point for descriptive purposes.

The control power (120 VAC) for the Loop enters on line 101 and passes through the Power On-Off button (PB9) and the Power On-Off switch (SS3). The control power then splits into two branches; both passing through contacts on relay K3 in the controller. (Relay K3 is picked up only when the field current in both motors is proper). One branch becomes wire number 13 and is effectively the "hot" side of the control schematic ladder on Sheets 1 and 2. The other branch (line 103) passes through the two motor overload relay contacts and becomes wire 9, the "hot" side of the control which supplies the controller.

Referring to line 106, LSOT is the track mounted limit switch located to detect launch vehicle over travel in the loading station and AS is the pressure switch on the main air line feeding the loading station. Normally these are both closed and wire 14 is hot. If the loading station exit brakes are "reset" (a normal condition, discussed later), contact RSES will be closed and the exit brakes solenoid valves (VSE1 and VSE2) are energized (brakes open). On line 107, contact K4 is on a "zero speed" relay in the controller to insure that the main contactor (K1) for the loading station motor (M1) cannot be picked up to start a sequence unless the motor is originally at rest. On lines 107 and 108, contacts K1 and K2 are auxiliary contacts on their respective contactors. Contact RSM is on a relay in the relay cabinet which essentially tells motor M1 to run, and is discussed later. Circuits for M2 are similar (lines 110, 111, and 112). On lines 114 through 126, the following relays are shown and are located inside the "Pre-set Module" in the controller:

1. FOR This relay commands a forward rotation of the motor, toward the Loop.

2. REV This relay commands a reverse rotation of the motor, towards the "home" position.

3. FAST This relay commands the "fast" speed, maximum train speed as it leaves a station.

4. INT This relay commands the "intermediate" speed, at which the launch vehicle returns "home".

5. SLO This relay commands the "slow" speed, used for manual operation.

The "creep" speed of the motor is commanded when the motor is "on", and the relays FAST, INT, and SLO are all off.

Relays RFX and RRX are mounted on a side panel in the controller cabinet, RFX provides the system with contact closures during "fast" speed operation. RRX does the same for reverse rotation. The other contacts and limit switches shown on lines 114 through 126 will be discussed below.

Lines 130 through 137 include the Automatic and Manual selection circuits. If the RSES and RFES contacts are closed (normal condition), and selector switch SS4 is in MAN, pushing the Automatic button (PB11) picks up RSA, RFA and RA. Pushing the Manual button (PB10) or turning SS4 to MAN, drops out these relays and returns the system to the Manual mode. Referring back to lines 114 through 126, note that if relay RA is off, only the "slow" speed can be commanded. Also, rotation is selected only by the RSMF, RSMR, RFMF and RFMR contacts which are manual control relays, discussed later. With relay RA picked up, its contact on line 114 opens and the one on line 117 closes, shifting the speed and direction command functions to the automatic sequence relays RSF, RFF, RSD, and RFD.

Referring to Sheet 1, we can now discuss the operating sequence in more detail. After the power is first turned on, wire 14 is hot; and assuming the launch vehicles are "home" and the train is "home" in the loading station, refer to line 18. Limit switch LAB (actuated by the train) is closed, and pushing the Exit Brakes Reset button will pick up relay RSES. This relay seals in through the Rotary Limit Switch contact LSE (overtravel), which will be closed. This closes the RSES contacts on lines 5, 19, 106, and 132, and effectively allows the system to operate.

Referring to line 2, if the system is in the Manual mode, the RSA contact is closed and the launch vehicle can be operated in both directions by using selector switch SS1, picking up relays RSMF or RSMR. Either of these relays picks up RSB and RSM on lines 4 and 5, and each selects a rotation direction on Sheet 3 (lines 115 and 121). Note that limit switch LSH on line 40 (actuated by the launch vehicle in its "home" position) picks up relay RSH and stops manual operation in that direction (line 5). In the "forward" direction, the launch vehicle stops when rotary limit switch contact LSE opens, dropping out relay RSES (line 18).

Normally closed RSA contacts on lines 33 and 36 also allow manual release of the station brakes with the Station Brake Release button (PB2), but only during Manual operation.

Assume now that the Automatic button is pushed. This disconnects the Manual controls and closes relay RSA contacts on lines 5 and 11, allowing the Automatic circuits to function.

Referring to line 42, the pressure switches associated with the run-out station brakes (AFB1 and AFB2) will be closed; limit switch LSP will be closed (actuated by the train in its "home" position); contacts RFB2 and RFB4 will be closed (indicating the automatic braking circuits are functional); and contact RFH will be closed (indicating the run-out station launch vehicle is "home"). Relay RSP will then pick up (the position light PLSP will light), its contact on line 10 will close and relay RSG will pick up, sealing itself in through the closed RFG contact on line 9. (The relay RSG tells the control system it is ready for a launch from loading station. When the train is in the run-out station, relay RFG picks up, indicating that the train is ready to launch from the run-out station).

Twenty seconds after RSP has picked up, contact TSP on line 11 closes and the Dispatch O.K. light (PLSD) comes on. Pushing the Dispatch button (PB1) starts the following sequence.

1. Relay RSD picks up, closing its contact on line 6, picking up RSM and RSB, and seals itself in through the rotary limit switch contact LSD. A RSD contact on line 13 also picks up relay RSF, sealing itself in through the rotary limit switch contact LSL.

2. Since relays RSM, RSD, and RSF are now picked up, contactor K1 closes (line 107) and the motor is commanded to run "forward" (line 117) at "fast" speed (line 120) and starts to accelerate to that speed under "current limit" control.

3. During the first two feet of travel, the restraint release pedals pass under their respective sensors and the proximity switch contacts (line 20) pick up relay RAB which seals itself in through the RSP contact on line 21 (now closed since the train has left "home"). The RAB contact on line 17 closes and maintains continuity to relay RSES as limit switch LAB opens. If a pedal is down, relay RAB does not pick up and when LAB opens, relay RSES drops out, stopping the train and setting all brakes.

4. As the launch vehicle passes Point "D", rotary limit switch contact LSD opens, dropping out relay RSD. Relay RSM stays sealed in by its contact on line 5, and since relay RSF stays picked up, the motor is still commanded in a forward direction (line 117) but only at "creep" speed.

5. The motor decelerates to creep speed (under "current limit control") and then rotary limit switch contact LSL opens when the launch vehicle nears the end of its travel. This drops out relay RSF and the motor is commanded to reverse (line 124) at intermediate speed (line 125) since rotary limit switch contact LSC is closed and LFC (in the run-out station drive assembly) is open.

6. The motor then drives the launch vehicle toward "home" at intermediate speed. When it is about six feet from "home", the rotary limit switch contact LSC opens and the motor drops to "creep" speed (since no "speed" relays are now picked up).

7. When the launch vehicle arrives "home", relay RSH (line 40) picks up, dropping out relay RSM (line 5) and stopping the motor and setting the station brakes.

8. In the meantime, the train has travelled through the

Loop and entered the run-out station. As its brake fins engage the two rotary speed switches, the following sequence takes place:

a. The brake fins bring the first rotary speed switch (ROF2) up to a speed corresponding to a train speed of at least 5 feet per second. The contact in ROF2 closes at that speed and picks up relay RFB3 (line 78). Since relay RSG is picked up, and its contactor line 76 is closed, relay RFB4 will pick up and seal itself in (lines 79 and 80).

b. On line 88, note that the RFB4 contact is now closed and as the train is slowed by the brakes to below 5 feet per second, the ROF2 contact (line 78) will open. This drops out relay RFB3, closing its contact on line 88, and energizes solenoid valve VFS2 to open this brake.

c. The same type of sequence occurs with rotary speed switch ROF1, relays RFB1 and RFB2, and solenoid valve VFS1. The net result is that the train is slowed to 2 feet per second by the run-out station brakes at which point the brakes release and allow the train to coast into its "home" position in the run-out station.

d. When the train arrives in that "home" position, limit switch LFP closes and relay RFP picks up (line 92). A contact on RFP then sets the brake operated by solenoid valve VFS1 (lines 84 and 85). Also, at this time an RFP contact picks up relay RFG (lines 59 and 60), which drops out relay RSG (line 9). This action effectively readies the control system for a "return" from the run-out station.

9. When the train arrives "home" in the run-out station, the Return Position light PLFP will light in the loading station operator's console (lines 91 and 92). When the operator at the run-out station pushes (and holds) the Return O.K. pushbutton and timer TFP has timed out, the Return O.K. light will light on the console (lines 60 and 61).

10. When the loading station operator pushes the Return button (line 61), the sequence is repeated for the train's return trip. Apart from the fact that there is no restraint release check, the control system for the return trip is identical to that described above except that another set of relays, limit switches, rotary speed switches, and brake solenoid valves are used. Sheet 2 of the Schematic Diagram covers the devices for the return launching sequence,

and Sheet 1 covers the return braking sequence.

B. Trouble Shooting and Maintenance

The single most important requirement for a good trouble shooting capability is a basic understanding of the overall system and the individual control circuits that make it work. All these circuits are relatively simple and once they are understood, tracking down any trouble should be a straight forward job.

Most of any problems will be caused by "field" devices: pressure switches, limit switches, and rotary speed switches. The following inspection of these items should be made on a weekly basis:

1. Pressure Switches These switches are set to operate (contact closes) at a pressure of 90 psi. To check the operation of each switch, reduce the pressure to 90 psi and determine that the contact opens. Be sure to increase the pressure back to operating level (100 psi) after this check.

2. Track Mounted Limit Switches Check for moisture intrusion and mechanical damage. Check tightness of limit switch arms. Also note that under normal operation the "final" track mounted limit switches (LSOT on the loading station side and LFOT on the run-out

station side) are never actuated. Every week these should be checked to confirm they are in good working order, as follows. Run the loading station launch vehicle manually forward until it stops automatically (stopped by rotary limit switch LSE). Holding down the Exit Brakes Reset pushbutton, run the launch vehicle forward until stopped by the action of LSOT. At this point someone must hold a temporary jumper on terminals 9 and 14 in the relay panel in order to remove LSOT from the circuit and enable the launch vehicle to be returned. Repeat this procedure with the run-out station launch vehicle (the appropriate jumper in this case is between terminals 9 and 17).

3. Rotary Limit Switches These switches are an essential part of the system controlling the speed and direction of the DC drive motor system. Therefore, it is very important that they be kept in good working order. Remove the cover of each switch and inspect for dirt or moisture. Also inspect each of the four switch actuating mechanisms for freedom of action.

4. Rotary Speed Switches Check for moisture intrusion and mechanical damage.

5. Tachometers Inspect each tachometer for moisture intrusion. Also inspect the coupling between the

tachometer and the motor shaft for tightness.

6. DC Motor Remove the inspection covers on the commutator end and inspect the commutator, brushes, and brush rigging for abnormal wear or color. Refer to the motor manufacturer's maintenance manual for other maintenance procedures.