Technical White Paper

Factory Inspection and Safety Requirements for Pneumatic Industrial Manipulators and Applicability of Relevant Standards

—An Engineering Interpretation of Lifting, Pneumatic, and Machinery Safety and Acceptance of Custom Tooling

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Abstract

A Pneumatic Industrial Manipulator is custom assist equipment that uses compressed air as its primary energy source to help an operator handle and position workpieces. It often integrates a balancing mechanism, rotary and articulating joints, custom end-of-arm tooling or a vacuum gripping system, and a load-bearing structure such as a column, jib, rail, or frame. Because its functions span lifting, pneumatic power, machinery and control safety, and custom gripping, no single standard or certificate normally encompasses every safety requirement.

Starting from the equipment's functional classification, this white paper outlines standard frameworks that may be relevant to lifting safety, pneumatic-system safety, and machinery and control safety for Pneumatic Industrial Manipulators. It then proposes systematic factory-inspection items, on-site installation and acceptance items, and a document-delivery list, followed by boundaries for certification and third-party testing and a typical Failure Mode and Effects Analysis (FMEA). Its purpose is to help engineering, quality, procurement, and user stakeholders establish a clear framework for safety and compliance decisions and define responsibilities early in a project.

This document is an engineering statement on standards applicability and factory inspection. The listed standards, inspection items, and decision principles are for reference. The classification, inspection depth, and certification needs of a specific machine must be assessed from its attributes, load risk, and regulatory requirements at the project location. Official standard texts and the contractual technical agreement take precedence.

Keywords

Pneumatic Industrial Manipulator; Pneumatic Balancer; vacuum lifting; Jib Crane; custom tooling; lifting safety; pneumatic-system safety; machinery safety; functional safety; factory inspection; on-site acceptance; standards applicability; FMEA risk analysis.

1. Introduction

As manufacturing places greater emphasis on ergonomics, productivity, and occupational health, Pneumatic Industrial Manipulators are increasingly used in automotive, appliance, machining, logistics-sorting, glass-handling, and panel-handling applications. Their common feature is the use of compressed air as the primary assist force, enabling operators to lift, rotate, position, and release medium-weight workpieces with less physical effort, reducing musculoskeletal-injury risk and improving cycle-time stability.

Pneumatic Industrial Manipulators are, however, highly customized in structure and configuration. Load range, reach, number of joints, tooling type, control logic, and installation conditions differ substantially by project, so safety requirements cannot be generalized through a single standard or certificate. The equipment combines lifted loads, stored pneumatic energy, moving mechanisms, and human interaction; weakness in any one area can create risk. A layered assessment of equipment attributes, load hazards, pneumatic systems, tooling, control logic, and installation conditions is therefore essential to a sound safety-and-compliance framework.

This white paper was prepared by the AUREK Engineering Resource Center as supporting technical documentation for factory inspection and customer acceptance. AUREK is identified only as the publisher and source of engineering context. This document makes no commitment regarding the qualifications, certification status, or compliance of any specific product. The standards, inspection items, and risk-analysis methods described are intended to provide consistent engineering terminology and decision criteria so that responsibilities, inspection depth, and deliverables can be defined in contracts and technical agreements.

Notice: This document is a Standard Applicability Statement + Factory Inspection Guide + Customer Acceptance Documentation; it is not a certification commitment. References to standards, regulations, and certification are deliberately cautious and must be assessed for the specific equipment and regulatory requirements at the project location. Official standard texts take precedence.

2. Equipment Classification and Standards-Applicability Boundaries

To determine which standards and inspections may apply to a Pneumatic Industrial Manipulator, its equipment classification must first be established. The following summarizes common related equipment configurations and engineering characteristics, then discusses their boundaries relative to the regulatory concepts of lifting machinery and special equipment.

2.1 Pneumatic Industrial Manipulator

A Pneumatic Industrial Manipulator normally consists of a fixed base or column, main arm, secondary arm (or multiple arm stages), rotary joints, a cylinder and balancing mechanism, brakes/locks, and end-of-arm tooling. Compressed-air force in the cylinder counterbalances the weight of the workpiece and mechanism, allowing the operator to guide the workpiece in a nearly weightless state. Unlike electrically driven lifting equipment, it generally uses the air supply rather than a main drive motor as its primary energy source, though solenoid valves, sensors, pushbuttons, and other electrical components may be integrated for control and protection.

2.2 Pneumatic Balancers and Assist Manipulators

Pneumatic balancers and assist manipulators are normally used for lighter loads or assisted handling of hand tools, emphasizing near-floating suspension within a defined stroke. Their structures are relatively simple, but still require stable air-supply pressure, loss-of-air protection, and inadvertent-release prevention. For standards-applicability decisions, distinguish them from full-arm Pneumatic Industrial Manipulators with more complete structures.

2.3 Vacuum Lifter

A Vacuum Lifter uses a vacuum generator or pump, an air/vacuum reservoir, and one or more suction cups to handle flat-surfaced workpieces such as sheets, panels, and enclosures. Principal safety concerns include generating and retaining the required vacuum, maintaining vacuum after loss of air or power, and suction-cup compatibility with different workpiece surfaces. Requirements for non-fixed lifting attachments, such as the direction of ISO 13155, may be relevant, but actual applicability depends on attachment type and project requirements.

2.4 Jib Crane

A jib crane is generally a rotating-arm lifting device mounted to a floor, column, or wall. It shares some functions with a Pneumatic Industrial Manipulator—both have arms, rotate, and lift—but normally differs in drive type, load range, and control logic. A jib crane may fall within the category of jib-type lifting machinery in some circumstances, for which lifting-machinery safety rules may be relevant. Whether a Pneumatic Industrial Manipulator should be treated in the same manner depends on its load, lifting function, and structural attributes.

2.5 Custom End-of-Arm Tooling and Vacuum-Cup Systems

End-of-arm tooling and vacuum-cup systems are normally customized for a specific workpiece and include mechanical grippers, clamps, dedicated supports, and single or multiple vacuum-cup groups. Safety concerns include retaining gripping or vacuum force, inadvertent-release prevention, behavior after loss of air or power, and compatibility with workpiece geometry. Because the equipment is highly customized, requirements are normally based on technical documentation, internal specifications, and general lifting-attachment/tooling principles; specific acceptance criteria must be stated in the technical agreement.

2.6 Rail / Frame System

Pneumatic Industrial Manipulators are often mounted on rails, beams, or gantry frames to extend their coverage. In addition to the arms, the rail travel mechanism must be assessed for derailment prevention, positioning brakes, structural stiffness, and connection reliability. Frame and rail capacity, deformation control, and installation accuracy directly affect overall stability and safety and must be included in design and acceptance.

2.7 Comparison with Industrial Robots

Industrial robots are typically electrically driven, programmable machines capable of autonomous motion. Their safety requirements address automatic motion and human–robot collaboration, and robot-specific safety standards may be relevant. A Pneumatic Industrial Manipulator, by contrast, emphasizes human-in-the-loop assistance and balancing: motion is normally guided by the operator, and the equipment does not autonomously determine its path. Because the hazard sources and control concepts differ, the applicable standards and inspection priorities also differ; robot standards should not simply be used to represent all requirements for a Pneumatic Industrial Manipulator.

2.8 Definition of lifting machinery and special equipment

Lifting machinery and special equipment are important regulatory concepts that may determine requirements for type testing, registration for use, and periodic inspection. Whether a Pneumatic Industrial Manipulator falls within these categories cannot be determined from its name alone. Its lifting function, rated load, structure, intended use, and other equipment attributes must be assessed against the special-equipment catalog and management rules at the project location. Conclusions may vary with load range, installation method, and local regulatory interpretation.

Notice: Whether equipment is classified as lifting machinery or special equipment must be determined from its attributes and the regulatory requirements at the project location. Official catalogs and regulations take precedence, and each party's responsibilities must be defined in the contract or technical agreement.

2.9 Boundaries of CCC / CE / Third-Party Testing (Overview)

Certification and compliance requirements vary by region and product configuration. Compulsory product certification, such as CCC, normally applies to products or electrical components within a specified catalog. Supply to export markets may involve the applicable compliance framework, such as the directives and harmonized standards associated with CE. Applicability may differ between a purely pneumatic machine and a subsystem containing electrical components. The need for certification or third-party testing must be determined from the equipment attributes and regulations at the project location. Section Eleven provides further discussion of these boundaries.

2.10 Standards-Applicability Reference Matrix

The following table summarizes standards that may be relevant to a Pneumatic Industrial Manipulator from different engineering perspectives. It is an overview of potential applicability, not a substitute for specific clauses and not a statement that any standard is fully satisfied or has been passed. The official text governs each standard's actual scope and requirements, which must be assessed against the equipment attributes.

Standard / Category (Reference Framework)	Description of Potential Scope
Basic Machinery Safety (ISO 12100 framework)	Provides a general machinery-safety and risk-assessment framework and may support inherently safe machine design and hazard identification. Applicability and the specific method are governed by the official text.

Standard / Category (Reference Framework)	Description of Potential Scope
Pneumatic-System Safety (ISO 4414 framework)	Provides general safety rules for pneumatic fluid-power systems, including principles for circuit design, pressure control, loss of air, and exhaust.
Lifting-Machinery Safety (GB 6067 series framework)	Provides safety rules for various types of lifting machinery. Relevant provisions may apply if the equipment is classified by its attributes as jib-type or light lifting equipment; applicability must be determined from those attributes.
Crane Design (GB/T 3811 framework)	Addresses complete-crane structures and load calculations and may provide a reference for evaluating structural strength, stability, and load capacity.
Electrical Safety of Machinery (IEC 60204-1 / GB 5226 series framework)	Provides safety requirements for machine electrical equipment. Relevant general and product-specific provisions may apply where the machine includes solenoid valves, sensors, controllers, or other electrical components.
Safety-Related Control Functions (ISO 13849-1 / IEC 62061 framework)	Addresses performance requirements for safety-related control parts and methods for determining the required performance level where functions such as emergency stop, safety limiting, or two-hand control are provided.
Ergonomics (ISO 11228 series framework)	Addresses evaluation of manual handling and operating forces and may support assessment of human workload and the force required to guide an assist arm.
Welding and Fasteners (Welding standards and GB/T 3098 framework)	Addresses weld quality and fastener property classes and may support inspection of structural welds, bolt selection, and loosening-prevention design.
Lifting Attachments / Tooling (ISO 13155 framework)	Addresses functional and protective requirements for non-fixed lifting attachments, including vacuum lifting devices, and may support acceptance of custom tooling and vacuum systems.
Export-Market Compliance (Frameworks associated with CE)	Supply to export markets may involve applicable compliance frameworks and harmonized standards. Scope and assessment method must be determined from the target market and equipment attributes.
Compulsory-Certification Catalogs (CCC framework)	Applicability is governed by the latest official catalog. A purely pneumatic machine and a subsystem containing electrical components may be treated differently; determine requirements from the equipment attributes and applicable regulations.
Company and Customer Acceptance Specifications	Includes acceptance items in the internal quality system, factory-inspection plan, and customer technical agreement. These are as important to equipment delivery as the standards frameworks above and must be defined in the contract.

Table 2-1. Standards-Applicability Reference Matrix. The table is for reference only. Official standard texts, equipment attributes, customer requirements, and regulations at the project location take precedence; the table is not a certification or compliance statement.

3. Engineering Interpretation of Lifting-Related Safety Requirements

Although assistance is its primary purpose, a Pneumatic Industrial Manipulator necessarily presents lifting hazards whenever it supports and lifts a workpiece. This section interprets potentially relevant lifting-safety requirements from the perspectives of load, structure, stability, travel limits, and braking. The discussion indicates engineering direction only; official standard texts and the equipment attributes govern specific requirements.

3.1 Rated Load and Safety Margin

Rated load is a fundamental parameter for safe use. Design must define the rated lifting capacity, allowable load at maximum reach, and their relationship, with an appropriate structural safety margin. The load range that the assist mechanism can balance must correspond to the rated load so that assist force or stability is not lost near the operating limit. The rated load and limiting conditions must be clearly marked on the nameplate and in the manual and verified by the applicable factory and on-site load tests.

3.2 Structural Strength and Stability

The arms, column, base, and connections form the principal load path; their strength and stiffness directly determine load safety. Structural design must address static, dynamic, eccentric, and potential impact loads and the effect of accumulated fatigue on long-term reliability. For fixed equipment, verify overturning stability and anchor requirements. For rail- or frame-mounted equipment, address stability in motion and derailment prevention. Welds and high-strength bolted joints are critical structural nodes and should be inspected against applicable welding and fastener standards.

3.3 Travel Limits and Overtravel Protection

Provide travel limits to prevent collision, instability, or structural damage when the mechanism exceeds its intended range. Limits may use mechanical stops, limit switches, or both and must reliably stop the drive, generate an alarm, or initiate protective action at the endpoint. Verify trigger reliability and reset behavior for every limit so the system produces a dependable safe response outside the design range.

3.4 Braking, Locking, and Fall Prevention

Braking and locking are core safety functions for preventing an unintended load descent or mechanism motion. For a Pneumatic Industrial Manipulator, assess behavior after loss of air, loss of electrical power, or interruption of operation: the mechanism should hold the load at its current position or descend slowly under control, never fall suddenly. Provide reliable braking or mechanical locking at critical degrees of freedom and validate it by loss-of-air testing. Select redundancy for fall-prevention functions according to the load-risk level.

3.5 Warning Labels and Visual Information

Clear warnings and visual information help reduce incorrect operation. The nameplate must state key parameters, including model, rated load, and rated supply pressure. Motion zones, gripping zones, and hazard points require appropriate warning labels. Apply relevant safety-color and sign standards as appropriate and verify completeness and correctness during factory inspection.

4. Engineering Interpretation of Pneumatic-System Safety Requirements

The pneumatic system is the energy core of a Pneumatic Industrial Manipulator. Compressed air provides assistance but also stores energy; abnormal discharge, leakage, or pressure fluctuation can directly affect load retention and machine stability. This section provides an engineering interpretation of potentially relevant pneumatic-system safety requirements. Applicable pneumatic-safety standards and their official texts take precedence.

4.1 Air-Supply Quality and Pressure Stability

Supply-pressure stability and cleanliness directly affect assist performance and component life. The system must operate stably throughout its specified inlet-pressure range, avoiding reduced assistance from low pressure and impact motion from pressure fluctuation. Control moisture, oil mist, and particles by filtration, water separation, and drying where required. Verify adjustment, drainage, and exhaust functions of filter-regulator components during inspection.

4.2 Pneumatic-Circuit Sealing and Leakage Control

Pneumatic leakage wastes energy and can also cause gradual loss of assistance, unintended load descent, or abnormal motion. Lines, fittings, valves, and cylinder connections must seal reliably and be leak-tested at operating pressure using leak-detection fluid or an electronic detector. Use reliable sealing and loosening-prevention measures on critical connections and, where necessary, a check device at the supply connection to slow abnormal depressurization.

4.3 Loss-of-Air Protection and Depressurization Behavior

Loss-of-air protection is a defining safety requirement for pneumatically assisted equipment. If the air supply is unexpectedly interrupted or the system loses pressure, the equipment should prevent a sudden load drop. Cylinder locks, check valves, counterbalance valves, or mechanical brakes can hold the mechanism in position or permit a controlled slow descent. Simulated loss-of-air testing should verify that the load is held reliably or released in a controlled manner under depressurized conditions.

4.4 Pressure Control and Overpressure Protection

The system must provide appropriate pressure control and overpressure protection to prevent component damage or hazardous motion caused by abnormal pressure rise. Pressure-safety, relief, and pressure-limiting devices must match the system design pressure and be functionally verified during inspection. Systems with air receivers or multi-stage vacuum also require assessment of vessel and line pressure capacity and associated safety accessories.

4.5 Exhaust and Residual Energy

Residual compressed air is a potential energy source during maintenance, repair, or an emergency. Provide safe exhaust and depressurization so maintenance personnel can release residual pressure under controlled conditions. State the procedure clearly in the manual and incorporate it into inspection and maintenance practices.

5. Machinery and Control Safety Requirements

In addition to lifting and pneumatic hazards, a Pneumatic Industrial Manipulator presents crushing, shearing, collision, and other mechanical hazards from moving components, as well as safety functions implemented by control logic. This section gives an engineering interpretation of machinery guarding and control safety. Relevant machinery-safety and functional-safety standards may provide methodological guidance; official texts take precedence.

5.1 Mechanical Guarding of Moving Parts

Rotary joints, hinges, moving cylinder components, and tooling opening/closing zones can create crushing or shearing hazards. Design should reduce hazardous gaps through inherently safe measures wherever practicable and provide guards or barriers where hazards cannot be eliminated. In areas of close operator interaction, assess the need for additional presence-sensing protection or safety-distance requirements based on the task.

5.2 Operating Method and Protection Against Incorrect Operation

Operating methods must balance efficiency and safety. Critical load-release operations should require a clear indication of intent, such as two-hand control, coordinated foot-pedal action, or a confirmation step, to reduce the risk of unintended release. A single incorrect operation must not cause hazardous motion; validate the logic through inadvertent-release-prevention testing.

5.3 Emergency Stop and Safety Functions

Where electrical controls are provided, emergency stop, safety limits, interlocks, and other safety functions must match the risk level. Functional-safety standards may guide the required reliability and architecture of safety-related control parts. Emergency stops must be readily accessible, easy to actuate, and place the equipment in a safe state; inspection must verify prompt and reliable response.

5.4 Electrical Safety (Where Electrical Components Are Included)

For equipment incorporating solenoid valves, sensors, controllers, or displays, apply relevant electrical-safety standards for machinery. Address component selection, wiring reliability, protective bonding and insulation, overload and short-circuit protection, and cable retention and protection. Interfaces between electrical and pneumatic subsystems, such as a solenoid valve controlling an air circuit, must not produce hazardous coupled motion under abnormal conditions.

5.5 Ergonomics and Operating Load

A fundamental purpose of a Pneumatic Industrial Manipulator is to improve ergonomics. Required guidance force, handle placement, sight lines, and working posture should follow ergonomic principles;

applicable ergonomics standards may support evaluation of operator workload. Good ergonomics improves comfort and also reduces incorrect operation and safety risk associated with fatigue or poor posture.

6. Factory Inspection Plan

Factory inspection should go beyond checking appearance and basic motion. For Pneumatic Industrial Manipulators, it should address safety-critical items including structures and welds, fastener security, pneumatic leakage and pressure, loads and end stops, brakes and loss-of-air protection, tooling holding force and inadvertent-release prevention, and complete documentation. The following table provides a systematic factory-inspection plan for reference. Inspection depth and acceptance criteria must be selected for the equipment and defined in the contract or technical agreement.

No.	Inspection Item	Description and Method (Reference)
1	Appearance inspection	Check the appearance of the coating, markings and welds to confirm that there are no obvious deformations, cracks, rust and burrs; check whether the nameplate information and safety warning signs are complete and clear.
2	Dimensional and assembly inspection	Check whether the key structural dimensions and installation positions comply with the drawings; check whether the joint clearance, bearing assembly and fit are normal; confirm that the movable parts move flexibly and there is no abnormal jamming.
3	Weld and structural parts inspection	Conduct visual inspection of welds to confirm that there are no obvious defects; non-destructive testing methods can be used to check important welds and structural parts; confirm that the connection parts meet the design requirements.
4	Bolt tightening inspection	Check the tightening of fasteners according to design requirements, and recheck the connecting bolts between the main structure and joints; confirm that anti-loosening measures (self-locking nuts, spring washers, etc.) are installed in place.
5	Pneumatic Leak Test	Pressurize the system to operating pressure. Use leak-detection fluid or an electronic detector to inspect lines, fittings, valves, and cylinder connections. Confirm reliable sealing and any required check-valve provisions.
6	Air-Supply Pressure Check	Verify that rated supply pressure stably reaches the design value and calibrate the pressure indication. Check air quality (water, oil, and particles) and the adjustment and drainage functions of filter-regulator components.
7	Filtration, Regulation, and Safety Components	Confirm correct installation and responsive operation of filtration, regulation, and oil-mist treatment components; functionally verify pressure-safety, pressure-limiting, and related protective devices.
8	No-load running test	Make each degree of freedom move through the entire stroke without load, check the smoothness of the movement and the brake action; confirm that there is no abnormal vibration, jitter or abnormal sound.
9	Rated-Load Test	Carry out lifting, turning and other actions under the rated load to verify the load-balancing ability and smooth operation of the assist mechanism; confirm that there is no impact in the lifting and does not exceed the safety limit.
10	Static-/Dynamic-Load Verification Approach	Static load: Keep stationary under the rated load and observe the load-bearing stability of the structure and braking; Dynamic load: Make continuous movements under the load and check whether there is any displacement or looseness (the specific load and duration are subject to the agreement).

No.	Inspection Item	Description and Method (Reference)
11	Rotary joint and brake testing	Check the smoothness and free range of the rotary joint motion; verify the reliability of the rotary lock or brake in the air-depleted state, and confirm that the joint will not rotate freely accidentally.
12	End-Stop and Anti-Collision Test	Verify timely and reliable end-stop actuation when the manipulator reaches a travel limit. Confirm that the system enters a reliably safe condition if the design range is exceeded.
13	Loss-of-Air Protection Test	Simulate interruption of the air supply and verify that the mechanism locks or descends slowly under control while retaining the load at its current position. Confirm protection against a sudden gravity-driven drop.
14	Tooling Grip / Vacuum-Holding Test	Functionally test the tooling or suction cups. Verify stable gripping of representative workpieces or vacuum holding at rated load, and check correct operation of directional and control components.
15	Inadvertent-Release Prevention Test	Verify the misoperation protection logic and confirm that the load can be released only under safe conditions; test whether the release locking behavior is effective in the event of air loss or power loss.
16	Vacuum-Retention Test	For equipment with a vacuum system, test vacuum retention after loss of air/power. Confirm that the vacuum level remains within the allowable range for the specified time and inspect vacuum-generation and control components for leakage.
17	Noise, Smoothness, and Operating Force	Confirm that operating noise is acceptable and motion is smooth and free of binding. For hand-guided equipment, verify that operating force is within a reasonable ergonomic range.
18	Nameplate, Labels, and Manual Check	Verify that the nameplate information is complete and correct, and that warning signs are complete; confirm that the instructions include safety warnings, operating procedures and maintenance requirements, and are accompanied by pneumatic circuit diagrams, electrical diagrams and inspection records.

Table 6-1. Factory Inspection Plan (Reference). Record every inspection result and obtain the responsible person's signature. Specific items, methods, and acceptance criteria must be selected for the equipment and are subject to the contract or technical agreement.

7. On-Site Installation and Acceptance

Passing factory inspection does not by itself establish that the equipment can be used safely on site. Safety performance also depends heavily on the foundation, installation accuracy, air-supply conditions, and operating environment. After installation, each item in a systematic acceptance plan must be verified and documented. The following table provides a reference plan for preparing an on-site acceptance form.

No.	Acceptance Item	Description and Method (Reference)
1	Foundation and Anchoring	Compare the foundation drawing with the installed foundation and confirm that site conditions meet the design requirements. Check anchor-bolt specifications, embedded locations, tightening, and loosening prevention, and verify the reliability of base-to-foundation connections.
2	Installation Verticality and Levelness	Measure the verticality and levelness of columns, jibs, and other components using a level or plumb reference. Confirm that there is no material inclination and correct with shims where necessary.
3	Working-Radius Verification	Confirm that the installed working radius meets design and use requirements and that the motion zone is unobstructed. At maximum reach, verify that joints do not interfere and that required safety clearance remains.
4	Lift-Stroke Verification	Operate to the travel limit both unloaded and at rated load. Verify the accuracy and stopping reliability of limit switches or mechanical stops, and recalibrate limits if overtravel occurs.
5	On-Site Air-Supply Pressure	Measure site supply pressure and confirm that it remains within the specified inlet range. Check supply-line diameter and filtration, and verify stable pressure with controlled pulsation.
6	On-Site Air Quality	Check moisture, oil, and particle levels in the compressed air and verify correct operation of filtration, water separation, and drying equipment. Where necessary, compare pressure indications with sensor readings.
7	Operating Space and Interference	Have the operator simulate normal work and check the entire motion envelope for interference with the ceiling, adjacent equipment, workpieces, or personnel routes. Confirm that the operating space meets ergonomic requirements.
8	Rated-Load Trial Handling	Under appropriate safety supervision, handle the rated load or an equivalent test load through lifting, transverse movement, and other required motions. Verify balance and responsiveness under actual operating conditions, with particular attention to brake response under load.
9	Workpiece-Gripping Verification	Trial-handle an actual workpiece to verify the compatibility and reliability of the tooling or suction cups. For vacuum lifting equipment, check sealing and vacuum level. Confirm correct release and reset behavior.
10	Operator Training	Train operators in machine functions, safe operation, and emergency response. Confirm familiarity with brakes, limits, emergency stops, and other safety devices, then document training completion.
11	Inspection-Checklist Delivery and	Provide the user with daily inspection and maintenance checklists stating frequencies, items, and criteria. Obtain acknowledgment of receipt and understanding of the implementation responsibility.

No.	Acceptance Item	Description and Method (Reference)
	Acknowledgment	

Table 7-1. On-Site Installation and Acceptance Plan (Reference). On-site acceptance must produce a written report stating conclusions and corrective-action recommendations. Issues must be corrected and pass reinspection before the equipment is released for use.

The installation environment materially affects safety performance. Insufficient foundation stiffness can cause machine movement and positioning error; inadequate air pressure or quality can destabilize assistance or accelerate component wear; and insufficient operating space can cause collisions in normal use. Verify these factors during acceptance and define responsibility for site conditions in the contract or technical agreement.

8. Document Delivery List

Acceptance covers more than the machine itself. Complete, clear accompanying documentation is equally important: it records the equipment's technical state and supports operation, maintenance, and allocation of responsibilities. Certificates, manuals, pneumatic and electrical schematics, inspection records, checklists, and the on-site acceptance form are therefore as important as the delivered equipment. The following table provides a recommended document list.

Document Name	Purpose and Contents (Reference)
Certificate of Conformity	States the product name, model, serial number, manufacturer, and manufacture date and serves as evidence that the product passed factory inspection.
Operation Manual	Describes machine structure and operating principles, operating steps, safety precautions, maintenance, and common troubleshooting. Pneumatic and electrical schematics and a parts list should be included.
Packing List	Lists the components, spare parts, and tools shipped with the equipment for verification at delivery and receipt.
Factory Inspection Record / Report	Summarizes the result and disposition of each factory-inspection item, including records for key items such as pressure, load, limits, loss-of-air protection, and tooling.
Pneumatic and Electrical Schematics	Provides pneumatic and electrical control schematics for on-site connection, maintenance, and troubleshooting.
Risk-Assessment Record	Documents identified equipment hazards and analysis of the corresponding safeguards as supporting evidence for safety design and acceptance.
Wear-Parts List	Lists consumable and wear parts, including seals, filter elements, and brake components, together with recommended replacement intervals for maintenance and spare-parts planning.
Inspection and Maintenance Plan	Provides a daily inspection checklist and maintenance manual stating inspection items, frequencies, and criteria to support long-term safe operation.
Tooling / Vacuum-Holding Test Record	For custom tooling or suction-cup systems, provides performance-test records for gripping force or vacuum holding, vacuum retention, and related functions.
On-Site Acceptance Form	Signed by the user or a third party after the on-site inspection passes, confirming that installation and functions meet the agreed requirements.
Training Records	Attendance or acknowledgment records for required operator safety and operating training.

Table 8-1. Document Delivery List (Reference). The contract or technical agreement must define the required document scope and format, and the agreed terms govern.

9. Boundaries of Safety Certification and Third-Party Testing

Certification and third-party testing are frequent customer concerns and common sources of misunderstanding. A standards-applicability statement is not a compliance commitment; saying that a standard may be referenced does not mean the equipment is certified to it, and typical treatment of an equipment category does not establish that this machine belongs—or does not belong—to that category. Determine certification and testing requirements from equipment attributes, load risk, and regulations at the project location, and define each party's responsibility in the contract or technical agreement.

9.1 Determination as Special Equipment / Lifting Machinery

Whether the equipment is regulated as lifting machinery or special equipment—and may therefore require type testing, registration for use, or periodic inspection—must be determined from its lifting function, rated load, structure, and installation method against the catalogs and management rules at the project location. The conclusion may vary with load range, local regulatory interpretation, and operating conditions. Official regulations and catalogs take precedence.

9.2 Compulsory Product Certification (e.g., CCC)

Compulsory product certification normally applies to products or electrical components within a specified catalog. Applicability may differ between a purely pneumatic machine and a subsystem containing electrical components. If motors, controllers, or other electrical components are integrated, determine their certification requirements from the latest official catalog and equipment attributes. The contract should state whether an application is required and which party is responsible.

9.3 Export-Market Compliance (e.g., Frameworks Associated with CE)

Supply to export markets may involve applicable compliance frameworks and harmonized standards. Determine scope, assessment method, and technical-documentation requirements from the target-market rules and equipment attributes. Such compliance normally involves risk assessment and preparation of technical documentation and differs from third-party certification; a qualified professional must confirm the project-specific requirements.

9.4 Third-Party Testing and Witnessing

Some industries or customers may require a qualified testing body to perform type testing or witness factory inspection or on-site acceptance. If the contract requires third-party participation, plan the inspection scope, acceptance criteria, and required documents in advance and allocate responsibility for organization, cost, and outcomes.

Notice: These certification and testing boundaries are for engineering reference only. Determine actual applicability from the equipment attributes and regulations at the project location. Official standards and regulations take precedence, and a qualified professional must review and confirm the requirements in the contract or technical agreement. A standards-applicability statement is not a compliance commitment.

10. FMEA Risk Analysis

Failure Mode and Effects Analysis (FMEA) is an engineering method for identifying potential equipment risks, assessing consequences, and developing controls. The following table addresses typical Pneumatic Industrial Manipulator risk scenarios and lists representative failure modes, causes, consequences, and mitigation directions for design, inspection, and acceptance. The content is a general example; design and safety engineers must complete equipment-specific analysis and ratings for each project.

Risk / Hazard	Possible Causes	Potential Consequences	Mitigation Measures (Reference)
Unexpected Load Release	Pneumatic pressure loss; balance-assist failure; overload	Workpiece drop causing personal injury or equipment damage	Provide reliable braking/locking and check valves; limit descent speed; clearly establish the rated load and strictly prohibit overload.
Crushing / Shearing Injury	Personnel in the motion path; insufficient joint clearance	Body pinched by moving components or tooling	Reduce hazardous gaps or provide physical guarding; establish safe-work procedures; use two-hand or confirmation-based control for critical release actions.
Structural Failure / Fracture	Accumulated fatigue; weld defects; unsuitable material selection or insufficient design margin	Failure of an arm or connection, potentially causing a serious accident	Verify the structure against loads and safety margins; inspect welds to applicable specifications; schedule periodic structural and fatigue inspections; use conforming materials.
Air-Supply Leakage / Pressure Loss	Aged lines; loose fittings; valve failure	Assist force gradually fails or motion becomes abnormal, causing the workpiece to descend	Periodically inspect and replace seals and tighten fittings; provide pressure monitoring and alarms; use loss-of-air protection to hold the load or permit controlled slow descent.
Loss of Vacuum	Poor suction-cup sealing; vacuum-component failure	Vacuum-held load falls	Select suitable suction cups and seals; provide vacuum retention and indication; regularly clean and replace aged components; provide a low-vacuum alarm and holding logic.
Electrical-Control Failure (If Present)	Solenoid-valve failure; loose wiring; missing protection	Loss of function or safety function	Apply relevant electrical-design standards; provide required protection and emergency stop; secure wiring reliably; schedule periodic electrical inspections.
Overload / Incorrect	Use above the rated load; operator error	Structural damage or unintended motion	Clearly mark load limits and train operators; provide error-

Risk / Hazard	Possible Causes	Potential Consequences	Mitigation Measures (Reference)
Operation			prevention and confirmation logic; add load sensing or limiting measures where necessary.
Noise Hazard	High-velocity airflow; mechanical friction	Hearing effects from prolonged exposure	Optimize pneumatic circuits to reduce turbulent-flow noise; apply noise controls at critical locations; provide required hearing protection in the work area.

Table 10-1. Typical Failure Mode and Effects Analysis (Example). This table identifies principal risks and control directions. For an actual project, design and safety engineers must complete the FMEA and risk rating using equipment-specific details.

11. Conclusion

A Pneumatic Industrial Manipulator is highly customized assist equipment whose functions span multiple engineering domains. Its safety requirements cover lifting, pneumatic power, machinery and control safety, and custom gripping, and therefore cannot be represented by one standard or certificate. A sound approach is to assess equipment attributes, load hazards, pneumatic systems, tooling, control logic, and installation conditions in layers, identify critical risks at each layer, and apply appropriate design, inspection, and protective measures.

Factory inspection must go beyond appearance and basic motion to address safety-critical items such as rated load, limits, braking, pneumatic leakage, loss-of-air protection, inadvertent-release prevention, tooling holding capacity, and documentation delivery. On-site installation and acceptance must additionally verify factors affected by site conditions, including foundation anchoring, installation accuracy, air-supply conditions, operating space, and trial handling at load, with results documented in a written acceptance record.

Certificates, manuals, pneumatic and electrical schematics, inspection records, checklists, and on-site acceptance forms are as important as the equipment itself because they document technical status and responsibility boundaries. Certification and compliance statements must remain cautious: standards applicability defines design and inspection references, not an automatic compliance guarantee. Determine whether special-equipment regulation, compulsory certification, or third-party testing applies from equipment attributes and regulations at the project location, and define responsibility in the contract or technical agreement.

All parties should agree early in the project on equipment classification, inspection depth, certification needs, and document-delivery scope and record those terms in the contract and technical agreement. A layered, traceable engineering method clarifies responsibility across design, manufacture, acceptance, and use while supporting long-term safe operation and continuous improvement.

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