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UL 3100

Outline of Investigation for Automated Guides Vehicles (AGVs)

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Summary of Topics

This first issue of the Outline of Investigation for Automated Guided Vehicles (AGVS), UL 3100, covers battery-operated automated guided vehicles (AGV's).

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INTRODUCTION

1 Scope

1.1 These requirements cover battery-operated automated guided vehicles (AGVs) that are intended to be used indoors in a commercial or industrial environment. The AGVs covered by this Outline include Industrial Truck AGVs (inherently load bearing), load bearing service AGVs, and non-load bearing service AGVs, as defined within this outline. Industrial truck AGVs are intended to be used in accordance with 1.2 and all AGVs shall be used in accordance with 1.3. The AGV is battery powered using either lead acid batteries or lithium ion based batteries that are charged through a conductive system while either on board or off board the vehicle.

1.2 The Industrial Truck AGV is intended to be used and installed in accordance with both the Safety Standard for Driverless, Automatic Guided Industrial Vehicles and Automated Functions of Manned Industrial Vehicles, ANSI/ITSDF B56.5-2012, and in accordance with the Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations, NFPA 505.

1.3 Portions of an AGV system, such as the charger, that are located off board the AGV, are intended to be installed in accordance with the National Electrical Code (NEC), NFPA 70.

1.4 This outline will indicate all requirements for battery powered AGVs and peripheral systems including the specific charging device intended to be used with the AGV.

1.5 This Outline does not include requirements for AGVs that function as people movers. Requirements for these devices are under consideration and may be included as part of a future revision.

1.6 This outline does not include requirements for industrial robots, which are covered under the Standard for Robots and Robotic Equipment, UL 1740.

1.7 This Outline does not include requirements for AGVs that function as commercial and industrial floor cleaning equipment. This equipment is covered under ANSI C22.2 No. 336, Particular Requirements for Rechargeable Battery-Operated Commercial Robotic Floor Treatment Machines with Traction Drives.

2 Components

2.1 Except as indicated in 2.2, a component of a product covered by this outline shall comply with the requirements for that component.

2.2 A component is not required to comply with a specific requirement that:

- a) Involves a feature or characteristic not required in the application of the component in the product covered by this outline; or
- b) Is superseded by a requirement in this outline.

2.3 A component shall be used in accordance with its rating established for the intended conditions of use.

2.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

3 Units of Measurement

3.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

4 Undated References

4.1 Any undated reference to a code or standard appearing in the requirements of this outline shall be interpreted as referring to the latest edition of that code or standard.

5 Glossary

5.1 The following terms apply for this document.

5.2 AUTOMATED GUIDED VEHICLE (AGV) – Any battery operated industrial truck or service vehicle that is operated autonomously without a driver.

5.3 INDUSTRIAL TRUCK AGV – An AGV that performs the same function as an industrial truck.

5.4 LOADING PLATFORM – The base or area on an AGV that is intended to support the load once it is placed on the base or loading area.

5.5 SERVICE AGV, LOAD BEARING – An AGV that is intended to perform a service function by carrying light loads, such as beverages to a table in a restaurant.

5.6 SERVICE AGV, NON-LOAD BEARING – AN AGV that is intended to perform a service function that does not require a load bearing means, such as scanning grocery store shelves for missing products.

CONSTRUCTION

6 General

6.1 Unless otherwise stated, compliance with the requirements in this outline is determined by evaluation and testing on a representative model of the AGV under evaluation.

6.2 AGVs covered by this outline shall be provided with a means of conductive connection to the external charging device. While connected to the charger, the AGV shall not be capable of being energized in manner that would allow movement of the AGV. Energizing systems for other than operation, such as communications, is allowed during charging.

6.3 No field modification of the AGV that could modify the AGVs operation, such as load capacity and the like, shall be permitted to be performed by the user. The user shall not be instructed on how to modify the AGV. Instructions shall indicate that no modification is allowed, see 51.8.

6.4 For all AGVs, the AGVs are considered suitable for use in a non-classified location. For all AGVs that are industrial truck based, and intended to be used in the same location as industrial trucks, the AGV may be used in an area that is classified, and the industrial truck AGV shall be suitable for the intended location in accordance with Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations, NFPA 505, for truck types E, EE and ES. For load bearing and non-load bearing AGVs intended to be operated in any area that is considered classified, further evaluation to determine suitability of the AGV in that location is required.

6.5 AGVs covered by this outline shall be evaluated for functionality in relation to safety systems that are used to protect people and property in the vicinity of the AGV or near the AGVs path of travel. Human overrides are allowed to shut down the AGV but shall not be the primary means of protecting people and property. See Protection Circuits and System Safety Analysis, Section 17.

6.6 For AGVs that are industrial truck based, and intended to be used in the same location as industrial trucks, this outline is intended to be used in conjunction with the Standard for Electrical-Battery-Powered Industrial Trucks, UL 583. This outline supplements or supersedes requirements contained in UL 583.

6.7 For service AGVs, load bearing or non-load bearing, the Outline contains all requirements necessary to evaluate the vehicle.

7 Battery and Battery Management Systems

7.1 General

7.1.1 The battery provided with the AGV shall be in accordance with 7.2 or 7.3.

7.1.2 For battery packs that are provided with an integral battery management system, the battery management system shall be evaluated as part of the battery pack in accordance with the requirements outlined below. If the battery management system or a portion of the battery management system resides in external components, such as the charger, then the combination of the external components and the battery pack are critical and shall be evaluated together in accordance with this outline, including faults in the battery management system on parts located outside the battery pack.

7.1.3 For swapped/removable batteries, the battery connections shall be keyed or configured in a manner that will prevent reverse polarity connections of the battery when it is replaced.

7.2 Lithium based batteries

7.2.1 Lithium based battery packs shall be provided with an appropriate Battery Management System (BMS), and shall be designed to safely withstand anticipated abuse conditions for the AGV involved. A lithium based battery pack used in AGVs covered by this Outline shall be in accordance with one of the following:

- a) The Standard for Batteries for Use in Electric Vehicles, UL 2580;
- b) The Standard for Batteries for Use in Light Electric Vehicle (LEV) Applications, UL 2271; or
- c) The Standard for Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made From Them, for Use in Portable Applications, UL 62133.

7.2.2 A lithium based battery pack in accordance with 7.2.1(c) is required to comply with the requirements in the Overcharge Test, 36.7, with single fault conditions in the battery control circuits; the Short Circuit Test, 36.8, with single fault conditions in the battery control circuits; Imbalanced Charging Test, 36.9; Shock Test, 36.11; and Vibration Test, 36.10.

7.2.3 A lithium based battery pack that relies on additional battery management external to the battery pack shall be subjected to the tests in 7.2.2 including single fault conditions in the battery control circuits external to the battery pack.

7.3 Lead acid batteries

7.3.1 Lead acid batteries shall be of the insulated type and measures shall be taken to reduce the risk of connections becoming loose and causing arcing or overheating.

7.3.2 For lead acid batteries that are enclosed, means shall be provided to vent the off-gassing during charging. No arcing or sparking parts shall be in the vicinity of the battery.

8 Chargers

8.1 For charging batteries, whether the battery is located on board the AGV or the battery is intended to be removed from the AGV, the charger shall be located off board the AGV and shall comply with one of the following:

- a) The Standard for Class 2 Power Units, UL 1310.
- b) The Standard for Power Units Other Than Class 2, UL 1012.
- c) The Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1.
- d) Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements, UL 62368-1.
- e) The Standard for Electric Vehicle (EV) Charging System Equipment, UL 2202.
- f) The Standard for Industrial Battery Chargers, UL 1564.
- g) The Standard for Battery Chargers for Charging Engine-Starter Batteries, UL 1236.

9 Transformers

9.1 Transformers provided as part of an AGV, shall comply with one of the following:

- a) Standard for Specialty Transformers, UL 506;
- b) Standard for Dry-Type General Purpose and Power Transformers, UL 1561; or
- c) Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and one of the following:
 - 1) Standard for Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2; or
 - 2) Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

10 Printed Wiring Boards

10.1 A printed-wiring board shall comply with the Standard for Printed-Wiring Boards, UL 796.

10.2 A printed-wiring board containing circuits involving a risk of fire or electric shock shall have a flame rating as specified in requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94 of V-2 minimum. Printed-wiring boards not involving a risk of fire or electric shock shall be rated HB minimum.

10.3 A conformal coating employed on the surface of a printed-wiring board, intended to be used for the acceptance of reduced spacings as described in Spacings and Separation of Circuits, Section 30, may be acceptable if it complies with the Standard for Printed Wiring Boards, UL 796.

11 Sensors and Controls

11.1 Sensors and controls provided to perform a safety function shall comply with the applicable requirements in the Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1.

11.2 With reference to 11.1, the safety functions includes load stability, load arrangement, oversized load detection, deviation from travel path, object sensing, low battery, safe starting, braking force, bumper activation, loss of braking, loss of power, maximum load determinations, and the like. Any system that involves a sensing device and/or control to mitigate a hazard shall comply with 11.1.

11.3 With reference to 11.2, the sensors for object sensing, bumper activation (if used), are required for all AGVs. The sensor for maximum load determination shall be required for all industrial truck based AGVs and load bearing service AGVs.

11.4 In addition to compliance with 11.1, the reliability and functionality of the safety system shall comply with the risk analysis and functional safety analysis in accordance with Section 17, Protection Circuits and System Safety Analysis.

11.5 AGVs shall be provided with an emergency stop switch that can be activated by a person in the vicinity of the AGV. The emergency stop switch shall be located such that a person can activate the switch without having to board the AGV, avoid moving parts (other than the AGV), not have to reach across live parts or inside any compartment. Software controlled or electronically controlled emergency stop functions may be provided in addition to the emergency stop switch but they shall not replace the emergency stop switch. The software or electronically controlled emergency stop means shall be subjected to the analysis of Section 17, Protection Circuits and System Safety Analysis.

12 Lasers

12.1 Equipment which employs laser-radiation shall be provided with documentation of compliance, as applicable, with the Federal requirements 21 CFR Part 1040 (Lasers) of the Department of Health and Human Services (DHHS).

13 Lamps / Horns / Alarms / Indicators

13.1 An AGV shall be provided with a signaling device to indicate when it is ready to start moving or when it is moving. The signaling device shall be both audible and visual. The visual signal shall be readily visible to people in the area of the AGV movement from any location around the AGV.

13.2 The signaling devices in 13.1 shall not have any means of manual override.

14 Object Detection and Avoidance

14.1 All AGVs shall be provided with a means to prevent injury or other hazards due to impact of the AGV with persons or with objects in the travel path. Object detection in the form of object sensing at a distance from the AGV shall be required for all AGV types. Industrial truck based AGVs may be provided with additional protection in the form of a bumper or touch activation. For all AGVs that will be used in the vicinity of the general public, object detection shall be supported by other means, such as protection that relies on bumpers or touch activation. All object detection and avoidance systems shall comply with the requirements in this section.

14.2 Object detection that is intended to sense objects in the vicinity of the travel path shall be capable of monitoring the travel path and peripheral areas such that objects entering the travel path are detected prior to moving in front of the AGV. If the AGV is intended to choose its own path or intended to choose a specific path in a guided system (e.g., fork in the road), the AGV object detection shall also be capable of monitoring the areas to sides of the AGV to prevent turning into an object.

14.3 For object detection systems that are monitoring the area in the vicinity of the travel path, the effective sensing distance shall be greater than the distance required to stop the AGV. See Section 15, Brakes and Braking Distance.

14.4 For AGVs used in and around the general public, the object detection provided by the sensors in 14.2 shall be supplemented by additional systems that further mitigate the risks associated with people moving in front of the AGV within the braking distance, people bumping into the AGV, contact with the AGV from other objects being carried by the general public, and the like. Object detection and avoidance systems relying on bumpers or physical touch sensors shall not exert more than 22 N (5 lbf) on the person or object and the AGV shall stop moving to prevent additional forces being exerted on the person or object. The bumper shall be tested in accordance with the Bumper Activation Test, Section 42.

14.5 The reliability and functionality of the object detection system or bumper system shall comply with the risk analysis and functional safety analysis in accordance with Section 17, Protection Circuits and System Safety Analysis.

14.6 Regardless of object detection type, the object detection system or individual components shall not be provided with a means to override the system. Debris or objects that are inadvertently placed on the AGV shall not have an effect on the reliability of the system.

15 Brakes and Braking Distance

15.1 Braking systems shall be provided on all AGVs. The braking system shall perform the functions of slowing the vehicle for motion control and hazard avoidance, stopping the vehicle for motion control and hazard avoidance, and holding (restraining) the vehicle from moving when it is required to be stationary.

15.2 Braking systems shall automatically operate to safely stop the vehicle when an object is detected in the travel path. Braking systems shall also automatically operate to safely stop the vehicle and prevent coasting in the event of power loss, including power loss due to a fault, due to the battery being fully discharged, or the like.

15.3 Braking systems shall be coordinated with any object sensing devices in order to stop the vehicle within the distance that the sensors can detect the object. The vehicle shall be capable of stopping while fully loaded prior to contacting the detected object. For AGVs that use a bumper or touch system for detection, the braking system shall activate upon detection in a manner that prevents a hazard in accordance with Section 14, Object Detection and Avoidance.

15.4 The braking action of the AGV shall not cause instability of the AGV or its load, if any. The AGV shall be provided with instructions detailing proper loading such that braking will not cause load stability due to misloading.

15.5 Either separate or as part of the overall braking system, an emergency brake shall be provided that will stop the AGV in a safe manner once a fault is detected in any system that is included as part of the overall motion control of the AGV.

15.6 Either separate or as part of the overall braking system, a parking brake shall be provided to prevent inadvertent movement of the AGV when it is intended to be parked, such as while charging.

15.7 Either separate or as part of the overall braking system, a service brake shall be provided such that if the AGV requires maintenance and it is being moved manually, the person or persons moving the AGV can apply brakes to stop or slow the motion of the AGV.

15.8 With reference to 15.5, 15.6, and 15.7, these brake functions can be separate systems or components or can be part of one overall system. As long as the brake functions are included, one braking system can satisfy the requirements. The brakes can be electromechanical, electrical or mechanical in nature.

15.9 Electromechanical brakes that operate at hazardous voltage levels shall comply with Part XVI, Miscellaneous Devices, in the Standard for Industrial Control Equipment, UL 508. Mechanical brakes shall be subjected to the Brake Test, Section 39.

15.10 The braking system, and its components and functions, shall comply with the risk analysis and functional safety analysis in accordance with Section 17, Protection Circuits and System Safety Analysis.

16 Ramp/Slope Operation

16.1 The AGV shall be capable of meeting all requirements for operation and control on an even grade and a sloped grade up to 3% of grade. If the AGV is capable of operating on a sloped grade above 3% based on manufacturer's specifications, then the AGV shall be evaluated for use on that grade and that maximum grade. AGVs not evaluated for use on a grade exceeding 3% shall be marked in accordance with 49.8.

16.2 The sloped grade mentioned in 16.1 includes both uphill and downhill operation.

17 Protection Circuits and System Safety Analysis

17.1 The AGVs protective circuits, and/or control circuits, shall undergo a safety analysis to verify that all potential hazards associated with the design are addressed in this evaluation. A circuit is to be included if it contains a circuit or a component that is considered critical for mitigating a fire, shock, explosion, or injury hazard in accordance with this Outline.

17.2 For battery management systems, the protective circuit shall maintain the cells within their normal operating region for charging and, if normal limits are exceeded, the protective circuit shall limit or shut down the charging or discharging to prevent excursions beyond normal operating limits. Compliance is determined by the analysis of 17.4 and the tests in this outline. If a battery management system is integral to a battery pack complying with Section 7, Battery and Battery Management System, then no further analysis is required.

17.3 Protection circuits used to monitor operational parameters that are critical to safe operation of the AGV shall also be evaluated based on the requirements in this section as applicable. Compliance is determined through a review of the design and the overall system, including the safety analysis of 17.4 and the tests in this outline, taking into account the end use application of the AGV. For end use application consideration, additional levels or more stringent protections shall be provided for AGVs used among the general public when compared to industrial truck AGVs. Examples of operational parameters that are considered to be linked to safety are shown below. This list shall not be considered all inclusive.

- a) Speed control;
- b) Starting control;
- c) Braking functions;
- d) Load stability determination;
- e) Load arrangement;
- f) Object avoidance;
- g) Load management and maximum load sensing;
- h) Path selection/action upon path deviation;
- i) Low Battery determination; and
- j) Loss of power controls.

17.4 An analysis of potential hazards, due to component/system faults (including an FMEA) or operation parameter faults, shall be conducted on the AGVs electrical system, including the charger and other safety circuits as needed, to determine that events that could lead to a hazardous condition have been identified and addressed through design or other means. Documents that can be used as guidance for the safety analysis include:

- a) The Standard for Analysis Techniques for System Reliability – Procedure for Failure Mode and Effects Analysis (FMEA), IEC 60812;
- b) The Standard for Fault Tree Analysis (FTA), IEC 61025;
- c) The Potential Failure Mode and Effects Analysis in Design (Design FMEA), Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA), SAE J1739; and
- d) The Procedures for Performing a Failure Mode, Effects, and Criticality Analysis, MIL-STD-1629A.

Other standards that are considered to provide equivalent analysis methods and results are also acceptable.

17.5 The analysis in 17.4 is utilized to identify anticipated faults in the system or its operational parameters which could lead to a hazardous condition and the types and levels of protection provided to mitigate the hazards. The analysis shall consider single fault conditions in the protection or control circuits as part of the anticipated faults.

17.6 When conducting the analysis of 17.4, active device shall not be relied upon for critical safety unless:

- a) They are provided with a redundant passive protection device; or
- b) They are provided with redundant active protection that remains functional and energized upon loss of power/failure of the first level active protection;
- c) They are determined to fail safe upon loss of power to the active circuit; or
- d) They are part of a protective circuit that has been shown to comply with an appropriate Functional Safety standard listed in 17.7, with a safety level defined by a corresponding hazard and risk analysis.

17.7 Devices relied upon for critical safety as noted in 17.4 shall be tested for functionality in accordance with appropriate functional safety requirements unless already evaluated through the other tests of this outline. Functional safety criteria can be found in one of the following standards as appropriate to the design of the electronic and software protection scheme:

- a) The Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, and the Standard for Software in Programmable Components, UL 1998, and Safety functions incorporating electronic technology, C22.2 No. 0.8;
- b) The Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1 and Automatic Electric Controls – Part 1: General Requirements, CSA C22.2 E60730-1;
- c) The Standard for Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems – Part 1: General Requirements, IEC 61508-1, and all parts; and

- d) The Standard for Safety of Machinery – Safety Related Parts of Control Systems – Part 1: General Principles for Design, ISO 13849-1, and the Standard for Safety of Machinery – Safety Related Parts of Control Systems – Part 2: Validation, ISO 13849-2.

Other standards that are considered to provide equivalent analysis and results are also acceptable.

18 Open Bus Bar Connection Systems

18.1 An AGV that uses an open bus bar connection system to automatically conductively connect to the charging system shall be constructed so that the connection system is not located in a classified area.

18.2 The connection system shall have maximum operating voltages less than 60 V dc and shall not allow make and break under load unless evaluated for that use.

18.3 Copper bus bars shall be used. If the bus bars are bent at any point in the design of the connection, there shall be no evidence of cracks in the copper.

18.4 The current density of the bus bar shall not exceed the values specified in Table 18.1 unless the bus bar has characteristics that do not result in maximum bus bar temperatures exceeding the values in Table 33.1. Forced air ventilation is allowed to maintain the bus bar temperature below the values in Table 33.1.

Table 18.1
Rating and sizes of single bus bars – 800 amperes maximum

Current rating in amperes	Copper bus			
	Bus size ^{ab}		Cross section	
	mm	(Inches)	mm ²	(Inch ²)
225	3.2 by 22.2	(0.125 by 0.875)	70.3	(0.109)
400	6.4 by 38.1	(0.250 by 1.500)	242.0	(0.375)
600	6.4 by 50.8	(0.250 by 2.000)	322.6	(0.500)
800	6.4 by 76.2	(0.250 by 3.000)	483.9	(0.750)
NOTES – 1 See 18.5 – 18.7. The minimum contact area at a clamped joint shall provide not less than 1 square inch (6.5 cm ²) per 200 amperes. ^a A bus bar having other dimensions is allowed when it has not less than the cross-sectional area specified in the table and when it has equivalent rigidity. ^b Minimum conductivity of 55 percent of International Annealed-Copper Standard.				

18.5 The cross section of the bus shall not be reduced by more than 5 percent due to rounding or shaping.

18.6 Removing part of the bus material for slots or holes (whether used or not) is allowed when:

- The remaining material at any cross section along the length of the bus bar has at least 70 percent of the required ampacity in accordance with Table 18.1 and 18.5, and
- The remaining metal in any 152 mm (6 inch) length of bus is at least 93 percent of the metal of a bus having the required ampacity in accordance with Table 18.1 and 18.5. For example, a 25.4 mm (1 inch) wide bus is capable of having 7.1 mm (9/32 in) holes on 25.4 mm centers or a 102 mm (4 inch) wide bus is capable of having 10.3 mm (13/32 inch) wide slots 81.3 mm (3.2 inches) long every 152.4 mm (6 inches).

Exception: The above limitations do not apply to a bus bar having characteristics that do not result in maximum bus bar temperatures exceeding the values specified in Table 33.1 under the test conditions indicated in Temperature Test, Section 33.

18.7 The limitations on current density mentioned in Tables 18.1 do not apply to a:

- a) Connecting strap, bus, or similar device comprising a part of a circuit breaker, switch, or fuseholder employed in the unit.
- b) Portion of a strap, bus, jumper, or similar part adjacent and connected to a terminal of a switch, circuit breaker, or fuseholder, and not more than 1 inch (25.4 mm) from the terminal, when a reduced cross section in that portion is required because of the recessing of the terminal or because of barriers adjacent to it.

19 Parts Subject to Pressure

19.1 Any part or system within an AGV that is subjected to vapor or liquid pressure shall be rated and found suitable for the application. Compliance is determined by the Hydrostatic Strength Test, Section 44.

19.2 Pressure relief valves that are provided in the pressurized system shall be included in the safety analysis of Section 17. A pressure relief valve shall be installed such that the valve drains back to a reservoir or to open air. If venting to open air, the discharge opening shall be located and directed so that no moisture is discharged onto electrical parts and so that no discharge is directed outward towards persons in the area.

INDUSTRIAL TRUCK BASED AGVs

20 Load Handling Device

20.1 The AGV provided with an actuator for load handling shall be provided with an emergency stop switch that will shut down power to the actuator. The emergency stop switch required to perform this shut down can be incorporated into the emergency shut down switch reference in 11.4 or can be provided as a separate device.

20.2 The AGV shall be provided with a system or interlock that prevents vehicle movement if the actuator is moving or is not seated in the travelling position as indicated by the manufacturer.

20.3 Visible or audible signals shall be provided to indicate that the actuator is prepared to move or is moving. This indicator can be combined with the AGV movement indicator referenced in 13.1.

20.4 A means shall be provided to limit the motion of the actuator unless the design anticipates and intends for a full range of motion. Limiting means may include mechanical stops to restrict motion or may include electrical components or programmable components to limit the range of motion. When mechanical stops are provided, they shall be capable of stopping the motion of the actuator under the conditions of rated load, maximum speed, and maximum extension. The mechanical means shall comply with the Endurance of Actuator Stop Means, Section 45. When electrical or programmable components are provided to restrict the motion of the actuator, the circuit or component shall comply with the risk analysis and functional safety analysis in accordance with Section 17, Protection Circuits and System Safety Analysis.

21 Towing / Load Capacity

21.1 For AGVs that have towing capability, the manufacturer shall specify the maximum drawbar pull force and the normal rated drawbar pull force for the AGV in Newtons (pounds). These values shall be specified in accordance with ANSI/ITSDF B56.5, clause 8.2.

21.2 For AGVs that have load capacity ratings, the manufacturer shall specify the maximum rated load capacity of the AGV in Newtons (pounds). These values shall be specified in accordance with ANSI/ITSDF B56.5, clause 8.3.

21.3 A means shall be provided to prevent overloading of the AGVs towing capacity or loading capacity, and that means shall comply with the risk analysis and functional safety analysis in accordance with Section 17, Protection Circuits and System Safety Analysis.

SERVICE AGVs

22 Enclosure of Hazardous Live Parts and Moving Parts

22.1 General

22.1.1 AGVs shall be constructed and assembled so that they will have the strength and rigidity necessary to resist the abuses and the environment to which it is likely or intended to be subjected, without increasing the risk of fire, electric shock, or injury to persons due to total or partial collapse resulting in a reduction of spacings, loosening or displacement of parts, access to hazardous electrical or moving parts, or other serious defects.

22.1.2 The enclosure shall prevent molten metal, burning insulation, flaming particles, or similar materials from falling on combustible materials outside the enclosure.

22.1.3 The frame or chassis of the device shall not be used to carry current during intended operation.

22.1.4 Contactors and fuses shall be located so as to be readily accessible for servicing, such as complete replacement or the replacement of contacts and inspection after the removal of a cover or covers. Other arcing and operating parts shall be accessible for servicing and inspection.

22.1.5 A part, such as a dial, display face, or nameplate, that serves as a functional part of the enclosure shall comply with the enclosure requirements in this outline.