Arrow Dynamics, Inc.
P.O. Box 160038
Freeport Center Bldg. H-12
Clearfield, UT 84016
Tel (801)825-1611
Fax (801)776-2671
eng@arrowdynamics.com

Bulletin No.: 99-1 rev. A
Release Date: April 2000
Effective Date: April 2000
Supercedes: 99-1
Completion Date: N/A

TECHNICAL BULLETIN

Ride Manufacturer: Arrow Dynamics, Inc.	Production Year: All
Ride Name: All Arrow Steel Coasters	Serial No.: All
Model: See Above	

Abstract Of Issue:

Roller Coaster Track and Structure Inspection and Maintenance

Reason For Release:

This document is being presented as part of the requirements of Section 4 - Manufacturer's Responsibility of the ASTM F 853 - 98; Maintenance procedures for Amusement Rides and Devices.

This document shall be considered as additional information and clarification to the existing Arrow ride manual. It shall supercede information contained in the original manual except for those items that may be considered specific to that particular coaster.

Action To Be Taken:

Incorporate this technical bulletin in the Arrow ride manual & park maintenance program.
Sign the attached acknowledgement and return to Carolyn Weaver

Detail Of Issue:

See Attached

ARROW

TECHNICAL BULLETIN 99-1
Revision A Date: April 2000

Roller Coaster Track and Structure Inspection and Maintenance

PURPOSE:

Arrow has many coasters in operation today, with several of them now reaching the age of at least 25 years. The most important factor in the safety of any steel coaster regardless of its age is the diligence of the inspection and repair. If proper inspection and repair techniques are performed, the overall safety of the ride should not be in question.

SCOPE:

The following inspection procedures for track and structure are intended to be the minimum required in order to safely operate the ride. If problems are found while performing the inspections, more diligent inspections shall be performed at the location of the problem and at similar locations throughout the ride as described in Section 5.0, Increased Inspection based upon Indication.

1.0 Level 1 Inspection

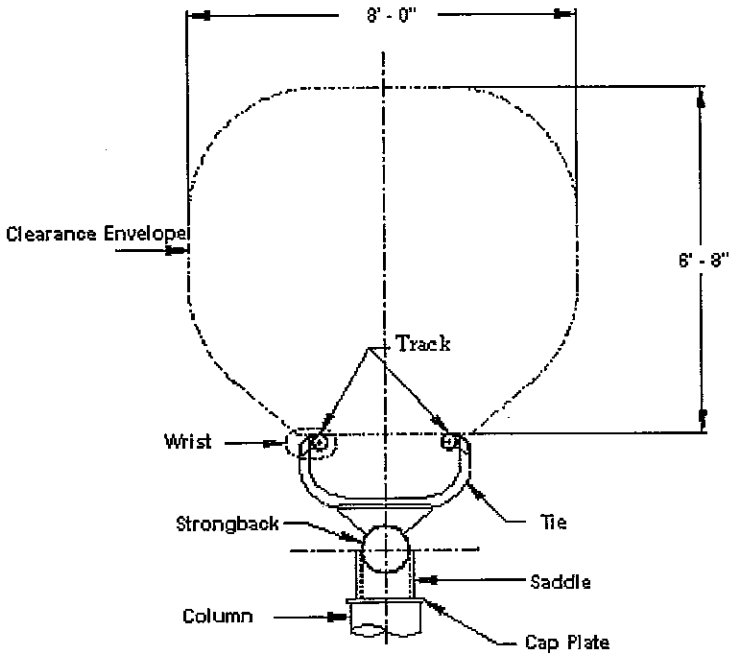


Figure 11-1 Standard Track Section

1.1 The entire track must be visually inspected in the Level 1 inspection to ensure there are no foreign objects in the area between the rails and strongback, or within the ride clearance envelope. Walking up the lift to view the high parts of the ride and walking on or below the track for the entire course must be done as a minimum. If there are objects that obstruct the view of the track from below, accommodations must be made to easily view the track. While walking the track, observe the track members, bolted connections, and welded connections for signs of loosening, cracking, or other unusual problems.

1.2 If problems are found while performing the inspections, more diligent inspections shall be performed at the location of the problem and at similar locations throughout the ride as described in the increased inspection based upon indication section 5.0.

2.0 Level 2 Inspection

A visual inspection of the track and structure should be made to look for member and connection problems.

2.1 A **close visual inspection of welds** should be made in the following areas:

2.1.1 Welds in the tie and all welds from the tie to rail and tie to strongback. High G areas and inverted elements of the ride should be done in the Level 2 inspection.

2.1.2 Saddle welds to strongback and column cap plates. High G areas and inverted elements of the ride should be done in the Level 2 inspection.

2.1.3 Welded joints in the rail and strongback. High G areas and inverted elements of the ride should be done in the Level 2 inspection.

2.1.4 All previous repairs and/or replacement areas should be done in the Level 2 inspection.

2.2 A **close visual inspection of the track rails** should be made in the following areas:

2.2.1 Running surface of road and guide wheels. High G areas and inverted elements of the ride should be done in the Level 2 inspection.

2.3 A **close visual inspection of bolted connections** should be made in the following areas:

2.3.1 Bolts in track bolted flanges and saddles. High G areas and inverted elements of the ride should be done in the Level 2 inspection. Bolts should be visually and/or hand checked for adequacy.

2.4 If problems are found while performing the inspections, more diligent inspections shall be performed at the location of the problem and at similar locations throughout the ride as described in the increased inspection based upon indication section 5.0.

3.0 Level 3 Inspection

A visual inspection of the track and structure should be made to look for member and connection problems.

3.1 A **close visual inspection of welds** should be made in the following areas:

3.1.1 Welds in the tie and all welds from the tie to rail and tie to strongback. All areas not covered in the Level 2 inspection should be done in the Level 3 inspection.

3.1.2 Saddle welds to strongback and column cap plates. All areas not covered in the Level 2 inspection should be done in the Level 3 inspection.

3.1.3 Column welds to base plates and mitered corners of all columns.

3.1.4 20% of all remaining welds outside those mentioned above in the track and structure should be closely inspected on a rotating basis for cracking in the weld or adjacent parent material. The welds inspected should be widely dispersed.

3.2 A **close visual inspection of the track rails** should be made in the following areas:

3.2.1 Running surface of road and guide wheels. All areas not covered in the Level 2 inspection should be done in the Level 3 inspection.

3.3 A **close visual inspection of bolted connections** should be made in the following areas:

3.3.1 Bolts in track bolted flanges and saddles. All areas not covered in the Level 2 inspection should be done in the Level 3 inspection. Bolts should be visually and/or hand checked for adequacy.

3.3.2 Base plate anchor bolts. An inspection of base plate anchor bolts should be made in order to verify that the anchor bolt is intact throughout its length by "sonically" testing the bolts for adequacy. The grout under the base plate should be visually inspected for excessive cracking in the grout, or for signs that the base plate is not continuously in contact with the grout. This is best observed while the ride is operating. Any anchor bolt in question shall be subject to ultrasonic inspection.

3.3.3 Bolts in the bolted flanges of all columns. All bolts should be visually and/or hand checked for adequacy.

3.3.4 20% of all remaining bolted connections outside those mentioned above should be visually and/or hand checked on a rotating basis. The bolts inspected should be widely dispersed.

3.4 If problems are found while performing the inspections, more diligent inspections shall be performed at the location of the problem and at similar locations throughout the ride as described in the increased inspection based upon indication section 5.0.

4.0 Level 4 Inspection

The entire track and structure should be inspected both visually and otherwise to look for member and connection problems.

4.1 A **thorough inspection of welds** in the following areas using Non Destructive Testing (NDT) methods are to be applied in the following areas, in accordance with the American Society for Testing and Materials (ASTM) Vol. 03.03 Nondestructive Testing. Magnetic particle testing applied in accordance with ASTM-E-709 is recommended.

4.1.1 Track rails, strongback, and ties. 20% of the track in the high G areas and inverted elements of the ride and 5% of the track in the remaining ride areas should be inspected using magnetic particle testing at each level 4 inspection on a rotating basis. The welds inspected should be widely dispersed in each area.

4.1.2 Saddle welds to strongback and column cap plates. 20% of the saddles in the high G areas and inverted elements of the ride and 5% of the saddles in the remaining ride areas should be inspected using magnetic particle testing at each level 4 inspection on a rotating basis. The welds inspected should be widely dispersed in each area.

4.1.3 All previous repairs and/or replacement areas should be done at each Level 4 inspection.

4.1.4 In the event that multiple unacceptable defects are found in the original inspection, an additional 20 % of the items affected are to be examined to the same standards. If multiple unacceptable defects are found on those items, 100 % of the items are to be subject to inspection by magnetic particle testing.

4.2 A **close visual inspection of welds** should be made in the following areas:

4.2.1 Track rails, strongback, and ties. All of the track outside of the areas receiving magnetic particle inspection should be done at each level 4 inspection.

4.2.2 Saddle welds to strongback and column cap plates. All saddles outside of the areas receiving magnetic particle inspection should be done at each level 4 inspection.

4.2.2 All column base plates – base plate welds to column and gussets; gusset welds to columns.

4.2.3 All column pipe size bell reducers and reducer cones.

4.2.4 All tower top beams - welds to cap plates and columns.

4.2.5 20% of all remaining welds outside those mentioned above should be put through a close visual inspection on a rotating basis, checking for cracking in the weld or adjacent parent material. The welds inspected should be widely dispersed.

4.2.6 If problems are found while performing the inspections, more diligent inspections shall be performed at the location of the problem and at similar locations throughout the ride as described in the increased inspection based upon indication section 5.0.

4.3 A **close visual inspection of the track rails** should be made in the following areas:

4.3.1 Running surface of road and guide wheels. All track should be done in the Level 4 inspection.

4.4 A detailed inspection of base plate anchor bolts should be made in order to verify that the anchor bolt is intact throughout its length. 20% must be accomplished by a testing agency capable of ultrasonically testing the bolts for adequacy on a rotating basis. All bolts in a base plate should be done at one time, but base plates groups should be widely dispersed. The remainder of the bolts shall be checked "sonically." Any anchor bolt in question "sonically" shall be subject to ultrasonic inspection.

4.5 The grout under the base plate should be visually inspected for excessive cracking in the grout, or for signs that the base plate is not continuously in contact with the grout. This is best observed while the ride is operating.

4.6 All bolted connections in the structure must be visually and/or hand checked for adequacy.

5.0 Increased Inspection based upon indication

5.1 In the event of a visual crack indication, magnetic particle testing inspection is to be applied to a six-inch radius circular area around the indication. Magnetic particle testing applied in accordance with ASTM-E-709 is recommended. If the presence of an unacceptable crack is confirmed in accordance with AWS D1.1-98 section 6 part c., it is to be rectified per AWS D1.1. Arrow can provide an approved repair procedure.

The presence of an unacceptable crack requires the following additional inspection to be done as a minimum:

5.1.1 For cracking in a track pipe rail: The application of magnetic particle, or equivalent, testing inspection is required on both rails for a length of the track equal to three ties on both sides of the original defect. The three-tie rule is to apply to every unacceptable finding.

5.1.2 For cracking in a track tie or its connection to the rail or strongback: The application of magnetic particle, or equivalent, testing inspection is required on all welds in the track tie, rails, and strongback for a length of track equal to three ties on both sides of the original defect. The three-tie rule is to apply to every unacceptable finding.

5.1.3 For cracking in a saddle: The application of magnetic particle, or equivalent, testing inspection is required on the saddle and all welds connecting it to the strongback and cap plate for the column affected and one column on each side of the original defect. This inspection is to apply to every unacceptable finding.

5.1.4 For cracking in a column support: The application of magnetic particle, or equivalent, testing inspection is required on all welds of the column and its connection to the base plate and cap plate for the column affected and one column on each side of the original defect. This inspection is to apply to every unacceptable finding.

5.2 In the event that a loose, broken or severely corroded bolt is found, that bolt system and all other bolt systems in that connection are to be replaced. Arrow can provide an approved bolt system and tensioning procedure. The presence of a bolting problem requires the following additional inspection to be done as a minimum:

5.2.1 For a bolting problem in a track splice: All bolts in track splices shall be checked for proper tension at one splice on each side of the original defect. This inspection is to apply to every unacceptable finding.

5.2.2 For a bolting problem at a saddle: All bolts in the saddle connection shall be checked for proper tension at one saddle on each side of the original defect. This inspection is to apply to every unacceptable finding.

5.2.3 For a bolting problem in a column or tower: All bolts in the support shall be checked for proper tension on all other connections in the support affected and one support on each side of the original defect. This inspection is to apply to every unacceptable finding.

ACKNOWLEDGMENT

I hereby acknowledge receipt of the information contained in Technical Bulletin 99-1 Rev A.

I understand that Arrow Dynamics, Inc. will not assume any responsibility for injuries or other liabilities that may result from negligence in complying with information contained in this bulletin.

Name (Print or Type)	Park
Signature	Date

COMMENTARY
TECHNICAL BULLETIN 99-1

Commentary on Frequency of Inspections

The type and percentage of items inspected at each inspection level has been determined based on the typical stress level of the item, philosophy in design of the item, availability of redundant load paths, and history of problem locations on rides in the past. The general philosophy may apply to rides other than those produced by Arrow, but may not be applicable to specific items based on different design and manufacturing parameters.

Level 1 Inspections
The Level 1 inspections should be done as part of the start-up procedure.

Level 2 & 3 Inspections
The Level 2 & 3 inspections are the intermediate inspections that are a portion of the level 4 inspection. These inspections should be evenly distributed during the running season. An owner should establish a specific program for level and frequency of inspections based on his or her historical experience with the ride. If an inspection history is not available, the following is recommended as a guideline.

A. The Level 2 inspections should be done 2 to 4 times between each Level 3 inspection.
B. The Level 3 inspections should be done 2 to 4 times between each Level 4 inspection.

Level 4 Inspections
The Level 4 inspection should typically be done in the off season in conjunction with the ride tear down. If the ride is located in an area where freeze-thaw cycles occur in the off season. The level 4 inspection should be done at the end of the off season.

Increased Inspections upon Indication – section 5
Upon finding an indication of a problem in a member, welded connection, or bolted connection, the repair of the problem and the further required inspection should take place at the earliest possible time. It is the owner/operator's responsibility to determine if and how long the ride can operate with the observed indication based on the severity of the problem, location of the problem, and its ability to be inspected for propagation while the ride is operating. No repair or further inspection should be delayed for more than one week under any circumstances. Arrow can provide assistance if requested by the owner.

Commentary on High G Areas and Inverted Elements

The location of the start and stop of inverted elements is at the low point of the track before and after the inversion. High G areas will typically extend out beyond these low points in each direction. The determination of high G areas on a ride can be determined several ways as

follows:

A. Accelerometer Run Results
   1. Vertical G's above 3.0 g
   2. Lateral G's above 1.0 g
   3. Areas with a lateral "jerk" over 10 – measured as Change in G-force per second.

B. Common Sense Approach
   1a. Major pullout areas at the bottoms of hills – These usually range from 3 g to 3.5 g
   1b. Entry and exit areas around inversions – These are usually 3.5 g +
   2. Horizontal curves where lateral forces push you into the sides of the seat larger than what you would feel lying on your side.
   3. Any area where there is a quick change in G-forces causing a noticeable bump or jolt when riding the coaster.

C. If the above two options are not available, Arrow can be contacted for further specific advice for the coaster being considered.

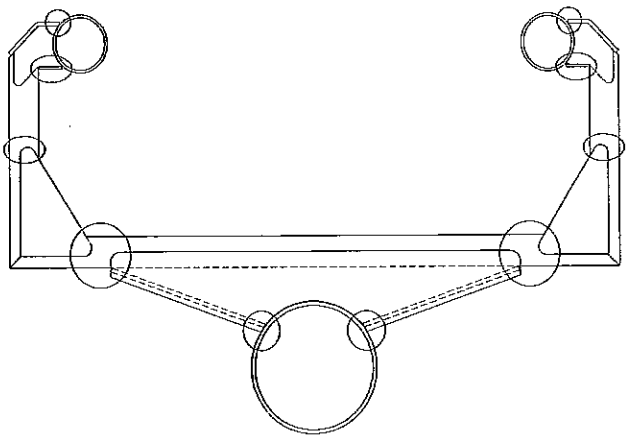
Commentary on Welded Connections & Track Rails

Close Visual Inspection – Sections 2.1, 2.2, 3.1, 3.2, 4.2, & 4.3 with all subsections.
The close visual inspection called out in the above sections does require the inspector to walk on or adjacent to the track where all members and welds can be observed. The use of binoculars, mirrors, or other methods to look at the hard to view areas is recommended. The use of a man basket or man lift is not required unless it is the only way to view the track.

Non-Destructive Testing – Sections 4.1& 5.1 with all subsections.
Non Destructive Testing on coated surfaces is possible with some NDT methods if the certified testing agency is satisfied that the results are accurate. It may be necessary to remove the coating chemically or mechanically if it is in poor condition of if the testing agency requires it for further inspection.

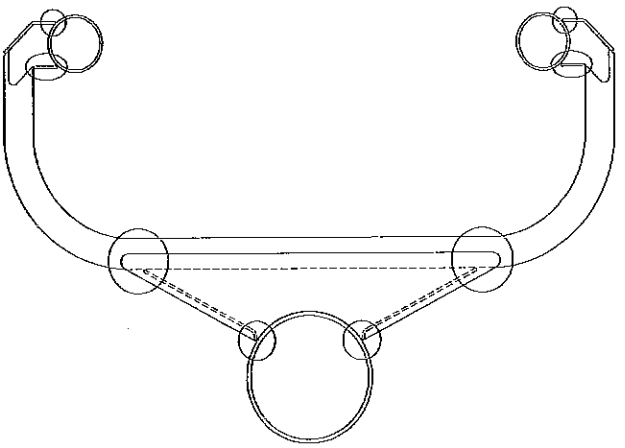
Inspection Locations on Ties & Saddles – Sections 2.1.1,2.1.2,3.1.1,3.1.2,4.1.1,4.1.2,4.2.1,4.2.2.
There is great length of fillet welds on most Arrow ties and saddles. The following pictures show areas of concern for inspection. If the circled areas are free of indications or problems, the rest of the areas on the tie or saddle need not be investigated.

MAJOR AREAS OF CONCERN FOR MAGNETIC PARTICLE & CLOSE VISUAL INSPECTION

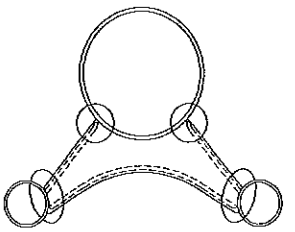


R.A.T./CORKSCREW WELDED TIE

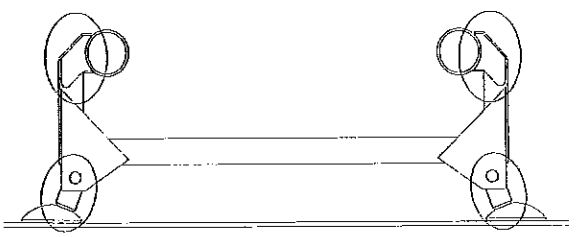
MOUSE



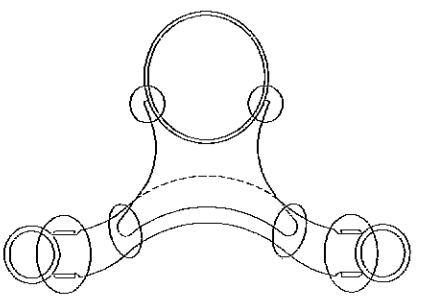
R.A.T./CORKSCREW BENT TIE



SUSPENDED

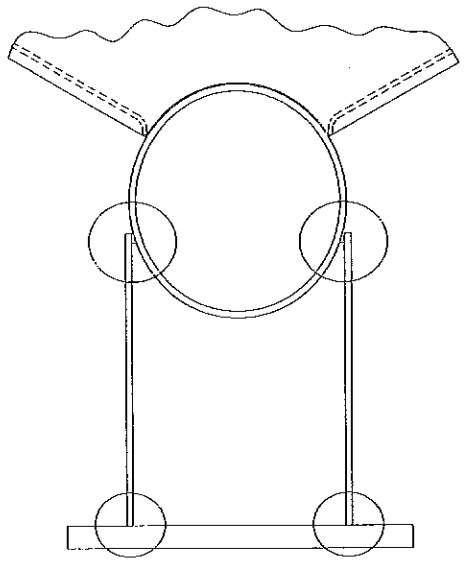


LEG & SOCKET



ARROWBATIC

MAJOR AREAS OF CONCERN FOR MAGNETIC PARTICLE & CLOSE VISUAL INSPECTION



Commentary on Bolted Connections

Close Visual Inspection – Sections 2.3.1, 3.3.1, 3.3.3, 3.3.4, & 4.6
The close visual inspection called out in the above sections is not intended to test the pre-load that is on the bolt or if the nut has been "torqued" properly. The visual and/or hand checking is simply to see that the bolt is not missing, broken, rattling loose, or severely corroded. The use of hand checking is sometimes necessary due to the fact that while on the track, you cannot always visually see each bolt. It is acceptable to reach around to check bolts out of site rather than hanging upside down to see them. The use of binoculars, mirrors, or other methods to view the hard to see connections is acceptable.

Checking for proper tension – Sections 5.2.1, 5.2.2, 5.2.3
When checking bolts for proper pre-load tension, it is not recommended that the nuts actually be rotated on the bolts. The intention is not to re-tighten any bolts; in fact if a loose bolt is found it is to be completely replaced along with the rest of the bolting system including nuts, washers, washer plates, and tension indicating washers or devices for the entire connection per section 5.2. If a local testing agency is capable determining tension in a bolt while in place without greatly disturbing the bolt system, that is the preferred method. Arrow does not typically recognize the use of a torque wrench as a proper indication of bolt tension for track and structure, but due to

the simplicity of use and availability, it is allowed as a check for these sections. Please be aware that painted and corroded bolts will give false readings for bolt tension if based on torque. A torque wrench will however find extremely loose bolts or break those that are extremely corroded or already cracked. Arrow can provide standard torque values upon request.

Bolt/Nut Marking Method

Marking the end of the bolted connection in such a way that a visual inspection can detect any rotation of the nut is good practice. This makes the close visual inspection even more indicative of proper tension and removes the need for anything other than visual to satisfy section 5.2. Unfortunately if this system was not in place as the time the bolts were installed, it cannot be used to mark existing bolts. It is recommended that this be done for all future replacement bolts.

Bolt Replacement

All bolts replaced due to a problem should be installed with a device that directly measures bolt tension not torque. Arrow can provide bolt system specifications, details, tension measuring devices, assembly procedure and parts upon request.

Commentary on Anchor Bolts – Sections 3.3.2 & 4.4

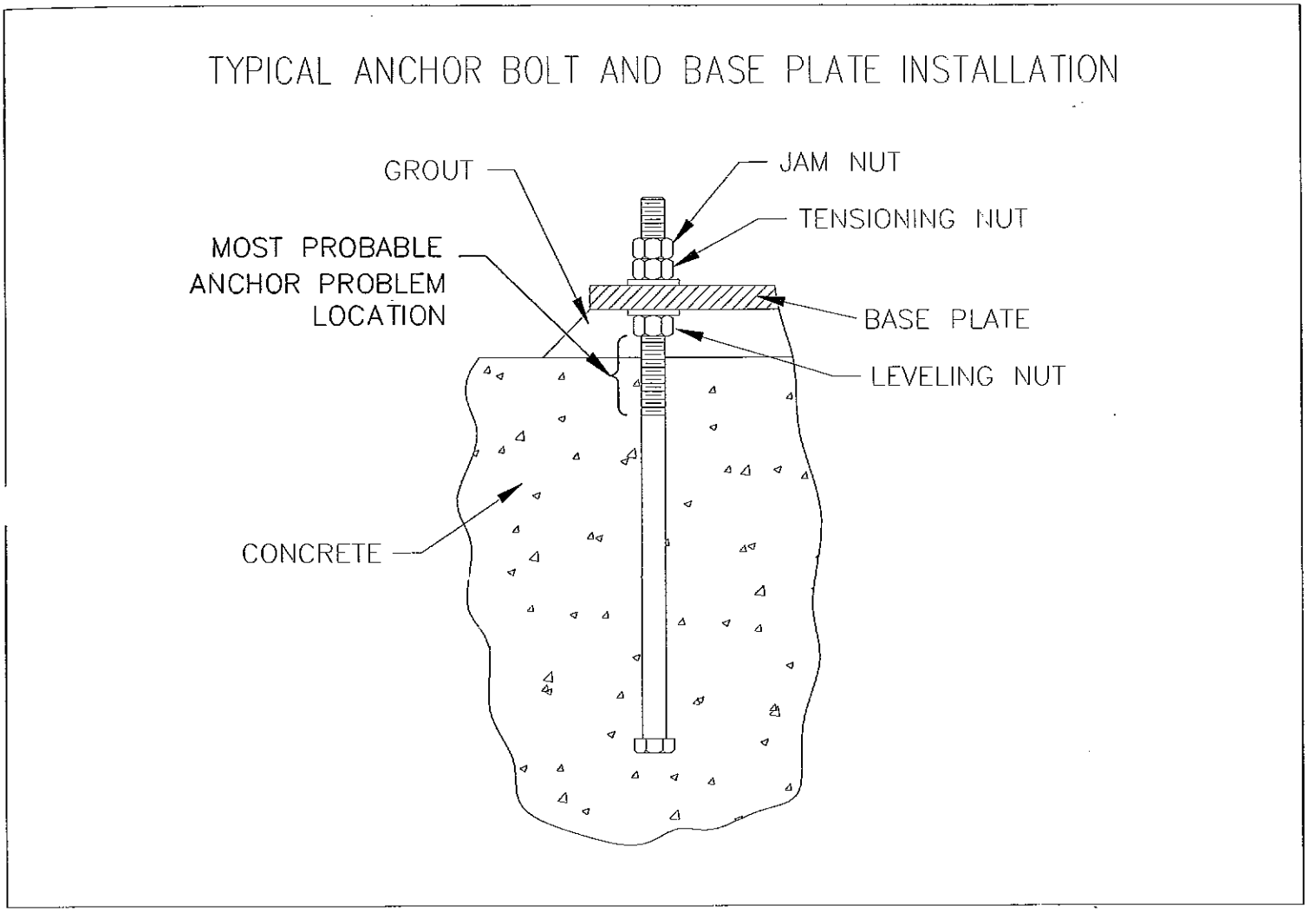
Anchor bolts can be inspected "sonically," simply by hitting the tops of the anchor bolts with a hammer and listening to the noise it makes. An intact anchor bolt will "ring" compared to a broken anchor bolt that will "clunk" when struck. Any anchor bolt in question shall be subject to ultrasonic inspection.

Using a steel hammer might cause damage to the anchor bolts over time. A hard rubber hammer similar to the type used to change truck tires can instead be used while still maintaining a difference in tone between intact and damaged bolts.

For columns installed with anchor bolt leveling nuts:

Most Arrow coaster columns are installed on anchor bolts with the use of a leveling nut directly beneath the base plate. The nut directly above the base is then tensioned down to the base plate stretching the bolt down to the leveling nut. A jam nut is then installed to retain the top nut from spinning. Using this system, a few main points arise:

A. The anchor bolts are only tensioned to the leveling nut; the portion of the anchor bolt below the leveling nut is not tensioned at all. Therefore tensioning of the anchor bolts after installation is not recommended due to possible damage. Once the bolt has been tensioned and secured from rotating with a jam nut or otherwise it should not be re-tensioned.
B. Since the anchor bolt is secured to the base with nuts top and bottom, the portion of the anchor bolt above the base plate will appear completely sound and intact even if the bolt is completely separated from the portion embedded in the concrete. Testing of the anchor bolt length is the only method that assures the anchor bolt is in tact and not severely corroded.



For columns installed with leveling shims plates:
Some Arrow coaster columns are installed on anchor bolts with the use of leveling shim plates directly beneath the base plate. The nut directly above the base is then tensioned down to the base plate stretching the bolt into the concrete. Because of long-term relaxation of concrete, tensioning of anchor bolts will not be sustainable in most situations. Tensioning of the anchor bolts after installation is not recommended due to possible damage. Re-occurring contact problems between the base plate and foundations may require a fix to the grouting rather than the anchor bolts.

All anchor bolts at a particular column will be the same length. Therefore when testing bolts ultrasonically or sonically (with a hammer), the length will not be required to be known in advance. A problem exists if any anchor bolt at a particular column yields a different result than the others. For most applications, all anchor bolts of the same diameter on a job will be the same length.