PSG Design Standards for Yaskawa America Incorporated Motoman Robotics Division (YAI-R)

Document Number:	SSGW-077
DCR Number:	10158
Release Date:	6/27/2016
Document Status:	RELEASED

Approved By: Tom Sipple
Senior Manger PSG

Yaskawa America Incorporated
Motoman Robotics Division (YAI-R)
100 Automation Way
Miamisburg, OH 45342
Phone: 937-847-6200

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION

1.1 About this Document 1-1
1.2 Reference to Other Documentation 1-1

CHAPTER 2 GENERAL REQUIREMENTS

2.1 Definitions 2-1
2.2 Manual Requirements 2-1
2.3 Marking Requirements 2-2
2.3.1 Permanent Markings 2-2
2.3.2 Marking Methods 2-2
2.4 Painted Surfaces 2-3
2.4.1 Standard Colors 2-3
2.4.2 Painted Surface Coating Guidelines 2-4
2.5 Shipping and Handling Requirements 2-6
2.5.1 General Shipping Requirements 2-6
2.5.2 Handling Requirements 2-6
2.6 Robot Awareness 2-7
2.6.1 Working Envelope 2-7
2.6.2 Envelope with Added Equipment 2-7
2.6.3 Payload Restrictions 2-8
2.6.4 Robot Limitation 2-8
2.6.5 Cable and Air Line Routing 2-8
2.6.6 Multi-dash Numbered Components 2-8
2.7 Recommended Spare Parts and Unique Tools 2-9

CHAPTER 3 MECHANICAL REQUIREMENTS

3.1 Fasteners 3-1
3.1.1 Fasteners 3-1
3.1.2 Washers 3-1
3.1.3 Screws with Captive Flats and Locks 3-2
3.2 Welding System Considerations 3-3
3.2.1 Independent Path 3-3
3.2.2 Amperage 3-3
3.2.3 Rotary Grounds 3-3
3.2.4 Brush Contacts 3-3
3.2.5 Conductive Grease 3-3

3.3 Equipment Design 3-4
3.3.1 Weldments 3-4
3.3.2 Material Finishes 3-4
3.3.3 Bearings 3-4
3.3.4 Barrier Assemblies 3-5

CHAPTER 4 WELD TOOLING STANDARDS
4.1 Weld Tooling Standards 4-1

CHAPTER 5 PNEUMATIC/HYDRAULIC REQUIREMENTS
5.1 Pneumatic Standards 5-1
5.1.1 Basic Design Requirements 5-1
5.1.2 General Equipment 5-1
5.1.3 Actuating Equipment 5-2
5.1.4 Piping to Equipment 5-2
5.2 Hydraulic Standards 5-3
5.2.1 General Equipment 5-3
5.2.2 Actuating Equipment 5-4
5.2.3 Piping to Equipment 5-4
5.2.4 Hydraulic Fluids 5-4

CHAPTER 6 ELECTRICAL STANDARDS
6.1 Disconnecting Means 6-1
6.1.1 General Standards 6-1
6.1.2 Rating 6-1
6.1.3 Mounting 6-1
6.1.4 Interlocking 6-1
6.1.5 Operating Handle 6-1
6.2 Protection 6-2
6.2.1 General 6-2
6.2.2 Motor Over-current Protection 6-2
6.2.3 Motor Overload Protection 6-2
6.2.4 Control Circuit Overcurrent Protection 6-3
6.3 Control Circuits 6-4
6.3.1 Control Circuit Voltage 6-4
6.3.2 Connection of Control Devices 6-4
6.3.3 Electro-mechanical Contact Requirements 6-4
6.3.4 Transient Suppression 6-4
6.3.5 Control Circuit Design 6-4
6.3.6 Automatic and Manual Mode 6-4

6.3.7 Jog or Inch Circuits 6-5
6.3.8 Emergency Stop Circuitry 6-5
6.3.9 Anti-repeat Operation 6-5
6.3.10 Two-hand Operation 6-5
6.3.11 Control of Valves 6-6
6.4 Programmable Logic Controllers (PLC) 6-7
6.5 Enclosures, Push Buttons, Junction Boxes and Terminal Strips 6-7
6.6 Operator Control Stations and Devices 6-7
6.7 Nameplates and Identification 6-8
6.8 Conductors 6-8
6.9 Wiring Methods and Practices 6-8
6.10 Grounded Circuits and Equipment Grounding 6-11

CHAPTER 7 SAFETY REQUIREMENTS
7.1 Manufacture, Remanufacture, and Rebuild of Robots 7-1
7.2 High Speed APV (Attended Program Verification) 7-1
7.3 Risk Assessment 7-1
7.4 Safeguarding of Personnel 7-1
7.5 Safeguarding Devices 7-1
7.6 Safety Circuits 7-1
7.7 Yaskawa America Incorporated Motoman Robotics Division Controller Compliance 7-1

APPENDIX A PREFERRED COMPONENTS

CHAPTER 1 Introduction

1.1 About this Document

This document combines, for easy reference, design specifications and procedures necessary to build equipment in accordance with Yaskawa America Incorporated Motoman Robotics Division (YAI-R) standards and policies.

This document was prepared by YAI-R's Product Solutions Group and is maintained by the Design Specification Committee. Any questions of interpretation should be directed to the Design Specification Committee.

This design specification ensures standardization of equipment for YAI-R systems. Strict adherence to these practices are outlined here.

YAI-R is a metric-based company. Metric products shall be used when available and economically feasible. YAI-R must approve any exceptions to this policy.

This document contains the following sections:

CHAPTER 1 - Introduction

Provides general information about the purpose and content of this document.

CHAPTER 2 - General Requirements

Provides general design requirements.

CHAPTER 3 - Mechanical

Provides standards for mechanical design.

CHAPTER 4 - Weld tooling Design

Provides standards for weld tooling design.

CHAPTER 5 - Pneumatics/Hydraulics

Provides standards for pneumatic/hydraulic design.

CHAPTER 6 - Electrical Standards

Provides standards for electrical design.

CHAPTER 7 - Safety Requirements

Provides general safety requirements.

APPENDIX A

Appendix A contains a list of preferred components.

1.2 Reference to Other Documentation

- National Electric Code
- NFPA 79, Electrical Standard for Industrial Machinery
- ANSI/RIA R15.06-2012 for Industrial Robots and Robot Systems

CHAPTER 2 General Requirements

2.1 Definitions

- **Contractor:** Any individual, company, partnership, association, or corporation holding a contract, letter of intent or purchase order to supply items for Yaskawa America Incorporated Motoman Robotic Division (YAI-R).
- **Identification:** Any marking applied to an item or its package for the purpose of engineering, manufacturing or inspection control.
- **Package:** The smallest enclosure into which an item(s) is placed for protection during storage or shipment.
  - — *Should:* Indicates an ethical or moral obligation, propriety or expediency.
  - — *Shall:* Indicates a duty or legal obligation.
  - — *Independent Path:* A dedicated, engineered path designed to carry welding current without doing damage to components within that path.

2.2 Manual Requirements

Manuals supplied to YAI-R shall contain the following information where applicable:

Table 2-1 Supplied Manual Requirements

Table of Contents	Reassembly Procedures	Documentation
Basic Safety Considerations	Installation and Initial Start-up	Parts List
Special Safety Cautions	Set-up Procedures	Spare Parts Bill of Material
Lockout Procedures	Changeover Procedures	Complete Bill of Material
Guard Location Diagram	General Maintenance Procedures	Operating Instructions
General Installation Procedures	Preventive Maintenance Procedures	PLC Program
Handling	General Electrical Control Theory	Changeover Considerations
Leveling Procedures	Theory of Operation	

2.3 Marking Requirements

2.3.1 Permanent Markings

- Permanent markings are required on finished items and shall not affect the function or serviceability of the item.
- Items which require more than one identification number, such as part number and revision number, serial number, etc., shall have each number on a separate line.
- Permanent marking should not be placed on contacting surfaces, nor on surfaces which are in motion with respect to the mating surface during the operation of the items. When permanent markings are placed on such surfaces, all raised metal and burrs shall be removed in accordance with the requirements given on the drawing.
- Permanent marking is not permitted on surfaces which have been chemically processed, painted, or plated unless the marking will be legible and the minimum requirements of the surface treatment process maintained or restored.
- Permanent markings are not to be located closer than 1mm to any corner, fillet, or edge unless specifically designated. Where a specific marking location as designated and dimensioned does not provide enough area for 1mm to any edge, corner, or fillet, the marking shall be centered upon the area without breaking over edge or encroaching on corners or fillets.
- Identification marking shall be legible and make full use of the available marking area. Characters shall be block form capital letters and Arabic numerals without serifs, such as “Gothic” or “Futura”. Condensed letters and smeared letters shall be cause for rejection. All characters shall be legible without magnification.

2.3.2 Marking Methods

The following are acceptable marking methods:

- **Integral:** Characters are produced by casting, forging, or molding into or on the item.
- **Engrave:** Characters are produced by a rotating cutter or grinder.
- **Scribe:** Characters are produced by a cutting or scratching action.
- **Band:** A band bearing the required identification marking is permanently attached to the item.
- **Pressure Sensitive Label:** An environment resisting label bearing the required identification, backed with pressure sensitive adhesive.
- **Laser:** Characters are produced by displacing material with a laser beam.
- **Impression Stamping:** Characters are formed by depressions in the material.
- **Ink:** Characters are produced by applying an ink by any means which does not injure the surface. When applied to a painted surface by ink stamping, the marking shall be protected with a suitable transparent coating.
- **Package Marking:** The package bears the identification of the item(s) which are too small or otherwise impractical to be marked.

2.4 Painted Surfaces

2.4.1 Standard Colors

Standard colors of painted items (reference YAI-R Standard Drawing 472476-*), unless otherwise specified, are as follows:

Dark Gray

- Bases used in non-welding environments
- Any weldment that is attached to a base
- Common equipment bases and attached weldment/components

Light Gray

- Cable wireways
- Electrical enclosures, junction and push button boxes

Flat Black:

- Robot risers
- All items attached to the robot
- Bases used in welding environments
- Arc screens
- Fence Filler Panels

Gloss White

- Enclosure panels **Exception:** MRC/ERC controller panels

Beige

- FS100, DX100, NX, and XRC Robot controllers
- Items mounted to controllers

Yaskawa Blue

- Positioners
- Headstock and tailstock columns
- MotoSweep O beam and attached covers
- MotoSweep F base frame and attached covers
- Rail and carrier assemblies

Nickel Metallic Textured and Dark Gray Textured

- DX200 Controller

Dark Gray Smooth

- Components mounted to DX200 Controller

NOTE: Application specific product lines may have specific color schemes as defined by the Marketing Department.

2.4.2 Painted Surface Coating Guidelines

2.4.2.1 Purpose

The purpose of these guidelines is to define the baseline performance characteristics for painted surfaces on YAI-R equipment used in typical welding and handling environments. (Specialized applications may require coating systems with enhanced performance properties.)

2.4.2.2 Pretreatment

Pretreatment of painted surfaces per the manufacturer's data sheet is necessary for YAI-R component suppliers to meet the performance requirements of our customers. Cost and ease of pretreatment are considerations for selection of the paint type listed in these guidelines.

2.4.2.3 Paint Type

Low VOC (high solids) two component polyurethane

2.4.2.4 Performance Specifications:

- **Color and Gloss**
  - *Custom Colors as Mixed* - Color within 1 Delta-E of YEC/YAI-R color and gloss control panel. Gloss within visual tolerance of YEC/YAI-R color and gloss control panel
  - *Custom Colors as Applied* - Color and gloss within visual tolerance of YEC/YAI-R color and gloss control panel

- **Curing**
  - Must be sufficiently dry to ship after curing overnight at ambient temperature (max. 12 hours)
    - Elevated temperatures (force) dry to ship - maximum 4 hours

- **Thickness**
  - *Performance Testing* - Per manufacturer's datasheet
  - *As received* - Sufficient for coverage and proper color rendition when compared to a color and gloss control coupon

- **Hardness**

  2H pencil hardness per ASTM D3363

- **Adhesion**

  Pass ASTM D3359

- **Impact Resistance**

  60in-lbs/min. direct per ASTM D2794

- **Flexibility**

  Pass ASTM D522, 180° bend, 3/16in. mandrel

- **Corrosion**

  100 hours - 1/8in. rust at scribe

■ **Chemical Resistance**

• No film degradation after full cure and five day exposure. Some staining is acceptable

Chemical	Part Number	Application Method
Anti-Splatter	471950-2	Rub
Grease	133174-2	Rub
Grease	132177-1	Rub
Grease	132412-2	Rub
Air Tool Lubricant	(ex. L0713-54)	Drip
Anti-Freeze	153169-1	Drip
Grease	132434	Rub
Cleaner	(ex. Zep ID Red)	Rub

2.5 Shipping and Handling Requirements

2.5.1 General Shipping Requirements

CAUTION: When using cables, a warning label is necessary to warn operators not to fork with cables in place.

Forking with cables in place can cause equipment damage.

All equipment shall be designed to fit within truck trailer limitations, including packing material considerations.

- *Trucks with Standard Overhead Door Styles:* Preferred method of shipment with an:
  - Opening: 2413mm (95in.)
  - Height 259mm (102in.).
- *Swinging Door Trailers*: Accepted by special request with an:
  - Opening: 2489mm (98in.)
  - Height 2794mm (110in.)

If the component uses structural steel components, and there are areas that are not meant to be fork pockets, use caps to prevent forking in those areas.

2.5.2 Handling Requirements

All equipment greater than 20kg (44lbs) shall include but not be limited to lifting provisions per one of the following methods:

Forklift Pockets

- When structure shapes are used for pockets, use minimum of 241mm x 64mm (9.5in. x 2.5in.) opening.
- Pockets should be spaced at a maximum of 900mm (36in.) center to center.

Tap Sizes for Eyebolts

Safe load for single eyebolt:

- M8 = 140kg
- M10 = 230kg
- M12 = 340kg
- M16 = 700kg
- M20 = 1200kg
- M24 = 1800kg
- M30 = 3600kg

2.6 Robot Awareness

2.6.1 Working Envelope

- Layouts shall be reviewed for the proper positioning of the robot arm and all equipment the robot arm shall service to ensure the robot can reach all areas required. The envelope that can be traversed by the P-point defines the area that a robot arm can reach. The P-point is normally the center of the B-axis joint for five and six axis robots and the center of the T-axis mounting flange for four axis and Scara robots. Consult the robot manual of the specific model robot being investigated for exact envelope sizes and shapes.
- The working envelope of the robot arm should be kept clear of all equipment and obstacles not intended to be serviced by the robot whenever possible.
- All robot arms have a “dead zone” in their S-axis travel through which the robot cannot pass. Consult the robot manual of the specific model robot being investigated for exact size and location of the “dead zone”. Layouts should place this “dead zone” in an orientation so that the optimal workflow does not cross through this zone.
- Cell designs should minimize robot moves that enter the last 5% of the working envelope. A larger robot should be considered in these situations.
- Many robot arms have special limitations to the published working envelopes that are intended to protect the robot from colliding with itself. These limits involve compound relationships between the positions of multiple axis when the P-point is near the robot control cable connectors. Layouts that require the robot arm to work in these positions shall be simulated with MotoSim or equivalent simulation software as part of the design review process.
- The S-axis travel should be restricted to its required working envelope by use of hard stop(s).

2.6.2 Envelope with Added Equipment

- The addition of an end of arm tool to the robot will effectively change the position of the working envelope. Layouts shall be reviewed for proper positioning of equipment with the actual tool included.
- Layouts shall be reviewed for interference of end of arm tooling with the robot arm and all equipment within the working envelope of the robot arm with tool.
- All critical working positions of the robot arm shall be reviewed for proper orientation of end of arm tooling.
- Layouts shall be reviewed for interference of the robot arm with any other equipment at all critical working positions and travel paths.

2.6.3 Payload Restrictions

- End of arm tooling should be designed to minimize the weight of the end of arm tooling.
- End of arm payload (tooling plus parts) should not exceed 95% of the maximum allowable payload for a given robot model. A larger robot should be considered in these situations.
- End of arm tooling shall be designed to minimize the moment of inertia.
- End of arm tooling should not exceed 95% of the maximum allowable moment of inertia for the T and B-axis of a given robot model. A larger robot should be considered in these situations.
- Most robot models provide mounting areas on the upper arm for additional equipment. All equipment mounted on the upper arm shall be reviewed with end of arm tooling to ensure that the maximum upper arm weight and moment are not exceeded.
- Some robot applications require the robot arm to apply a force to a work piece that can be seen as an additive mass or moment by the robot arm. These applications shall be reviewed with all upper and end of arm mounted equipment to ensure that maximum payload, moments of inertia and maximum upper arm payloads will not be exceeded.

2.6.4 Robot Limitation

- Path accuracy changes as a robot arm travels through all possible orientations. Applications that have critical path accuracy requirements shall be reviewed with Senior Application Technicians and Managers for proper mounting of end of arm tooling.
- A singularity condition can arise when a robot arm shall work with the T-axis in line with the R-axis (and possibly S-axis in some models). This condition can result in a required roll of the R-axis at a speed that exceeds the robot's capabilities. System and end of arm tooling designs shall be reviewed for working positions that cause singularities.

2.6.5 Cable and Air Line Routing

- Cabling and hoses terminating at end of arm tooling shall be minimized by placement of valves and terminal blocks on the end of arm tools when possible.
- A "service loop" of cabling and hoses terminating at end of arm tooling is necessary to allow for motion of the robot arm. This loop shall be minimized to allow for proper motion of the robot with no chance of interference or catching on equipment.
- Cabling and hoses terminating at end of arm tooling shall be securely strain relieved at the tool to eliminate any connections from working loose or breaking prematurely.

2.6.6 Multi-dash Numbered Components

- All dash numbers of mechanical parts shall be modeled.
- The draft file shall include a minimum sized thumbnail view for each dash number.

2.7 Recommended Spare Parts and Unique Tools

The mechanisms' designer will determine the list of parts and the exact number recommended. This recommended spare parts list is provided in the product manual. Spare parts amounts should be rounded up when necessary to insure spare parts availability.Guidelines for types and quantity of parts are as follows and are given as a percentage of the total being used on the mechanism:

List and Quantity

- Fuses – 20%
- Bearings/Bushings – 10%
- Grease/oil – 2 complete refills
- Sensors – 20%
- Switches – 20%
- Quick disconnect cables – 20%
- Quick connection block – 10%
- Valves – 10%
- Non-standard fasteners – 10%
- Items with exceptional lead times (as defined by the Project Engineer)
- Any unique tool required or special tools (as defined by the Project Engineer).

CHAPTER 3 Mechanical Requirements

3.1 Fasteners

3.1.1 Fasteners

- Fasteners and mechanical locking devices shall be designed and sized to guarantee against loosening and failure during normal operation. Secondary locking devices (locknuts, weld keys, lockwire, castle nuts with cotter pins) shall be installed where function or safety dictate.
- Unless otherwise noted, proprietary head design(s) requiring a screw driver shall not be used to secure mechanical components. Preferred designs are hex and socket head.
- Where bolts are used as fasteners, they should be torqued to the proper tightness for the application and fastener and marked for verification. Reference *Yaskawa America Incorporated Motoman Robotic Division (YAI-R) Drafting Standard, Appendix B*.
- Where components are tapped for bolt holes in soft material (e.g., aluminum, copper, brass, etc.), inserts such as Helicoils or Keenserts should be used depending on tightening frequency and torque requirements.
- On sizes of M12 and smaller, use Socket Head Cap Screws unless otherwise specified.

Exception: *Use of Socket Head Cap Screws in the welding area of the robot shall not be used.*

- On sizes of larger than M12, use Hex Head Screws.
- Blind dowel pin holes are unacceptable unless approved by YAI-R.

3.1.2 Washers

Conical or Belleville washers are springs. They are used for heavy loads where small deflections can be tolerated. Applications include a bolted joint that is used to transmit motion where the relation of each joined component is critical. These washers maintain a constant force throughout the dimensional changes in mechanical systems due to wear, relaxation, or thermal changes. Application examples include:

- Mounting RV's into housings
- Attaching mechanical components which transmit motion

Spring or Split washers are commonly called "lock" washers. These hardened circular washers are split and then bent out of a flat plane. Their principal purpose is to take up for relaxing bolt tension or looseness in the joint. These washers do not maintain a constant force on the joint and should be used where high strength joints are not required. Use these washers in applications where additional locking is required and the joint is not critical to the operation of the device.

3.1.3 Screws with Captive Flats and Locks

Use PPH, with Zinc Chromate finish or Nickel Plated to:

- Attach components on any electrical panel.
- Attach gland plates.

Use SHC, with Blk finish to:

- Attach covers to bases and columns.

Use HHC, with Chromate finish to:

- Attach covers to positioners assemblies.

3.2 Welding System Considerations

3.2.1 Independent Path

An independent path for weld grounding is a requirement to protect the various components in a positioner. The temperatures generated and the potential for arcing in the components carrying a welding current can be damaging to the bearings and reducers in the system. Particular care shall be taken to keep the grounding contact surfaces free of insulating coatings (e.g. paint or oxide finishes).

3.2.2 Amperage

The current carrying capacity of the brush system shall be verified by manufacturers specs or through YAI-R in-house testing. Note that the capacity of the brush system is not an absolute limit, rather it is an average value over time. Additionally, all components of the grounding system should be examined for ampacity.

3.2.3 Rotary Grounds

Rotary grounding systems have been found to be effective when properly sized and lubricated according to the manufacturers' instructions.

3.2.4 Brush Contacts

A commercial copper graphite brush and holder system against a steel or other suitable commutator should be considered on all new or retrofit systems.

Lubrication and plate finishes shall be in accordance with brush manufacturers' recommendations.

3.2.5 Conductive Grease

Conductive lubricant should be used when appropriate to insure ground continuity.

3.3 Equipment Design

3.3.1 Weldments

- Weldments and fabrications shall be clean of weld spatter, of good structure and aesthetic quality. Finishes shall conform to the design requirements. Weldments should be normalized/stress relieved prior to any required machining.
- Support structures should have leveling screws as well as anchoring holes in sizes which meet design specifications.
- Venting is required for all tubing that is sealed off or where end caps are placed. A 3mm hole would be considered adequate venting.
- Plug vent holes in aluminum weldments when anodized.
- Gussets shall be minimum half the thickness of the thinnest joining parts.
- When mounting the item, the recommended minimum thread engagement is 0.8 times the nominal diameter of the screw size used. Any exception requires project engineer approval.
- Use similar plate thickness where possible.
- Avoid weldment design that requires any machining feature through a welded joint.
- Design for ease of accessibility in welding.
- Allow for machining/surfacing where necessary.

3.3.2 Material Finishes

All metal shall have one of the following finishes, unless otherwise specified:

Steel

- Zinc Chromate
- Paint as specified (see *section 2.4*)
- Black Oxide
- Nickel Plate

Aluminum

- Anodize as specified on drawing
- Conversion coating
- Paint as specified (see *section 2.4*)

Stainless Steel

- Passivation

Note: *Any metal surface with a machine finish which is not coated by one of the above methods shall be coated with a rust inhibitor that conforms with MIL-C-16173E, Grade 2. The YAI-R approved product is LPS#3, manufactured by LPS Laboratories. Use of any other rust inhibitor must be approved by YAI-R engineering before parts can be shipped.*

3.3.3 Bearings

Bearings shall be designed and sized to provide a minimum service life of 40,000 hours of continuous duty under full load.

3.3.4 Barrier Assemblies

3.3.4.1 Fence Kits

- Fence panel height:
  - Minimum fence height 2000mm (78.7in.) when mounting the fence to a base.
  - Maximum fence height 2134mm (7ft) when mounting the fence to a base.
  - Minimum fence height 2300mm (90.5in.) when mounting the fence directly to the floor.
- The maximum allowable sweep space (floor to bottom of fence) is 100mm (3.9in.). Sweep space of fence panel, which mounts the light curtain, may be 165mm (6.5in.).
- Panels are to be designed in either 1ft or 100mm increments, when possible.
- Sliding doors are to be minimum of;
  - 900mm (35.4in.) wide x 1900mm (74.8in.) tall if mounted to a base.
  - 900mm (35.4in.) wide x 2200mm (86.6in.) tall if mounted directly to the floor.
- Fence post mounting pads:
  - 50.8mm x 142mm (2 in. x 5-19/32 in.) with 14 mm diameter mounting holes with 11mm x 22mm (7/16 in. x 7/8 in.) slots in the for door interlock post and 11mm (7/16 in) through holes for fence mounting holes. Both floor and base mounted fence,
  - 50.8mm x 114mm (2in. x 4.5in.) with 11mm (7/16inch) wide x 22mm (7/8in.) long slot. Use on fence posts mounting to a base.
  - 61mm x 140mm with two 14mm diameter mounting holes. Use on fence posts supporting light curtains.
  - 80mm x 110 mm (3-5/32in. x 4-11/32in.) as an min with four 11mm (7/16in.) diameter mounting holes. Use on fence posts supporting light curtains.
- Doors must have standard door interlocks attached with tamper proof screws.
- Fence designs shall meet the requirements of ANSI/RIA 15.06-2012 unless justified by a risk assessment.

3.3.4.2 Arc Curtains

- Arc curtains are to be affixed to fence and door(s) when risk of arc flash exists.
- Curtains are to be 25mm (1in.) smaller, in both height and width, than fence panel.
- Material: SP-25 (orange) spectra, 14mm thick.

3.3.4.3 Light Curtains

- Refer to specification for size and placement of light curtains.
  - Per ANSI/RIA 15.06-2012: Ds = [K x (Ts + Tc + Tr)] + Dpf

    Where:

    Ds = minimum safe distance between safeguarding device and the hazard.

    K = speed constant: 1.6m/sec (63in./sec) minimum based on the movement being the hand/arm only and the body being stationary.

NOTE: *A greater value may be required in specific applications and when body motion must also be considered.*

Ts = worst stopping time of the machine/equipment.

Tc = worst stopping time of the control system.

Tr = response time of the safeguarding device including its interface.

NOTE: *Tr for interlocked barrier may include a delay due to actuation. This delay may result in Tr being a deduct (negative value)*

Dpf = maximum travel towards the hazard within the presence sensing safeguarding devices (PSSD) field that may occur before a stop is signaled. Depth penetration factors will change depending on the type of device and application.

3.3.4.4 Arc Screens/Door Panels

- Arc screens and doors shall be designed to prevent penetration by robot.
- Doors must have safety switches which interlock to drop servo power when opened, purposely or inadvertently, when the robot is working in the vicinity.

CHAPTER 4 Weld Tooling Standards

4.1 Weld Tooling Standards

For all Yaskawa America Incorporated Motoman Robotics Division (YAI-R) Weld Tooling Standards, reference the following tooling specification:

- *Standard Tooling Specification, ASGW-038*

CHAPTER 5 Pneumatic/Hydraulic Requirements

5.1 Pneumatic Standards

5.1.1 Basic Design Requirements

- A detailed drawing of the machine pneumatic schematic and bill of materials shall be submitted to, and approved by, the assigned responsible engineer prior to release of the equipment for manufacture and the purchase of components.
- All systems shall be designed to operate at or below 6.9bar (100psi) air pressure and sized for an incoming operating pressure of 4.1 – 5.5bar (60 - 80psi). All components are rated for a minimum burst pressure of 20.7bar (300psi).
- Air logic is not a preferred method of pneumatic control. Electrically actuated controls are preferred. Air logic controls will be allowed where only air is available and approved by Yaskawa American Incorporated Motoman Robotic Division (YAI-R) engineering.
- Preferred equipment shall be used in accordance with *Appendix A* of this standard.
- Equipment numbers and nameplates shall be in accordance with *section 6.7 "Nameplates and Identification"*.

5.1.2 General Equipment

- All pneumatic equipment shall be provided with one manual main air shut-off valve of a lockable, slap style, pressure release type to shut off all sources of air to the equipment. This valve shall be located in an easily accessible location not to exceed 1.5m (4.9ft) from the floor level.
- In the case where sufficient air pressure is critical to the safety of personnel or the operation of the system, a pressure switch shall be installed on the incoming supply line capable of providing a signal to the PLC or the control associated with the device when the air pressure has dropped below an acceptable level.
- All pneumatic equipment shall be provided with a filter and regulator. A lubricator shall be provided for all equipment requiring lubrication. If both oil-free and lubricated air is required, a filter and regulator shall be installed in a separate circuit. A single main connection shall supply both circuits.
- All filters shall have a filter mesh of 5 micrometers or smaller. All filters shall be easily accessible for periodic maintenance or be of an automatic draining type where not easily accessible.
- All regulator adjustment controls shall be lockable by means of a jam nut or snap. Regulators shall have a pressure gauge graduated in both bar and psi. Range shall be 0 – 10.3bar (0 – 150psi) unless otherwise required. The filter and regulator can be of one unit if applicable.
- All pressure gauges shall be labeled indicating the function of the gauge and the correct operating pressure.

- All lubricators shall have a sight glass and are to be capable of being filled without shutting off the air pressure.
- All compressed air exiting a pneumatic device shall pass through an exhaust muffler. Where required due to potential part contamination or other specific requirements, an exhaust cleaner shall be installed in place of the exhaust muffler to eliminate air-borne mist and contaminants.

5.1.3 Actuating Equipment

- All solenoid valves shall be 24VDC, equipped with a manual override and LED indicators to indicate coil state. Valves should be installed in such a manner to allow easy access to regulators and overrides, and allow a clear view of LED indicators.
- All solenoid valves shall be clearly and permanently labeled and protected from hazardous environments.
- When critical to the operation of the equipment, cylinders, grippers, and actuators should be supplied with position sensors at both ends of travel. Sensors should be easily visible when possible. Cylinders equipped with magnetic piston rings and magnetic switches are the preferred types.
- When critical to the operation of the equipment, cylinders, grippers, and actuators should have flow control valves installed for both directions of cylinder travel. These valves should be installed in a manner to allow easy access and adjustment. The valve adjustment shall have a locking device to secure its setting. Flow controls shall be installed on the exhaust and be mounted as close as possible to the device it is controlling.
- A mis-alignment coupling at the end of the rod shall be used when cylinder bodies are rigidly mounted to a device, so that the air cylinder and rod are never subjected to side loads.
- Cylinder travel should be controlled using hard stops, adjustable if necessary. The full extent of travel is considered a hard stop. Threaded cylinder rods with lock nuts are an acceptable means of assembly, but should not be used as a method for controlling travel.
- Grippers shall be designed to mechanically lock on a part or use a pilot operated check valve to retard the accidental loss of grip pressure due to interruption of air system.

5.1.4 Piping to Equipment

- All pneumatic lines, piping, and hosing shall be of suitable material and of proper size for the machine application. Flexible air lines shall be protected from abrasion or spatter.
- The insides of pipes shall be thoroughly flushed to remove all matter and contaminants prior to assembly.
- All piping and pneumatic components shall be securely fastened to equipment or machine frame. All branching or joining of pipe, tubing, or hosing shall be securely fastened to equipment or machine frame. Adequate spacing shall be maintained around all piping as necessary for access.

5.2 Hydraulic Standards

- A detailed drawing of the machine hydraulic schematic and bill of materials shall be submitted to, and approved by, the assigned responsible engineer prior to release of the equipment for manufacture and the purchase of components.
- Hydraulic systems shall be designed to operate within a maximum pressure of 103.4bar (1500psi). All hosing and pipe fittings shall be rated for a minimum burst pressure of 206.8bar (3000psi).
- Hydraulic tank units shall be mounted within a drip-proof oil pan with accessible drain plug to allow for draining of the pan. Pan size should be large enough to capture all of the fluid within the tank in the event of a rupture.
- All connections shall be leak free. Oil leak checks shall be performed on all connections after assembly.
- Preferred equipment shall be used in accordance with *Appendix A* of this standard.
- Equipment numbers and nameplates shall be in accordance with *section 6.7 "Nameplates and Identification"*.

5.2.1 General Equipment

- The hydraulic system shall be provided with one main electrical disconnect to shut off power to the pump in the event of an emergency or maintenance. Disconnect shall be of lockable type and easily accessible.
- A pressure switch shall be installed on the hydraulic tank supply line capable of providing a signal to the PLC or the control associated with the system, when the hydraulic pressure has dropped below an acceptable level.
- A low oil level detection device capable of providing a signal to the PLC or the control associated with the system shall be provided to prevent damage to the pump.
- The pump unit shall be sized for sufficient output to maintain cylinder speed and for peak output required.
- The oil supply port, discharge port, and filter shall be designed for maximum flow and pressure.
- The hydraulic system shall be provided with a replaceable automotive type spin-on filter of 6 microns or less on the return line.
- Maximum ambient temperature shall be 30°C (87°F) for design purposes. Hydraulic tanks should be sized to dissipate heat so, under normal conditions of continuous operation and without the use of coolers or heat exchangers, fluid temperatures may not exceed 65°C (150°F). Rule of thumb: Minimum tank size = three times pump GPM.
- Maximum noise level for pump unit should be 80db.
- Pressure gauges should be of glycerin filled type capable of reading three times the normal pressure with scales to be in metric (bar) and British (PSI)
- All pressure gauges shall be labeled indicating the function of the gauge and the correct operating pressure.

5.2.2 Actuating Equipment

- All solenoid valves shall be 24VDC, equipped with LED indicators to indicate coil state. Valves should be installed in such a manner to allow a clear view of LED indicators.
- All solenoid valves shall be clearly and permanently labeled and protected from hazardous environments.
- When critical to the operation of the equipment, cylinders should be supplied with position sensors at both ends of travel. Sensors should be easily visible when possible.
- When critical to the operation of the equipment, cylinders should have flow or pressure control valves installed for both directions of cylinder travel. These valves should be installed in a manner to allow easy access and adjustment. The valve adjustment shall have a locking device to secure its setting. Flow controls shall be installed on the exhaust and be mounted as close as possible to the device it is controlling.
- A misalignment coupling at the end of the rod shall be used when cylinder bodies are rigidly mounted to a device, so that the hydraulic cylinder and rod are never subjected to side loads.

5.2.3 Piping to Equipment

- All hydraulic lines and piping shall be of suitable material and of proper size for the machine application. Flexible lines shall be protected from abrasion or spatter.
- The insides of pipes shall be thoroughly flushed to remove all matter and contaminants prior to assembly.
- All piping and hydraulic components shall be securely fastened to equipment or machine frame. All branching or joining of pipe or hosing shall be securely fastened to equipment or machine frame. Adequate spacing shall be maintained around all piping as necessary for access.
- All return lines shall be large enough to prevent back pressure.
- Liquid sealant (Loctite #69 or equivalent) shall be used to seal pipe threads. Sealant should be used two threads from the end to prevent sealant from getting into the hydraulic system. Teflon sealing tape shall not be used to seal threads.

5.2.4 Hydraulic Fluids

Mobil DTE 24 or equivalent shall be used. All required fluid types shall be specified in the service manuals. MSDS sheets shall be provided.

CHAPTER 6 Electrical Standards

6.1 Disconnecting Means

A disconnecting means shall be provided for each incoming circuit supply.

- The disconnecting means shall be manually operated and be provided with fusing or circuit breaker.
- The specific disconnecting means for control enclosures other than the robot controller shall, at a minimum be mounted in a NEMA Type 12 enclosure.

6.1.1 General Standards

- A single electrical supply source and single disconnecting device should be provided for each individual machine. The disconnecting means shall disconnect all ungrounded conductors of the supply circuit simultaneously.
- There shall be no exposed live parts when the disconnecting device is in the off position.
- Control devices and terminals located in the enclosure, but energized from a remote source need not be de-energized if identified by yellow wiring.

6.1.2 Rating

The ampacity of the disconnecting means shall not be less than 115% of the sum of the full-load currents required for all equipment that may be in operation at the same time under normal conditions.

6.1.3 Mounting

The disconnecting means shall be mounted within the main control enclosure. The disconnecting means shall be mounted at the top of the control panel. No other equipment or wiring shall be mounted directly above it. In control panel enclosures with three or more doors, the disconnecting means should be mounted at the extreme right.

6.1.4 Interlocking

The disconnecting means shall be interlocked mechanically with the control panel enclosure door(s). A suitable device operated by a screwdriver or other common hand tool shall be provided so that the interlocks may be bypassed and the control panel door(s) opened without disconnecting the main power. Interlocks shall be reactivated automatically when control panel door(s) are closed. Progressive interlocking door to door shall not be used.

6.1.5 Operating Handle

- The operating handle of the disconnecting means shall be readily accessible. The center of the grip, when in its highest position, shall not be more than 2.0m (79in.) above the floor.
- The operating handle of the disconnecting means shall be such that it can only be padlocked in the OFF position. The design shall be such that the switch cannot be closed when locked in the OFF position by a single padlock or locking device.

6.2 Protection

This section shall apply to all industrial equipment which operates at a supply voltage of 600 volts or less, with the exception of bench-type machines powered by a single motor and rated less than one (1) horsepower.

6.2.1 General

- Protective devices shall be selected and applied with proper consideration of the inrush and normal operating current of the load as well as the short circuit protection.
- Time delay fuses shall be applied for current limiting as well as protection from nuisance blowing caused by inrush currents.
- Time delay (dual element), high interrupting capacity (energy limiting) fuses shall be used as follows:
  - On motor branch circuits (including combination starters).
  - To coordinate with other time delay fuses in the circuit.
- In addition, the ampere rating of the fuse and fuse clips shall not exceed the nameplate ampere rating of the main disconnecting means.

6.2.2 Motor Over-current Protection

- Each three phase induction motor over 3.73kW (5hp) shall be supplied and protected as a separate branch circuit. Exception: When the main disconnect overcurrent protection provides adequate protection for a single motor, additional branch circuit protection is not required.
- Two motors from 746W (1hp) to 3.73kW (5hp) may be on the same branch circuit.
- Multiple motors each not exceeding 746W (1hp) may be used on a single branch circuit of 600 volts or less protected at not over 15 amperes where all of the following are met:
  - The full load rating of each motor does not exceed 6 amperes.
  - Overload devices are provided to protect each motor and conductors against excessive overheating.
- The rating or setting of the overcurrent protective device does not exceed the rated current value for the smallest conductor in the circuit.

6.2.3 Motor Overload Protection

- Each motor and its related conductors shall be protected against running overload by the use of a separate current sensitive overload device in each phase.
- The rating of the overload-sensing device shall be based on the motor nameplate full load current. If the motor rating does not match a standard size, then the next standard larger size shall be used.
- Embedded thermal sensing overload devices shall be sensitive to the temperature of the motor or to both temperature and current. Indication of the tripped state shall be provided.
- In all cases, the protection device shall open the coil circuit of the motor control contactor on overload. All motor control latch circuits shall be designed to unlatch the circuit in an overload condition.
- Motor overload reset shall be located inside the control panel enclosure.

6.2.4 Control Circuit Overcurrent Protection

- Control conductors shall be protected against short circuits and steady overloads. An overcurrent device shall be connected in series with each ungrounded leg of all control branch circuits. Individually protected control branch circuits should be used as an aid for isolation and troubleshooting of remote equipment and tooling.
- The overcurrent device rating shall be as low as practical and shall be rated no greater than the rated current carrying capacity of the smallest conductor in the branch circuit.
- Control transformers shall be protected on the primary and secondary circuits against short circuits and overloads.

6.3 Control Circuits

The source of the supply for the control circuit shall be taken from the load side of the main disconnecting means.

6.3.1 Control Circuit Voltage

The control circuit voltage shall be 24VDC (preferred) or 120VAC, having a minimum of 20% spare ampacity.

6.3.2 Connection of Control Devices

- Yaskawa America Incorporated Motoman Robotics Division (YAI-R) robot controllers: Inputs are sourcing and require a NPN or sinking device to turn-on, or change state of inputs. Transistor outputs are sinking and the load requires connection to 24VDC to be energized. When using relay contact outputs the common may be 24VDC or 0VDC. The preferred connection is 24VDC as the common.
- No pilot light shall be in series with any operating coil.

6.3.3 Electro-mechanical Contact Requirements

Contacts shall not be used in excess of their ratings. Contacts shall not be connected in parallel to increase ampacity. Not more than ten contacts shall be connected in series to operate a control device. This limitation includes any combination of contacts.

6.3.4 Transient Suppression

Surge suppressors shall be used on all inductive devices such as solenoids and relays.

6.3.5 Control Circuit Design

- *Fail-safe (dual channel) circuits*: shall be incorporated in the equipment design wherever control malfunctions or improper sequencing may create a hazard to personnel, cause damage to equipment or parts in process. The circuitry shall provide protection against the following:
  - — Failure of one or more devices to function properly.
  - — Improper sequencing in manual and automatic operation.
- *Control circuits:* shall be such that during the power-up sequence no motion shall occur. Control circuits shall be designed so that motion can occur only when Cycle is set for:
  - — *Automatic operation* and Cycle Start pushbutton(s) is depressed
  - — *Manual operation* and pushbutton(s) for a particular function is depressed.

6.3.6 Automatic and Manual Mode

- *Automatic Mode:* will be initiated only from one operators control station at a time.
- *Manual Mode*: pushbuttons or momentary selector switches shall be provided to perform individual functions. Manual functions shall not operate during Automatic mode.

6.3.7 Jog or Inch Circuits

Jog or Inch circuits shall operate only in Manual or teach mode. Jog or Inch circuits shall be designed to operate only while the Jog or Inch button is held depressed.

Exception: *Jog may be permitted in an Automatic mode provided there is sufficient safety devices to protect the operator from entering the work area.*

6.3.8 Emergency Stop Circuitry

- Emergency Stop shall be designed to be initiated through removal of energy to control devices. All equipment motion stopped by Emergency Stop circuitry shall be able to be re-started only by deliberate sequence of actions by the operator.
- All equipment shall incorporate one or more Emergency Stop controls which, upon actuation, stop all equipment motion and, when actuated, shall not create other hazards. Emergency stop shall override all other functions and operations in all modes. Emergency stop controls shall be located at each operator station and at other locations where emergency shutdown may be needed.
- For multi-station and large machines where Emergency Stop buttons are not within easy reach, pull cord operated, hand reset type switches shall be used.
- Safety circuit devices, such as operator emergency stops, safety gates, safety light curtains, safety mats, shall be hard wired into the stop circuit logic and not dependent on non-safety rated programmable device logic controlling the machine. Reference: ANSI/RIA R15.06-2012, section 4.5.

6.3.9 Anti-repeat Operation

On equipment where continuous consecutive cycles of operation of the equipment are not normal or desired, the circuit shall be designed so that continuous cycle(s) cannot be set up or obtained by the operator. Specifically, continuous consecutive cycles shall not result even though the Cycle Start button(s) is held depressed continuously in the start position.

6.3.10 Two-hand Operation

In the case of protection against pinch points or other hazardous movement, two push buttons shall be provided for each operator to initiate action.

- The circuits shall require maintained depression of each button throughout the complete cycle or until a point is reached in the cycle where no hazards to the operator(s) exist.
- Each pair of buttons shall be located and arranged so that operation by means other than two hands of the operator is prevented.
- The circuit shall be designed and wired to prevent tying down a pushbutton during any part of the cycle, and cannot be operated unless both buttons at each station are released between successive operations.

6.3.11 Control of Valves

- Electrically controlled hydraulic and pneumatic solenoid valves shall be applied in such a manner that in the event of a power failure there shall be no hazard to personnel or damage to the equipment.
- Solenoids that are mechanically interlocked, shall also be electrically interlocked to prevent simultaneous applying of energy. An Ethernet network connection shall also be provided.
- Workpiece clamping solenoid valves shall be selected and applied to prevent unintentional clamping or unclamping of the work pieces.

6.4 Programmable Logic Controllers (PLC)

- PLC's can be used for equipment control when the robot controller is not capable, practical, or cost effective. Hard wired logic may be used for small equipment with less than 4 relay outputs with YAI-R approval.
- A dedicated fused 120VAC receptacle shall be provided for the PLC programming terminal.
- There shall be 15% spare I/O capacity.
- Input/Output module voltage shall be 24VDC unless approved by YAI-R.
- Programming documentation and passwords, if applicable, shall be provided to YAI-R at completion of project.

6.5 Enclosures, Push Buttons, Junction Boxes and Terminal Strips

- Operator station control boxes and junction boxes shall have NEMA 12 rating minimum.
- End cover at exposed terminal end, and end clamps at both ends of all terminal strips shall be used.
- Preferred labeling of 24VDC supply terminals are "1" for +24VDC and "2" for 0VDC. All remaining terminals shall be numbered sequentially.
- When multiple terminals are used for common supply (i.e. 24VDC) terminals shall be jumped together using a jumper bar.
- Voltage supply terminals may be separated by use of a separator plate.
- Control enclosures that meet or exceed 1.22m (48in.) by 1.52m (60in.) shall be provided with internal fluorescent lighting. The lighting circuit shall be 120VAC and include circuit protection and an on/off switch.
- A high-voltage warning label shall be placed on the exterior of the cabinet for enclosures which contain voltages greater than 120 volts.
- DIN rail and wire duct should be used inside control panels whenever possible. Install DIN rail the full length inside a panel, between two pieces of wire duct.
- Spare terminals shall be provided in control panels and j-boxes. Wires shall not be terminated on either side of these terminals. The number of spare terminals should be ten percent of the number of used terminals. There should be a minimum of five spare terminals in control panel terminal strips and three spare terminals in j-box terminal strips.
- All j-box terminal strips shall contain a ground terminal.
- Terminal blocks for power circuits should be grouped separately from control circuits.

6.6 Operator Control Stations and Devices

- Pushbutton and selector switch operators, indicator/pilot lights and similar devices shall be, at a minimum NEMA 12 construction.
- Reference NFPA79 for operator color designations.
- Emergency stop pushbutton operators shall be red in color with a yellow background, unguarded, of the palm or mushroom type that require manual resetting. Mounting must comply with NFPA 79.
- Indicating/pilot light color codes must comply with NFPA 79.
- Light beacon

6.7 Nameplates and Identification

- Control and power devices shall be plainly and permanently identified, using the same identification as shown on the documentation. Identification tags shall be mounted adjacent to the device on the sub-plate. Characters shall not be smaller than 3.0mm.
- Plugs and receptacles shall be labeled by identification tags. Characters shall not be smaller than 3.0mm.
- Warning signs shall identify unavoidable hazards associated with specific equipment.
- A legend plate shall be provided for each control station device to identify its function. Legend plates shall be located so they can be easily read from the normal operating position.

6.8 Conductors

- Conductors should be of type MTW or equivalent.
- Conductors shall have UL/CSA listing.

6.9 Wiring Methods and Practices

- Conductors shall be identified at each termination with a marking corresponding with the documentation.
- Wire markers shall be of plastic tube type, or pressure sensitive adhesive label capable of being wrapped around the wire in a manner that the number is easily visible use clear Coveris on label if characters can be smeared easily.
- Conductors and cables shall be run without splices from terminal to terminal.
- Terminals shall be plainly and permanently marked to correspond with documentation.
- Terminal blocks shall be mounted and wired that no wires cross over the terminals. Not more than two conductors shall be terminated at each terminal connection.
- Where equipment is constructed so that wiring must be disconnected for shipment, plugs and receptacles shall be provided at the sectional points.
- When running 24VDC and 0VDC through a cable assembly, pin 1 or pin A should be used for 24VDC, and pin 2 or pin B should be used for 0VDC. All remaining conductors shall be identified sequentially by connector definition (i.e., 3, 4, 5 etc., or C, D, E etc.).
- Connections to continuously moving parts shall be made by high-flex cable.
- Where high-flex, multi-conductor cable is used for flexing applications a suitable strain relief shall be used at the connector end of the cable.
- Disconnected plugs or receptacles shall not have any voltage to exposed pins.
- When using shielded cable and grounding of the shield is required, the preferred cable will have an internal drain wire.
- Heat shrink shall be applied to the exposed shield on all braid shielded cables.
- Always specify terminals/contacts that have adequate current capacity for the application.
- When specifying crimped terminals/contacts, always utilize those with adequate capacity for both the conductor and the insulation. This is especially true for situations where a double crimp (two wires crimped into one terminal/contact) can be utilized (as preferred to splicing).

- For current terminal/contact specifications, refer to the manufacturers product and application specifications or to the Crimp Master Database located on the *Component Assembly Team (CAT) site* on SharePoint.
- When specifying conduit type, refer to the chart in *Table 6-1*. When specifying conduit size, refer to the charts in *Table 6-2*.
- Analog feedback signals should be routed in conduit free of AC voltage.
- Communication signals should use twisted pair and shields as specified by the communication network standard.

Table 6-1 Conduit Type Chart

Conduit Type Chart

Units: Inches

Size	Type UA					Type HCX				
	I.D.		O.D.		Bend	I.D.		O.D.		Bend
	Min.	Max.	Min.	Max.	Radius	Min.	Max.	Min.	Max.	Radius
1/2"	.622	.642	.822	.840	3.5	.620	.640	.820	.840	2.5
3/4"	.820	.840	1.030	1.050	5	.815	.835	1.030	1.050	3
1"	1.041	1.066	1.290	1.315	6	1.030	1.055	1.290	1.315	4
1-1/4"	1.380	1.410	1.630	1.660	7	1.370	1.395	1.635	1.660	4.5
1-1/2"	1.575	1.600	1.865	1.900	6.5	1.575	1.600	1.865	1.900	6.5
2"	2.020	2.045	2.340	2.375	7	2.020	1.900	2.340	2.375	7
2-1/2"	2.480	2.505	2.840	2.875	9.5	n/a	n/a	n/a	n/a	n/a
3"	3.070	3.100	3.460	3.500	15	n/a	n/a	n/a	n/a	n/a
3-1/2"	3.500	3.540	3.960	4.000	16	n/a	n/a	n/a	n/a	n/a
4"	4.000	4.040	4.460	4.500	17	n/a	n/a	n/a	n/a	n/a

Specifications:

Type UA	Type HCX
Core: Zinc coated steel Jacket: Thermoplastic PVC, UV resistant Temperature Rating: -4° to +140° F (-20° to +60° C)	Core: Galvanized steel with cord packing Jacket: High temp thermoplastic PVC Temperature Rating: -76° to +302° F (-60° to +150° C)
Approvals:	Approvals:
Exposed and concealed installations. Hazardous locations per NEC Section 501-4B Class 1, Division II; Class 2, Division I and II; Class 3, Division I and II. Direct burial up to 2". UL Listed and CSA Approved.	None; May only be used where listed products are not required.
Notes:	Notes:
Compatible with standard UL approved liquid-tight conduit fittings. Copper ground wire in sizes 3/8" thru 1-1/4" only.	Compatible with standard liquid-tight conduit fittings. For high temperature use. Not approved or recommended for high flex applications. Available only with black PVC jacket.

Table 6-2 Conduit Size Chart

Maximum Number Style 1015/MTW Conductors In Type U.A. Conduit

CONDUIT SIZE TYPE U.A. (U.L./C.S.A.)	WIRE SIZE	26	24	22	20	18	16	14	12	10	8	6	4	2
	Area in Sq. In.	.005	.006	.007	.008	.009	.012	.015	.019	.027	.054	.090	.117	.163
1/2"	.323	32	27	23	20	18	13	10	8	6	3	1	1	1
3/4"	.553	55	46	39	34	30	23	18	14	10	5	3	2	1
1"	.892	89	74	63	55	49	37	29	23	16	8	5	4	2
1-1/4"	1.560	156	130	111	97	86	65	52	41	29	14	8	6	4
1-1/2"	2.000	200	166	143	125	111	83	66	52	37	18	11	8	6
2"	3.282	328	273	234	205	182	136	109	86	60	30	18	14	10
2-1/2"	4.925	492	410	351	308	273	205	164	129	91	45	27	21	15
3"	7.540	754	628	538	471	419	314	251	198	139	70	42	32	23
4"	12.812	1281	1067	915	800	711	534	427	337	237	118	71	54	39

Note 1: 50% fill, based on NFPA 79, Electrical Standard for Industrial Machinery, 2002 Edition, Paragraph 14.5.2

Note 2: Multiconductor cable shall be treated as a single conductor when calculating area.

Note 3: To calculate fill, divide total conductor area, including insulation by conduit area.

Note 4: Regardless of configuration or calculation, conduit fill shall not exceed 50%.

Maximum Number Style 1015/MTW Conductors In Type HCX Conduit

CONDUIT SIZE TYPE HCX	WIRE SIZE	26	24	22	20	18	16	14	12	10	8	6	4	2
	Area in Sq. In.	.005	.006	.007	.008	.009	.012	.015	.019	.027	.054	.090	.117	.163
1/2"	.321	32	26	23	20	18	13	10	8	6	3	1	1	1
3/4"	.547	54	45	39	34	30	22	18	14	10	5	3	2	1
1"	.873	87	72	62	54	48	36	29	23	16	8	5	3	2
1-1/4"	1.527	152	127	109	95	85	63	51	40	28	14	8	6	4
1-1/2"	2.000	200	166	143	125	111	83	66	52	37	18	11	8	6
2"	3.282	328	273	234	205	182	136	109	86	60	30	18	14	10

Note 1: 50% fill, based on NFPA 79, Electrical Standard for Industrial Machinery, 2002 Edition, Paragraph 14.5.2

Note 2: Multiconductor cable shall be treated as a single conductor when calculating area.

Note 3: To calculate fill, divide total conductor area, including insulation by conduit area.

Note 4: Regardless of configuration or calculation, conduit fill shall not exceed 50%.

Note 5: This type conduit is NOT U.L Listed or C.S.A. Approved.

6.10 Grounded Circuits and Equipment Grounding

- Conductors used for grounding and bonding purposes shall be copper.
- Grounding conductors shall be insulated with green or green with yellow stripe insulation, with the exception of multi-conductor cable.
- For minimum size of grounding conductor refer to NFPA 79.
- The machine and all exposed, non-current-carrying conductive parts shall be effectively grounded.
- All separately mounted electrical enclosures or equipment shall be bonded to the main control enclosure.
- Equipment grounding conductors shall be terminated in each electrical enclosure on a common ground bar or terminal strip which is bonded to the sub-plate.

CHAPTER 7 Safety Requirements

This section is intended as a supplement to the ANSI/RIA 15.06-2012 Standard. For additional information reference the ANSI/RIA 15.06-2012 Standard.

7.1 Manufacture, Remanufacture, and Rebuild of Robots

Robots rebuilt or re-deployed shall, at a minimum, comply with the standard in effect on the date of the original manufacture.

7.2 High Speed APV (Attended Program Verification)

Yaskawa America Incorporated Motoman Robotic Division (YAI-R) does not support High Speed APV.

7.3 Risk Assessment

- A Risk Assessment shall be performed on all YAI-R designed systems. The Risk Assessment developed for the standard product may be utilized if deemed acceptable by the project engineer but should be reviewed and updated if necessary to insure accuracy.
- When integrating equipment with dissimilar circuit performance the lesser of the performance categories shall be used when completing the Risk Assessment.
- The establishment of the restricted space shall be covered by the Risk Assessment. If it is deemed necessary to add limit switches hard stops, or Functional Safety to the cell, it will be the responsibility of the Project Engineer to implement.

7.4 Safeguarding of Personnel

When integrating multiple robots in a cell assembly that have overlapping restricted spaces, simultaneous teaching shall be prevented by hardware-based circuitry.

7.5 Safeguarding Devices

- Safety fence doors or gates shall be designed, installed, applied and maintained so that they open laterally or away from the hazard, and not into the safeguarded space. The door or gate cannot close by itself and activate the interlocking circuitry.
- When area scanners are used, the scanned area shall be visibly marked on the drawing.

7.6 Safety Circuits

All safety circuits (i.e. emergency stop, safety gate, and light curtain interface) that are used in safeguarding personnel from the robot or robot system shall be control reliable in accordance with ANSI/RIA 15.06-2012. All safety system equipment must be selected and implemented based on the outcome of the risk assessment.

7.7 Yaskawa America Incorporated Motoman Robotics Division Controller Compliance

For specific information on how YAI-R robot controllers comply with applicable standards, reference the following documents:

- *TB-52 North American Standard (NAS) DX100 Controller*
- *TB-53 NAS FS100 Controller*
- *TB-55 NAS DX200 Controller*

APPENDIX A Preferred Components

Yaskawa America Incorporated, Robotic Division (YAI-R) preferred components are listed below.

Electrical	
Connectors	*Manufacturer:* DDK *Series:* DMS3101A, DMS3102A, DMS3106A, DMS3108A or B
Switches (pushbutton and selector)	*Manufacturer:* Use the latest approved manufacturer per engineer.
Pilot Lights (panel)	*Manufacturer:* Use the latest approved manufacturer per engineer.
Conduit Backshells	*Manufacturer:* Sankei, *Series:* KMKD, KM90KM, KMKM, KM90KD
Relays	*Manufacturer:* Omron *Series:* K7S, LY2, MY2, MY3, MY4, RY2
Wire (internal YAI-R use)	UL1015 or equivalent
Relay Sockets	*Manufacture:* Omron *Mfr.:* PYF
Din Rail Components	*Manufacturer:* Phoenix 35mm DIN Rail components
Photo-Electrics	*Manufacturer:* Banner
Cord Grips	*Manufacturer:* RACO *Series:* 3702, 3703, 3704, or 3705
Enclosures	*Manufacturer:* Hoffman
Molded Connector Cables	*Manufacturer: T*urck
Multi-Conductor Cable	*Manufacturer:* Belden
Safety Switches (disconnects)	*Manufacturer:* Square-D
Flange Mounted Disconnects	*Manufacturer:* Allen-Bradley
Terminals, Ring Tongue and Fork	*Manufacturer:* AMP
Wiring Duct (internal)	*Manufacturer:* Panduit or Taylor
Power Supplies	*Manufacturer(s)*: Use the latest approved manufacturer per standards engineer.

Electrical	
Wireway (external)	*Manufacturer:* Hoffman *Series:* F-44xxx, F-66xxx, F-88xxx *Manufacturer:* Legrand *Series:* Cablofil V-Trough
Safety Relay	*Manufacturer:* Pilz
Light Curtains	*Manufacturer:* Banner

Mechanical	
Pneumatic Valves	*Manufacturer(s):* SMC and Numatics
Hardware	*SAE: Grade 5 or higher* *Property Class*: 8.8 or higher for hex head cap screws *SAE: Grade 8 or higher* *Property Class:* 12.9 or higher for socket head cap screws
Pneumatic Fittings	*Manufacturer:* SMC, Legris, Parker

Weld Tooling	
Fixture Clamps	*Manufacturer:* Destaco, BTM, or ISI
Proximity Sensors	*Manufacturer:* Turck, Weld field immune, Schmersal