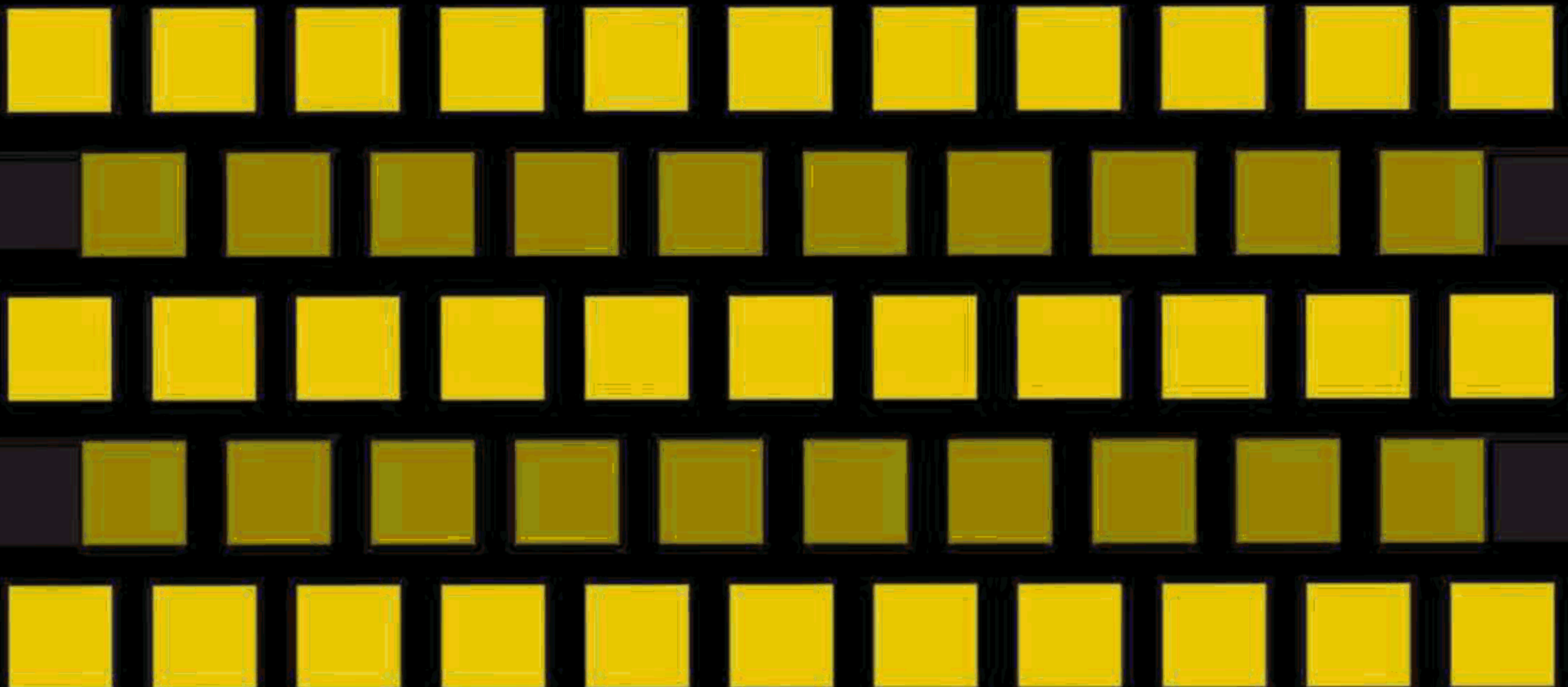


COMPARISON OF FEM STORAGE/RETRIEVAL MACHINE DOCUMENTS TO THE ASME B30.13 SPECIFICATION



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FOREWORD

The consumer activity that is present in the North American market creates the need for guidelines to facilitate safe design, maintenance and operation of Automated Storage and Retrieval System (ASRS) and the included SR Machines. The intent of this document is to provide a broad perspective on the major differences between the FEM and ASME standards that can be used for consideration to maintain the technical relevance of ASME Codes and Standards products.

Established in 1880, the American Society of Mechanical Engineers (ASME) is a professional not-for-profit organization with more than 127,000 members promoting the art, science and practice of mechanical and multidisciplinary engineering and allied sciences. ASME develops codes and standards that enhance public safety, and provides lifelong learning and technical exchange opportunities benefiting the engineering and technology community. Visit www.asme.org for more information.

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ABSTRACT

The content of this report evaluates variances between Federation Europeenne de la Manutention (FEM) Automated Storage and Retrieval System (ASRS) standards and ASME B30.13 2003 Storage/Retrieval (S/R) Machines and Associated Equipment [1]. The intent of this document is to provide a broad perspective on the major differences between the FEM and ASME standards that can be used for consideration to maintain the technical relevance of ASME Codes and Standards products.

This document compares thirteen FEM ASRS documents that are outlined below to the ASME B30.13 specification.

- FEM 9.001 Terminology - Dictionary, Storage and Retrieval Machines
- FEM 9.101 Terminology - Storage and Retrieval Machines - Definitions
- FEM 9.221 Performance Data of SR Machines - Reliability/Availability
- FEM 9.222 Standards of the Acceptance and Availability of Installations with Storage Retrieval Machines and Other Machinery
- FEM 9.223 Basic Data and Criteria for the Construction of Automatic High Bay Warehouses with Distribution Systems
- FEM 9.311 Rules for the Design of Storage and Retrieval Machines - Structures
- FEM 9.512 Rules for the Design of Storage and Retrieval Machines - Mechanisms
- FEM 9.754 Safety Rules for Automatic Mini-Load Storage and Retrieval Machines
- FEM 9.831 Calculation Principles of Storage and Retrieval Machines - Tolerances, Deformations and Clearances in the High-Bay Warehouse
- FEM 9.832 Basis of Calculation Principles for SR machines - Tolerances, Deformations and Clearances in Automatic Small Parts Warehouses (not silo design)
- FEM 9.851 Performance Data of SR Machines - Cycle Times
- FEM 9.871 Logbook for Storage and Retrieval Machines and Transfer Devices
- FEM 9.881 Project Planning Data for Selection of Drives for Storage and Retrieval Machines

European ASRS equipment suppliers and consumers follow FEM standards while the ASME B30.13 specification is focused on applicability to the North American market. FEM standards cover a broad spectrum including project planning, equipment simulation and throughput, design standards, safety, defined operating clearances, etc. The ASME B30.13 specification is primarily directed to outlining safety and safe practices as it relates to equipment design, inspection, maintenance and operation. As a result, variances in the FEM and ASME B30.13 specifications exist. These variances could create opportunities for enhancements to the ASME B30.13 specification (if the safety directive of B30.13 was expanded) or new document development opportunities.

1 INTRODUCTION

The ASRS Market in North America was nearly \$268 million dollars in 2008 as reported by the Material Handling Institute of America (MHI). Comprised in this figure are 37 systems which consist of 185 Storage Retrieval (SR) Machines. A few statistics are worthy of consideration in defining North American ASRS consumers.

- 65% of companies that purchased systems in 2008 did not have prior ASRS systems
- 76% of companies that purchased ASRS systems in 2008 used them as a component of a larger automated material handling process
- 84% of companies who purchased ASRS in 2008 were not Fortune 500 companies

MHI reports categorize the North American ASRS market in four basic areas:

- Unit-Load Equipment: SR Machines handling load weights in excess of 1000 lb.
- Mini-Load Equipment: SR Machines handling load weights between 250 and 1000 lb.
- Micro-Load Equipment: SR Machines handling load weights up to 250 lb.
- Aftermarket: Post-warranty parts and service, equipment replacement and refurbishment and existing system expansions.

Over the past seven years, the ASRS industry in North America has experienced steady growth at an annual average rate of 15%. The MHI defined market segments have seen varying annual average rates in support of this figure.

The Unit-Load market during this period has been volatile with individual annual volumes being erratic from year to year. However, the Unit-Load market over the past seven year period has declined by nearly 3% per year.

Mini-Load equipment has experienced a cyclic market that overall has had steady growth. The average growth rate over the past seven year period has been just over 17% per year.

The Micro-Load market has seen rapid growth since 2002 as individual case and tote handling has become more widely accepted in the United States. This market has increased at an average rate of nearly 40% per year during the past seven year period.

The Aftermarket segment has also seen rapid growth during the past seven year period with an annual average rate of nearly 44%.

The consumer activity that is present in the North American market creates the need for guidelines to facilitate safe design, maintenance and operation of ASRS and the included SR Machines. The ASME B30.13 document is a necessary specification to ensure the basic aspects of consumer safety. The FEM documents outlined in this report cover a much broader spectrum than consumer safety which includes other topics that help guide manufacturers and consumers in system design and implementation.

2 FEM 9.001 TERMINOLOGY – DICTIONARY STORAGE AND RETRIEVAL MACHINES [2]

2.1 FEM 9.001 Specification Description

The FEM 9.001 specification does not provide definitions for Storage and Retrieval Machine terms as its title implies. Rather, this document contains an extensive list of Storage and Retrieval Machine terms and their comparative terms in other languages. This document could be useful to facilitate international technical equipment and system discussions and reduce confusion when language barriers exist. Each term is listed in German, English and French. The document contains three sections where the terms are sorted alphabetically by each language. This allows the English speaking reader to search for the English term alphabetically and see the corresponding terms in German and French. It allows the German speaking reader to search for the German term alphabetically and see the corresponding terms in English and French, and the French speaking reader to search for the French term alphabetically and see the corresponding terms in English and German. According to the document revision notes, Italian terms were included prior to 1982 but were then eliminated.

2.2 FEM 9.001 and B30.13 Specification Considerations

B30.13 does not contain a list of terms and their corresponding terms in other languages. B30.13 does include an English listing of ASRS terms with their definitions. The need for multi-lingual content in the B30.13 document could be considered if the document is intended to be revised with anticipated global use.

3 FEM 9.101 TERMINOLOGY – STORAGE AND RETRIEVAL MACHINES – DEFINITIONS [3]

3.1 FEM 9.101 Specification Description

The FEM 9.101 document provides a comprehensive description of SR Machines and their major components, and is intended to provide the reader with a basic understanding of various machine types and how they function. This document serves as a basic introductory primer to someone not familiar with SR equipment. It does not dictate equipment requirements and is not technically detailed in content or encompassing of all equipment designs and options. The document content includes:

- The definition of an SR Machine
- A description of typical SR Machine operation
- A brief description and illustration of machine configurations including
 - Suspended from top
 - Top running
 - Floor running
 - Machines of mixed design (mid rack supported)
- A brief definition and illustration of single mast, double mast and multi-mast machines
- A basic description of operator interfaces to the SRM is described:
 - Operator with manual control
 - Operator with semi-auto control
 - Automatic operation
- Potential power options are listed: electric, hydraulic, pneumatic
- Standard control options are noted as open loop or closed loop
- Main Assemblies are defined including
 - Mast
 - Lift carriage
 - Travel drive
 - Hoist unit
 - Load handling device(s)
- A brief description and illustrations of aisle transfer means are presented including
 - Floor running transfer car
 - Top running unit
 - Aisle changing by switch system and curved rail
- Communication means to the SRM are noted as infrared and radio

- Electric power interface to the SRM is defined as sliding contacts, flexible cables or on-board batteries.

3.2 FEM 9.101 and B30.13 Specification Considerations

The B30.13 specification includes a single paragraph defining the basic operation of an SR Machine (Section 13-0.2). Also included is a single sentence definition for an “aisle transfer car”, an “automatic (SR) machine”, and an “operator ridden (SR) machine”. Section 13-0.2.2 contains a list of terms used in the specification and their definitions as they relate to specification provisions. Illustrations of a “Typical Unit Load SR Machine”, a “Typical Aisle Transfer Car”, and a “Typical Operator Ridden SR Machine” are included. No other introductory equipment descriptions or component variations are included. The B30.13 specification assumes the reader to be knowledgeable of Storage Retrieval Machine operation and the interaction of components that make up a Storage Retrieval Machine. Basic upper-level presentation of the technology is not included.

4 FEM 9.221 PERFORMANCE DATA OF SR MACHINES – RELIABILITY/AVAILABILITY [4]

4.1 FEM 9.221 Specification Description

This specification contains a standard method for determining the reliability and availability of SR Machines. It defines basic information relating to testing reliability and availability. The document also specifies which test period interruptions are the responsibility of the customer and which are the responsibilities of the SR Machine supplier, and what downtime should and should not be included in the reliability and availability calculations. Throughput is briefly mentioned and cycle time determinations are referenced to be defined in FEM 9.851. The specification allows a supplier to provide a throughput rate that increases with time due to customer familiarity with the system and recovery means related to inexperienced customer personnel. Included are application examples utilizing the presented calculations for a single aisle system and another with multiple aisles. Forms are included for fault recording during the test period and for evaluation of test data once test information is acquired.

4.2 FEM 9.221 and B30.13 Specification Considerations

The specification outlines a theoretical approach to reliability and availability calculations. It includes basic criteria for a single aisle and multiple aisle systems and does not attempt to cover all potential options utilized in ASRS applications such as aisle changing machines, transfer cars, degraded operation (machines that reach through and pick loads in adjacent aisles), multiple extractors on one SR Machine that continue to function in degraded mode with the remaining extractor(s), etc. As mentioned in the specification, the customer and the supplier must understand the basic rules and agree to some application of the presented FEM material during the system design/configuration phase based on the system being considered, the equipment involved, and its effect on total system availability. B30.13 does not present any information relating to reliability or availability of SR Machines.

5 FEM 9.222 STANDARDS OF THE ACCEPTANCE AND AVAILABILITY OF INSTALLATIONS WITH STORAGE RETRIEVAL MACHINES AND OTHER MACHINERY [5]

5.1 FEM 9.222 Specification Description

The FEM 9.222 document targets availability, reliability and system acceptance data relating to the application of a total material handling solution with varied type equipment components. It does not expressly deal with SR Machines. This specification provides recommendations to determine system availability. It presents availability and reliability calculations and defines which should or should not be included for system acceptance. It defines availability and reliability calculations for equipment installed in series and in parallel. Considerations to achieve system designs targeting high availability are presented. System acceptance testing is discussed including inspections, partial hand-overs, and warranty start. System availability is generally improved over time due to familiarity of personnel with equipment and system recovery, and provisions are mentioned for retest if satisfactory results are not achieved. A basic outline of contract activities is presented with assigned responsibilities. Finally, examples of determining system availability using the included methods are presented.

5.2 FEM 9.222 and B30.13 Specification Considerations

The FEM 9.222 document includes helpful information with respect to outlining the responsibilities of the customer and supplier as it relates to the acceptance of availability requirements for material handling solutions. In practice, when implementing turn-key systems, responsibility for many of these items can be confused and tend to become part of the supplier scope. The main benefit of this specification may be activities defined during the design and configuration phase as it allows the customer the visibility of configuration decisions and how they affect the overall availability of the system. Many customers do not actively participate in the system design to this level and, therefore, do not have an intricate understanding of system availability and the impact that configuration decisions can have. Without this knowledge, customers can be surprised by how component downtime can affect system performance once the system is implemented and equipment is installed and operating. At that point, system changes can be difficult and expensive to implement.

This specification presents basic criteria and is not all encompassing due to the variations of system design and available solutions. System benefits such as degraded mode operation (continued operation at reduced levels) is not included. Such variances would need to be discussed between supplier and customer and acceptance criteria assigned. The specification also outlines the customer as being responsible for the holding of spare parts. Today's spare part agreements can counter this requirement with spare part consignment programs and on-site supplier owned spare part inventories. The B30.13 does not address or include the information presented in this specification.

6 FEM 9.223 BASIC DATA CRITERIA FOR THE CONSTRUCTION OF AUTOMATIC HIGH BAY WAREHOUSES WITH DISTRIBUTION SYSTEMS [6]

6.1 FEM 9.223 Specification Description

The FEM 9.223 document provides a guideline for the necessary operational steps involved in project execution for the implementation of an automated high bay warehouse and distribution system. The document suggests possible project phases and assigns responsibility. Compliance to this specification is optional. The suggested outline encompasses warehouse management and material flow systems, racks, roof and wall supporting racks, fire sensing systems, heating and ventilating systems, lighting, fire sprinkler systems, SR Machines and aisle equipment, transport systems and system controls.

The document is presented in a two column format. The first column outlines project tasks and the second column identifies the responsible party for each task. Major defined phases are as follows:

- Project specification
- Project planning
 - Concept development
 - System design and specification
- Tendering and bid appraisal
 - Invitation to tender
 - Invitation to tender and bid appraisal
 - Allocation
 - Conclusion of the contract
- Implementation
- Hand-over, test run, acceptance
 - Hand-over for test run
 - Test run
 - Acceptance
- After-sales service.

6.2 FEM 9.223 and B30.13 Specification Considerations

This document is in checklist form and creates an outline for general implementation when executing construction of a material handling system. The major benefit of this document is that it allows the customers to fully understand their scope and have visibility of the necessary resources needed for successful system completion. B30.13 does not include any content defining project management steps and project phases when implementing a material handling system.

7 FEM 9.311 RULES FOR THE DESIGN OF STORAGE AND RETRIEVAL MACHINES – STRUCTURES [7]

7.1 FEM 9.311 Specification Description

The specification covers general design constraints for sizing the main SR Machine structure, the aisle runway, aisle buffers, equipment test loads and the lift carriage emergency brake. The specification content is a technical example of an upper level structural design approach and prompts design factors to be applied.

7.2 FEM 9.311 and B30.13 Specification Considerations

This specification does not clearly address several issues and raises additional questions when attempting to apply the criteria. Some issues are that stress allowables for design are not clearly established, application of safety factors are not clearly defined and not all SR Machines design configurations are included (i.e. single mast versus double mast) in the application(s) presented. Other things to keep in mind are that, in general, U.S. specifications do not define basic engineering means – the outcome requirements are defined. ASME, CMAA, AWS and other organizations document maximum stress allowables including design safety factors for structural applications that may be of use and/or referenced. Also, given the date of this specification, many things have changed in the evolution of structural design tools since it was generated. FEA modeling programs allow visibility of accurate stress levels in components which may reduce the need for the application of conservative design factors that are noted in the FEM document.

Table 1 - Specification Comparison

FEM 9.311 Section	Title	Requirement	B30.13 Section	Requirement
1	Calculation	Defines general rules, methods and stresses.	Not covered	
2	Assumed loads	Load type definitions	Not covered	
2.1.1	Deadloads	Definition	Not covered	
2.1.2	Lifted loads	Definition	13-0.2.2	Has definition of "rated load."
2.1.3	Effects of vertical forces of inertia	Definition	Not covered	
2.1.3.1	Deadload coefficients	Defines dead load coefficient to be applied to structural stresses based on track and wheel material and speed.	13-1.3.2	Runways shall be constructed to accommodate wheel loadings from the manufacturer.
			13-1.3.2.1 (1)	Designed to withstand loads and forces imposed by the SR Machine under normal operating conditions.
2.1.3.2	Lift load coefficients and lifting classes	Defines lifting coefficient to be applied to stresses based on vertical speed and average vertical acceleration.	Not covered	
2.1.4.1	Dynamic oscillation coefficient	Defines maximum dynamic deformation and oscillation of mast structure.	13-1.3.2.1 (2)	Structure to be free from detrimental vibration under normal operating conditions.
2.1.4.2	Effects of horizontal forces of inertia	Defines constraints for SR Machine stability.	Not covered	

FEM 9.311 Section	Title	Requirement	B30.13 Section	Requirement
2.1.4.3	Friction force coefficient	Defines wheel to rail coefficient to be used in design calculations.	Not covered	
2.1.4.4	Lateral forces	Lateral forces transverse to the runway shall be transmitted to the floor rail.	Not covered	
2.2.1	Forces due to running askew	Defines how to calculate forces from skewed wheels on floor rail.	13-1.3.1	The foundations and anchorage shall be constructed to accommodate the equipment loadings specified by the manufacturer.
2.2.2	Temperature effects	Defines general temperature variations for ambient conditions. Defines coefficient of thermal expansion for steel to be used in calculations.	Not covered	
2.2.3	Loads on platforms and handrails	Defines loading for platform design.	13-1.6.2 (a)	Defines loading for platform design, handrail dimensions and ladder access openings.
2.3.1	Buffer forces	Defines collision speeds for design, energy calculation, buffer design constraints, applied design coefficients and reductions for means to limit speeds at the end of aisle (if electric, two devices are required).	13-1.7.2	Defines collision speed, defines interaction with transfer car and defines restrictions when an operator is on-board.
2.3.2	General function test	Defines test load at 1.25 of payload, applied coefficients and general criteria.	13-2.2.2	Defines test load at 1.25 of rated load and general test criteria.
2.3.3.1	Function test of the catching device	Defines testing of lift carriage over speed brake including speeds, applied coefficients (based on device type, accel profile and the lifting speed), actuation speeds, and deceleration criteria.	13-1.10.7	Defines when over speed devices are needed, how activated, actuation must remove motor power and set motor brake, released by raising carriage.
			13-1.10.8	Brake must operate independently from all other systems, defines actuation speed, marked with actuation speed setting, speed adjustment means sealed.

8 FEM 9.512 RULES FOR THE DESIGN OF STORAGE AND RETRIEVAL MACHINES – MECHANISMS [8]

8.1 FEM 9.512 Specification Description

This specification defines theoretical design life for mechanisms used in SR Machines and is primarily focused on the theoretical design life for travel and hoist drive units. An operating class designation is determined based on the anticipated operating time per day (operating time being defined as the time when a machine is in motion). Then, a load class designation is determined based on a cubic means formula involving the various applied loads and applied time durations. The operating class designation and the load class designation are then combined in a chart to establish a design life designation. These factors can be applied to hoist and travel mechanisms separately based on their individual operational duty. Sample calculations are included for hoist and travel drives. Minimum design life hours are then established from the design life designation.

8.2 FEM 9.512 and B30.13 Specification Considerations

The B30.13 specification does not address design life for SR Machine components. Therefore, the content of this specification is not presented in the B30.13 document. Some customers include design life requirements in their compliance specifications. When provided by the customer, the typical design specification in the U.S. requires that bearings are sized such that 90% survive anywhere from 30,000 to 40,000 hours of operation. This assumes all preventative maintenance work and machine alignments are performed as specified by the manufacturer. One fallacy in the FEM specification is that the life specification does not specify the percent failures to be assume at the defined life. Component sizing results will vary dramatically if for example 50% failures are allowed instead of 10% failures. Assuming 10% failures at the specified FEM life, typical U.S. design life requirements exceed the information in the FEM specification which is a minimum of 12,500 hours. When European machines are introduced into U.S. markets, the variance in design criteria could be a significant issue. The lower design life requirements for the European machines could significantly lower their cost, making them more attractive when initially considered.

9 FEM 9.754 SAFETY RULES FOR AUTOMATIC MINI-LOAD STORAGE AND RETRIEVAL MACHINES [9]

9.1 FEM 9.754 Specification Description

The FEM 9.754 specification defines safety rules for Mini-Load SR Machines which:

- Are used for the automatic service of shelves
- Operate in an enclosed area
- Have a maximum height of 12.50 meters (41 feet)
- Have a maximum payload of 315 kg (693 lb.)
- Do not transport bulky materials (load length + width + height < 2.5 meters)
- Do not carry persons.

Machines that do not meet these requirements fall under the requirements in FEM 9.753 – Safety rules for storage and retrieval machines (this document appears to be out of publication).

The specification includes basic definitions used, and encompasses definitions that are outlined in FEM 9.101 section IX. Many items identified in this FEM specification are included in B30.13. Comparison highlights are identified in the chart below.

9.2 FEM 9.754 and B30.13 Specification Considerations

Many items noted in the FEM specification that are not included in the B30.13 document are covered in the Federal Code of Regulations that is enforced by OSHA.

Table 2 - Specification Comparison

FEM 9.754 Section	Title	Requirement	B30.13 Section	Requirement
2.4	Operator's position	Each place in which movement of the SR Machine can be commanded must lie outside of the enclosed area. If multiple operator positions exist, one must have priority over the others.	Not covered	
3	Construction and equipment	Machines must comply with state-of-the-art engineering and regulations in FEM Section IX and meet relevant regulations in the country of the user.	Not covered	
4.1	Construction of the installation and operation	A performance specification between the supplier and user is required identifying the place of erection, the kind of load, throughput, factors related to safety, factors related to environment, noise, etc. If no special conditions are agreed upon, those of the manufacturer are applied.	Not covered	

FEM 9.754 Section	Title	Requirement	B30.13 Section	Requirement
4.2.1	Delimitation for the enclosed area	The enclosed area shall not be accessible during operation. Access prevented by permanently installed enclosures or by invisible barriers. Only qualified and authorized personnel may enter. The opening of an access must provoke an immediate standstill. If access is a door, it must open outwards, open from the inside without a key and only open from the outside with a key.	13-1.6.5	Machine aisles and runways shall be clearly designated to be used by authorized personnel only. Physical means to restrict aisle access is not defined.
4.2.2	Warning and directional signs	Visible warning signs at access points which prohibit access to the enclosed area, prohibit the traveling of persons on SR Machines or other indications.	13-1.1.2 Warning Markings	Aisle access points must have CAUTION label and cautionary language against unauthorized personnel entering the aisle, entering the aisle with the machine in operation, operating the SR Machine by other than designated personnel, clearing malfunctions by other than designated personnel, removing labels.
4.3	Load units	Loads must comply with accepted specifications. Customer is responsible to ensure load stability and compliance.	13-3.2	Load dimensions or weight not to exceed the design load. Pallet or container must be in good condition. The customer is responsible for load stability.
4.4	Application	Machine is not to be used for purposes other than what it was constructed for.	Not covered	
5	Safety equipment	Considering the legal regulations of the country, accident prevention must be considered.	Not covered	
5.1	Removable protection equipment	Protection coverings are to be provided with safety contacts which prevent dangerous movements of the machine when removed.	13-1.7.6	Components which might constitute a hazard under normal operating conditions shall be guarded. Each guard to support 200 lb. unless located where it is not reasonable to do so.
5.2	Brakes	Drives for travel and hoist must be equipped with brakes which actuate automatically in the event of power failure.	13-1.8	Hoisting motors to have holding brake applied directly to the motor shaft. Hoist brake to be rated for 125% of full load hoisting torque. Thermal capacity depending upon the frequency of operation. Brakes to be automatically applied when power is removed. Brakes must have a means to compensate for lining wear. Parts must be free of defects that affect operation.
			13-1.8.4	Brake shall be provided for horizontal travel. Brake to be automatically applied when power is removed. Brakes must have means to compensate for lining wear. Brakes to be free of defects that affect operation. Brakes must stop the SR Machine at 1 ft/s/s minimum. Brakes shall have thermal capacity for the frequency of operation.
5.3	Limitation of the traveling and lifting movement	To delimit traveling movements the following are to be provided: preliminary limit switch to reduce the speed, limit switch with an automatic opener which turns off the main current on all poles over the main relay, appropriate buffers have to be provided to take-up the energy of the travel movement.	13-1.3.2.1	Stops shall be provided at the limits of travel. Stops to withstand applied forces.

FEM 9.754 Section	Title	Requirement	B30.13 Section	Requirement
			13-1.9.4	Limit sensor shall be provided to shut down any drive that goes beyond designated travel. Limit sensors may be used to reduce speed before actuating EOT sensor.
			13-1.7.2	Buffers required at EOA capable of stopping equipment with rated load at 100% of rated speed without structural damage.
5.4	Anti-collision protection	If multiple machines are in same aisle, the aisle must be provided with a device to prevent collisions.	13-1.7.2	When more than one SR Machines are on same runway, bumpers (buffers) shall be provided on adjacent equipment ends to meet EOA buffer sizing requirements.
5.5	Anti-derailment, anti-tipping, anti-falling devices	Machine stability must comply with FEM 9.311. Devices to prevent derailment upon travel or guide roller breakage. Rail sweeps must be provided in front of the travel wheels.	13-1.7.3	Means should be provided to limit the drop of the SR Machine to ½ inch in case of wheel or axle failure. Means should be provided to limit lateral movement in the event of wheel or axle breakage.
			13-1.7.4	Runway sweeps shall be provided in front of runway wheels.
5.6.1	Earthing	Auxiliary circuits used for SR Machine control must be earthed on the secondary side.	13-1.9.1(g)	Exposed metal parts shall be joined to form a continuous electrical conductor so entire machine will be grounded on installation.
5.6.2	Devices for emergency disconnection	Device for emergency disconnection with mechanical interlock must be provided on the control station outside the enclosed area. Several devices must be installed to cover whole concealed area. Opening of these devices may only occur by means of a key or a device that ensures equal safety.	13-1.9.8	Section notes that an SR Machine fault shall result in activation of an emergency stop switch. If there is any reason to be in the aisle, emergency stop actuators shall be accessible.
5.6.3	Putting into service	Putting into service after emergency disconnection may only be possible from the main control station. These devices may be placed inside the enclosed area but must be located outside the reach of operation of the machine and be connected to a device for emergency disconnection.	13-1.9.8(f)	Correcting the fault shall not cause the automatic cycling to be reestablished without performing a specific starting procedure. Location of fault correction location is not specified.
5.6.4	Manual operation	A device is needed to switch from automatic to manual control. The device must be placed outside the protective device. Switching may only be possible in connection with the key mentioned in 3.1.1 of FEM 9.753 which may only be only removed in the "Off" position. Push buttons for manual control movement are integrated into a console which may be situated in the enclosed area outside the operating range of the machine. If outside the enclosed area, the console must be covered with a lockable cover.	13-1.9.9(d)	When controls are provided for manual operation, fault conditions in 13-1.9.8 shall remain operational. Controls for maintenance or clearing malfunction may be provided to override fault conditions. Means and location of manual controls are not discussed.
5.6.5	Power supply	Unprotected conductors of power supply must prevent unintentional contact by personnel.	13-1.9.1(f)	Open access for contact conductors should be facing to the side or downward. Collector shoes either guarded or mounted to prevent inadvertent contact.

FEM 9.754 Section	Title	Requirement	B30.13 Section	Requirement
5.7	Lighting	Machine must be designed to make it possible to install lighting in the maintenance area.	Not covered	
6.1	Maintenance, inspection, repair	Maintenance to be performed at regular intervals.	13-2.3.1(a)	Maintenance program should be established based on the manufacturer's recommendation.
6.2	Maintenance, inspection, repair	Maintenance to be carried out by qualified personnel.	13-2.3.3	Adjustments and repairs shall be done only by designated personnel.
6.3	Maintenance, inspection, repair	Maintenance to be performed in accordance with manufacturer's instructions and confirmed with signature and date. Documentation to be accessible.	13-2.3.1	Maintenance program based on manufacturer's recommendation. Dated records should be available to appointed personnel.
			13-2.3.3(b)	Maintenance performed according to manufacturer's recommendation.
6.4	Maintenance, inspection, repair	During maintenance work, the SR Machine is to be switched off and secured against unauthorized starting.	13-2.3.2	For maintenance, SR Machine to be in location where it will cause the least interference with other equipment, remote commands to SR Machine shall be prevented, SR Machine shall be prevented from responding, main power disconnect locked out and tagged unless power to SR Machine is required, warning signs visibly placed, rail stops or other suitable means required to prevent other SR Machines or T-cars from interfering.
6.5	Maintenance, inspection, repair	If two SR Machines are in one aisle on same rail and one SR Machine is being serviced, both machines must be removed from operation and secured. If one machine must be kept running, a buffer and electric contact must be provided to protect the area of maintenance.	13-2.3.2 (a)(5)	Where other SR Machines or aisle transfer cars are in operation on the same runway, rail stops or other means are required.
6.7	Maintenance, inspection, repair	Defects or found damage must be reported immediately for repair. If obvious danger for personnel or machine, the equipment must be stopped immediately.	13-2.1.3	Any deficiencies shall be examined and determination made as to whether they constitute a hazard.

10 FEM 9.831 CALCULATION PRINCIPLES OF STORAGE AND RETRIEVAL MACHINES – TOLERANCES, DEFORMATIONS AND CLEARANCES IN THE HIGH-BAY WAREHOUSE [10]

10.1 FEM 9.831 Specification Description

The scope of the document is to present an understanding of admissible tolerances and deformations pertinent to the safe operation of a high-bay warehouse. It is geared toward load handling using a telescopic fork mechanism on the SR Machine. It provides information for steel rack structures that are of a silo or free standing design. The specification is not applicable to automatic small parts high density warehouses. Information is presented pertaining to the following:

- **Floor slab**
Floor slab information pertains to floor flatness criteria. Dynamic and settling issues are discussed. However, only a dynamic angular variance in a localized area is numerically provided.
- **Floor rail**
Floor rail installation tolerances are provided relative to track length, variances from level and variances from side to side. Specifications are provided for grinding welded track joints.
- **Upper guide rail**
Upper guide rail installation tolerances are included. Also included are tolerances for static and loaded deflections, sagging and twist.
- **Load**
Load information is discussed and tolerances for the Euro-Pool-Pallets are presented. Information provided defines what should be included in the load design envelope.
- **Profile pallet checking**
The specification outlines load profile checking. It is required for use when the load is to be handled by an automatically controlled SR Machine.
- **Centering the load for SR Machine pickup**
Tolerances for centering the load for P&D pick-up in both directions are included.
- **SR Machine**
The document examines areas in which deformations and clearances must be included when configuring the automated system for safe movement of the SR Machine and loads. In general, they refer to inclusion of mast deflection, track roller clearances, variances in track or upper guide rail installation, mechanical wear, positioning variances, etc.
- **Rack structure**
Racks are to be considered one of two classes which depend upon the tolerances that are needed. Rack tolerances are presented in each case for column tolerance and deflection, down aisle tie variances and load opening variances. Also discussed are deformations that must be included from loading conditions such as wind or snow loads. Earthquakes or crane buffer impact loads need not be taken into account – according to the specification. Rack information is included for post and beam design racks as well as conventional ASRS (one column between each load) designs.

A section is included that presents how to interpret and utilize the specification information with literal examples.

10.2 FEM 9.831 and B30.13 Specification Considerations

The FEM 9.831 is a helpful specification for suppliers and customers attempting to understand clearances and considerations that are used when configuring an ASRS. Given the complex nature of a system, it is difficult for such a document to be all inclusive of every situation and every dynamic concern. However, it does lay out basic useful concepts. When considering the variation in equipment interfaces from supplier to supplier, the bulk of this document becomes a discussion of general items that need to be determined based on the equipment being used.

The B30.13 specification contains some general references to clearances within the system, building construction variations and acceptable tolerances. Those sections are referenced below.

- Section 13-1.2 states that clearances and tolerances within the system are based on proper design for operation and are to be determined by the manufacturer, user and/or his representative. Consideration needs to be given to the load, the equipment configuration, interactions with personnel and building variations.
- Section 13-1.3 .1 discusses general construction. “The foundations and anchorage shall be constructed to accommodate the equipment loadings specified by the manufacturer.”
- Section 13-1.3.2 defines that runways for SR Machines are to be constructed to accommodate the wheel loadings specified by the manufacturer. The runways and supporting structures are to be designed to withstand the load and forces that result in normal operating conditions. The structure is to be free from detrimental vibrations. Floor rails are to be level, straight and jointed to be compatible with the design of the SR Machine.
- Section 13-3.2 discusses the load. Information specifies that the SR Machine is not to be loaded with a load whose dimensions or weight exceed the design load – except for testing purposes specified in 13-2.2.2 (load test to be 25% of rated load). The pallet or container is to be in good condition and within design tolerances. The profile of the load and pallet is to be within design tolerances. Loads being input into the system are to be positioned within the tolerances specified by the manufacturer.

11 FEM 9.832 BASIS OF CALCULATION PRINCIPLES FOR SR MACHINES – TOLERANCES, DEFORMATIONS AND CLEARANCES IN AUTOMATIC SMALL PARTS WAREHOUSES (NOT SILO DESIGN) [11]

11.1 FEM 9.832 Specification Description

The scope of the document is to determine the admissible tolerances and deformations in order to optimize the factors relating to economical dimensioning, manufacturing and assembly that are required for safe functioning of SR Machines that are being used in automatic small parts warehouses. In these systems, loads are usually stored by means of load carriers or other make-up accessories such as boxes, trays and cases. These load handling devices typically lift, pull or grab the load. This document requires that calculations for system clearances and entry clearances be made following the methods presented. Document information includes:

- **Factors of influence**
Factors that affect operating clearances include tolerances and deformations caused from surface/foundations, floor slab, floor rail, guide rail, load make-up accessories including the load, profile check, storage location, SR Machine and the rack structure. Different load handling mechanisms also affect clearances needed. Examples of load handling devices include telescopic tables, mechanical pulling devices, lateral grabbing devices, belts or conveyors and other types. Racking can have single or multiple loads per opening, the configuration of which also affects system parameters. Finally, several positioning systems can be used, each of which has different tolerances with respect to SR Machine positioning.
- **Floor slab**
Two types of floor slab systems are discussed. The first type is a rigid slab (or slabs) which lies fully on a flat surface. The other type is a slab (or slabs) which lies on supports such as ceilings in buildings or floor slabs on piles. For each type of floor slab, information pertaining to floor flatness criteria is presented. Dynamic and settling issues are discussed. Deflection criteria for slabs that lie on supports are also included.
- **Floor rail**
Floor rail installation tolerances are provided relative to track length, variances from level and variances from side to side. Specifications are provided for grinding welded track joints.
- **Upper guide rail**
Upper guide rail installation tolerances are included. Also included are tolerances for static and loaded deflections, sagging and twist.
- **Load**
Load information is discussed including what components make up the load such as trays, boxes and containers. The loads are required to pass through a profile check. Definition is also provided for guiding loads into the rack openings. Load friction (for sliding loads when moving in and out of the rack) must be taken into account when considering rack deformations.
- **Profile checking**
Profile load checking is required. Tolerances for how closely load profiles are checked are included.

- **SR Machine**
The document examines areas in which deformations and clearances must be included when configuring the automated system for safe movement of the SR Machine and loads. In general, they refer to inclusion of mast deflection, track roller clearances, variances in track or upper guide rail installation, mechanical wear, positioning variances, etc.
- **Rack structure**
Discussions of rack with a single load between columns and those with multiple loads between columns are presented. Minimum load support contact is also included for when loads are moved completely to one side of the opening. Fabrication and installation tolerances are defined in down aisle, cross aisle and vertical directions. Rack deformations from dynamic forces are to be included in the clearance analysis.
- **Entry clearances**
Entry clearances for the load and extractor into the rack are discussed so that all variances can be considered. The space location and amount is highly dependent upon the means of load handling.
- **Data tables**
Data tables are included as a tool in which all calculated or anticipated tolerances and dynamic variations can be listed and combined so that necessary clearances can be determined.
- **Calculation check**
The specification requires that verifying calculations be carried out by the person responsible for the system in each individual case. To optimize the overall system, suppliers ensure that the overall tolerances are at the worst-case condition. The worst-case condition is defined as 70% of the total of all individual tolerances and dynamic deformations.

A section is included that presents calculation examples. It provides insight into how calculations are included and how the data tables are utilized.

The final section of the document includes a “Measurement and Acceptance Report.” This section establishes a multi-page form to be used by the supplier to note the rack manufacturing variances and their compliance to the specification calculations. The report requires validation that defined system clearances are being met during fabrication.

11.2 FEM 9.832 and B30.13 Specification Considerations

This specification provides an understanding of clearances and considerations that are used when configuring an ASRS. Small parts storage systems have different criteria than general SR Machine systems and an understanding of those variances and how to account for them is meaningful. Given the complex nature of a system, it is difficult for such a document to be all inclusive of every situation and every dynamic concern. However, the basic useful information is presented. When considering the variation in equipment interfaces from supplier to supplier, the bulk of this document becomes a discussion of general items that need to be determined based on the equipment being used. However, this document does require upfront clearance calculations and then the collection of fabrication and installation tolerances during the build phase to ensure that the original anticipated clearances will be met.

B30.13 contains some general references to clearances within the system, building construction variations and acceptable tolerances. Those sections are referenced below.

- Section 13-1.2 states that clearances and tolerances within the system are based on proper design for operation and are to be determined by the manufacturer, user and/or his representative. Consideration needs to be given to the load, the equipment configuration, interactions with personnel and building variations.
- Section 13-1.3 .1 discusses general construction. “The foundations and anchorage shall be constructed to accommodate the equipment loadings specified by the manufacturer.”
- Section 13-1.3.2 defines that runways for SR Machines are to be constructed to accommodate the wheel loadings specified by the manufacturer. The runways and supporting structures are to be designed to withstand the load and forces that result in normal operating conditions. The structure is to be free from detrimental vibrations. Floor rails are to be level, straight and jointed to be compatible with the design of the SR Machine.
- Section 13-3.2 discusses the load. Information specifies that the SR Machine is not to be loaded with a load whose dimensions or weight exceed the design load, except for testing purposes specified in 13-2.2.2 (load test to be 25% of rated load). The pallet or container is to be in good condition and within design tolerances. The profile of the load and pallet is to be within design tolerances. Loads being input into the system are to be positioned within the tolerances specified by the manufacturer.

12 FEM 9.851 PERFORMANCE DATA OF SR MACHINES – CYCLE TIMES [12]

12.1 FEM 9.851 Specification Description

This document provides a basis for calculating SR Machine cycle times and handling rates. Content is also included for cycle time items as they relate to planning, contracts, construction and hand-over to the user. Flow diagrams are presented to provide an understanding of SR Machine operational cycles including when an aisle transfer mechanism is used. Several graphical illustrations are presented to define load placement in the rack to be used for a load retrieval/deposit cycle based on various P&D locations. The intent is to provide a definition for a test cycle in which an operational time can be determined and subsequently validated in the field. Double deep storage system test cycles and dual load handling mechanisms are also discussed. Formulas are presented to calculate operational move time for the above cycles.

12.2 FEM 9.851 and B30.13 Specification Considerations

A significant portion of this FEM specification is dedicated to determining the mean cycle time based on system parameters such as P&D location, aisle length and system height. Cycle time calculations and potential throughput capability of an ASRS is not included in the B30.13 document. Modern simulation tools can use SR Machine performance parameters and cycle through months of machine operation to determine throughput criteria. This provides significant insight into peak demand and normal demand. Parameters can be included to account for SKU quantities in the system, demand based on customer parameters and velocity rack loading for frequently used SKUs. Given such software tools, the need for pseudo cycle time predictors would seem obsolete. Also, due to the complexity of modern SR Machines, it is nearly impossible to develop mean cycle time predictors in a specification for all potential equipment and system options, i.e., multiple extractors on an SR Machine, deep lane storage with mole or satellite mechanisms, simultaneous or single picking of multiple load extractors in the rack and/or P&Ds, P&D window control, multiple P&D locations in the same aisle, picking replenishment systems, etc.

13 FEM 9.871 LOGBOOK FOR STORAGE AND RETRIEVAL MACHINES AND TRANSFER DEVICES [13]

13.1 FEM 9.871 Specification Description

This document outlines the content of an equipment logbook which is to be used by manufacturers of SR Machines and subsequently maintained by the user. The logbook is intended to contain important data for each machine including tests, inspections and other records. The logbook may be adapted by each manufacturer to suit specific needs. The outlined content is meant to be the minimal requirements for the logbook content.

The document defines several terms used throughout the logbook so that all providers are supplying equivalent information. The presented logbook forms contain a specification sheet for SR Machine parameters and another for transfer devices that, in summary, include:

- Manufacturer
- Year of construction
- Rated load
- Component weight
- System height
- Electrical supply parameters
- Axis speeds.

Forms are presented for verification of testing of design, specification conformity and acceptance testing. Records for periodic inspection and testing are also included. Forms are presented for testing of the over speed lift carriage mechanism and the end-of-aisle hydraulic buffers. As parts are repaired or replaced, a description of the action and the date of action are to be recorded.

13.2 FEM 9.871 and B30.13 Specification Considerations

The B30.13 specification does not specify the use of a logbook. However, there are several sections that define markings and/or specific documentation that is suggested and/or required.

- Section 13-1.1.1 requires that the SR Machine be marked with the rated load.
- Section 13-1.10.8 requires that the lift carriage over speed device be marked in a legible and durable manner with its set actuation speed.
- Section 13-1.11 requires suppliers to provide maintenance manuals, operating manuals and drawings that are necessary for operations and maintenance.
- Section 13-2.1.5 requires that dated inspection reports be kept on critical items such as drives, sheaves, chains, ropes, sprockets, shuttles and safety devices. The records should be available to appointed personnel.
- Section 13-2.3.1 recommends that a preventative maintenance program be established and that dated records be kept and made available to appointed personnel.

14 FEM 9.881 PROJECT PLANNING DATA FOR SELECTION OF DRIVES FOR STORAGE AND RETRIEVAL MACHINES [14]

14.1 FEM 9.881 Specification Description

This document provides a framework of information and environmental conditions that are necessary for the selection and design of drives for SR Machines. Such items presented that must be considered include:

- Masses to be moved
- Tractive resistance
- Service life
- Cycle time
- Positioning accuracy
- Starting and braking characteristics
- Running smoothness and vibrational characteristics
- Power supply
- Energy consumption and efficiency
- Electromagnetic compatibility
- Type of protection
- Commissioning, reliability and maintenance.

Environmental conditionals also need to be considered when selecting drive components. SR Machine environmental conditions include:

- Surroundings which are extremely dirty and dusty
- Refrigeration plants
- Clean room systems
- Explosion proof areas
- Chemical stores
- Noise-sensitive environments.

The specification presents a project planning checklist which contains each of the topics outlined above. The checklist discusses possible effects of each item and includes various FEM and International (EN and UIC) specifications that pertain to each.

14.2 FEM 9.881 and B30.13 Specification Considerations

The FEM document provides a good tool that references many applicable standards for several different areas that address the design and safety of SR Machines. It also provides a comprehensive check list for SR Machine interface issues.

The content of this document is not included in the B30.13 specification.

15 B30.13 SPECIFICATION INCLUSIONS THAT ARE NOT COVERED IN THE REVIEWED FEM SPECIFICATIONS

The B30.13 specification has content that was not covered in the FEM specifications that were reviewed. Comments in the individual FEM specification sections in the prior text note requirements where similar information was covered in both the B30.13 and FEM specifications. However, the content for the sections noted below are areas that are outlined by B30.13 but have no FEM coverage in the documents reviewed.

- Section 13-1.3.3 Welded Construction
All welding procedures and operator qualifications are to be in accordance with ANSI/AWS standards.
- Section 13-1.3.4 Modifications
SR Machines may be modified or re-rated providing they are analyzed by a qualified person or the manufacturer. Modified machines are to be tested to specification.
- Section 13-1.4 Cabs
FEM documents do not cover cab location or construction requirements for operator-ridden machines as defined in this section. A fire extinguisher is required for operator-ridden machines. Lighting is also required for operator-ridden machines.
- Section 13-1.5 Lubrication
Lubricating points should be accessible without removing guards or other parts.
- Section 13-1.6 Platforms, Ladders and Personnel Access to Aisles and Runways
FEM did discuss platform design and loading requirements. However, it did not include B30.13 items such as a non-skid surface, handrail configuration and ladder access openings.
- Section 13-1.6.3 Fixed Ladders
Ladder design requirements for configuration and safety devices are included.
- Section 13-1.6.4 Access to Cab or Service Platform
No step-over greater than 12 inches.
- Section 13-1.7.1 Stops
Mechanical stops are required for shuttle devices to keep members from becoming disengaged.
- Section 13-1.8.3 Control Braking Means
Control braking means shall be capable of maintaining controlled travel speeds and shall have the thermal capacity for the frequency of operation.
- Section 13-1.9 Electrical Equipment
This section defines wiring outside of, and internal to, the main electrical enclosures on an SR Machine that is not included in FEM documents.
- Section 13-1.9.5 Control Voltages
Voltages at operation stations shall not exceed 150 VAC or 300 VDC.
- Section 13-1.9.6 Controls for Operator-Ridden Operation
This section defines required controls for operator-ridden machines.

- Section 13-1.9.7 Warning Devices
Visual or audible warning devices are to be on an SR Machine or transfer car. This section also defines when they are to be activated.
- Section 13-1.9.9 Automatic and Remote Operations
This section defines the sequence of operations allowed if automatic sequence is interrupted. This section also identifies requirements surrounding entering the aisle with power applied to the SR Machine.
- Section 13-1.10 Hoisting Equipment
This section defines requirements for hoist components including sheaves, drums, ropes, sprockets, hoisting chains, and load share equalizers that are not represented in the FEM documents.
- Section 13-2.1.2 Frequent Inspection
This section defines the items that must be comprised in frequent equipment inspections.
- Section 13-2.1.4 SR Machines or Aisle Transfer Cars Not in Regular Use
An inspection is required for equipment which been idle for more than 1 month before being placed in service.
- Section 13-2.3.4 Lubrication
Lubrication should be performed at regular intervals with specified materials.
- Section 13-2.4 Rope Inspection, Replacement, and Maintenance
Rope inspection intervals and inspection criteria are defined. Rope replacement requirements and maintenance are also specified.
- Section 13-2.5 Roller Chain and Leaf Chain Inspection, Replacement, and Maintenance
Roller and leaf chain inspection, replacement, and maintenance requirements are specified.
- Section 13-2.6 Welded Link Chain Inspection, Replacement, and Maintenance
Welded link chain inspection, wear measurements, replacement, and maintenance are specified.
- Section 13-3.1 Qualifications For and Conduct of Operators
This section identifies the qualifications that operators must have to operate various included equipment. It also specifies the required conduct of operators.

16 SUMMARY OF RESULTS

The ASME B30.13 specification is devoted to safety and safe practices as it relates to equipment design, inspection, maintenance and operation of SR Machines. It can be referenced and utilized by government bodies when performing on-site regulatory equipment inspections. FEM documents contain specifications and define processes that encompass various aspects of the ASRS/SR Machine design and project execution. FEM document content is not limited to aspects surrounding safety. The FEM documents dictate a larger scope including terms to be used when defining a system, how a system is to be designed, how a project should be managed, how equipment should be designed and safety aspects that are needed.

A wide spectrum of documents with varied content makes it difficult for specification bodies to keep all documents current with technology and adaptations, or developments that evolve from equipment and system suppliers. The FEM documents have many areas in which they are not current with the available technology, advances in equipment, or advances in how SR Machines are applied within an ASRS. If documents are to remain viable and meaningful to consumers, the task of researching advances and updating specifications must become continuous and routine.

The broad scope of the FEM specifications would suggest that there is interest in ASRS and SR Machine information beyond safety. ASRS consumers may have significant interest in many of the FEM documents as an educational means rather than a governing specification. As mentioned in the introduction of this report, 65% of North American ASRS consumers have not had a prior ASRS system. With this kind of new interest in ASRS technology, educational tools may be in significant demand. To enhance document sales, the B30 committee may consider development of additional documents with an educational focus. If they were introduced as governing specifications, they could restrict the application of technology or advantages that one supplier may have over another. Some of the topics that could be of interest for new U.S. ASRS consumers might be:

- Descriptions of a typical ASRS and the basic components comprised within the system
- Definition of reliability and availability determination for ASRS and the various components that comprise a system
- Equipment design life
- Simulation basics for SR Machines and ASRS
- Advanced concepts – theoretical discussion on the effects and enhancements of multiple SR Machines per aisle, multiple extractors per lift carriage, multiple lift carriages per SR Machine, etc.

ASME B30.13 has several requirements that are not included in the FEM specifications. Consideration could be given to remove or restrict content in these areas due to SR Machine design or technological advancements. These items include:

- Wiring requirements – many of those outlined in B30.13 are redundant with other wiring codes.
- Wire rope inspection criteria – much of the B30.13 inspection information is redundant with that published in the Wire Rope Users Manual that is maintained by the Wire Rope Technical Board.
- Welded link and roller chain inspection criteria – welded link chain is not used as a current hoisting mechanism for SR Machines. Roller chain as a hoisting mechanism has limited use

in new SR Machine design. Chain manufactures publish inspection information for their products that is directly applicable and could be referenced.

- Operator ridden SR Machines – the B30.13 specification contains extensive requirements for full operator-ridden SR Machines. FEM specifications have no reference to operator-ridden cranes. Very few, if any, new SR Machines are fabricated with full time operator-ridden controls. Occasionally, operator-ridden cranes are produced for latent systems where the SR Machines are being replaced due to mechanical, structural or part-obsolescence issues. However, these systems are slowly vanishing as upgrade options involve switching to automation. The operator-ridden information in B30.13 could be considered for removal or modification at some future date.

FEM safety related documents have a few areas that could be considered for inclusion in the ASME B30.13 specification.

- Operator stations – the B30.13 specification does not include information relating to operator stations for the SR Machine aisle(s). In automated systems that are operating from a host computer system, system visibility may not exist. However, all local or remote stations should have access to emergency stop push buttons. Local stations could include requirements for aisle power lock-out and mechanisms to permit safely entering the aisle with power applied.
- Equipment signage and maintenance information – SR Machine signage and maintenance information should be supplied in English for North American consumers. This could become an increasing issue as Asian and European suppliers import equipment for installation and support.
- Guarding requirements for aisle access – B30.13 has limited discussion of safe guards surrounding protection of access to the SR Machine aisle(s). The B30.13 document (section 13-1.6.5) only requires that the aisles be designated to be used by authorized personnel. FEM documents go beyond this requirement by defining locked-door access or gating that, when opened, causes the SR Machine to halt operation.

There are several advancements in SR Machine technology that should be considered to determine if additional safety coverage needs to be included in the B30.13 specification. These items include:

- Systems that use side-by-side machines in the same aisle capable of passing each other in operation.
- ASRS aisles that have short SR Machines that are modular and stacked one aisle above the other.
- SR Machines that utilize multiple extractors on-board one- or two-lift carriages.
- Dual independent hoist drive units used to lift each end of a single-lift carriage.
- Two SR Machines in the same aisle that are capable of working individually or can be used to work in tandem to carry a single load.
- Many current load extraction devices slide loads into and out of the rack. This may present increased reliance on the integrity of rack backstops. B30.13 makes no mention of requiring load back stops. Load back stops could be a significant safety issue so that loads are not pushed out of the rack if the SR Machine attempts to deposit a load in an occupied rack opening.

- Emerging SR Machine designs use toothed belt designs for hoist mechanisms. Toothed belt hoist systems create provisions for new specification information regarding inspections, replacement, slack belt requirements, etc.
- SR Machine designs can utilize toothed belts for horizontal travel. Toothed belts can be used to pull the SR Machine back and forth in the aisle with the drive on-board or off-board, or can be used to connect front and rear wheels so that both wheels work together to propel the SR Machine. This again creates specification opportunities for inspection, replacement and drive system braking considerations.
- B30.13 covers the safety provisions needed for operator-ridden SR Machines and it addresses safety provisions for automatic SR Machines. However, safety requirements for automatic machines that can occasionally be ridden for machine or rack maintenance are not addressed.

Consideration of the aforementioned items would result in a more useful B30.13 specification devoted to SR Machine safety and would have broader appeal as equipment option criteria is considered and included. More market research may be needed, but additional documents focused on consumer education may also prove to be worthy of consideration for enhanced document sales to the ASRS community.

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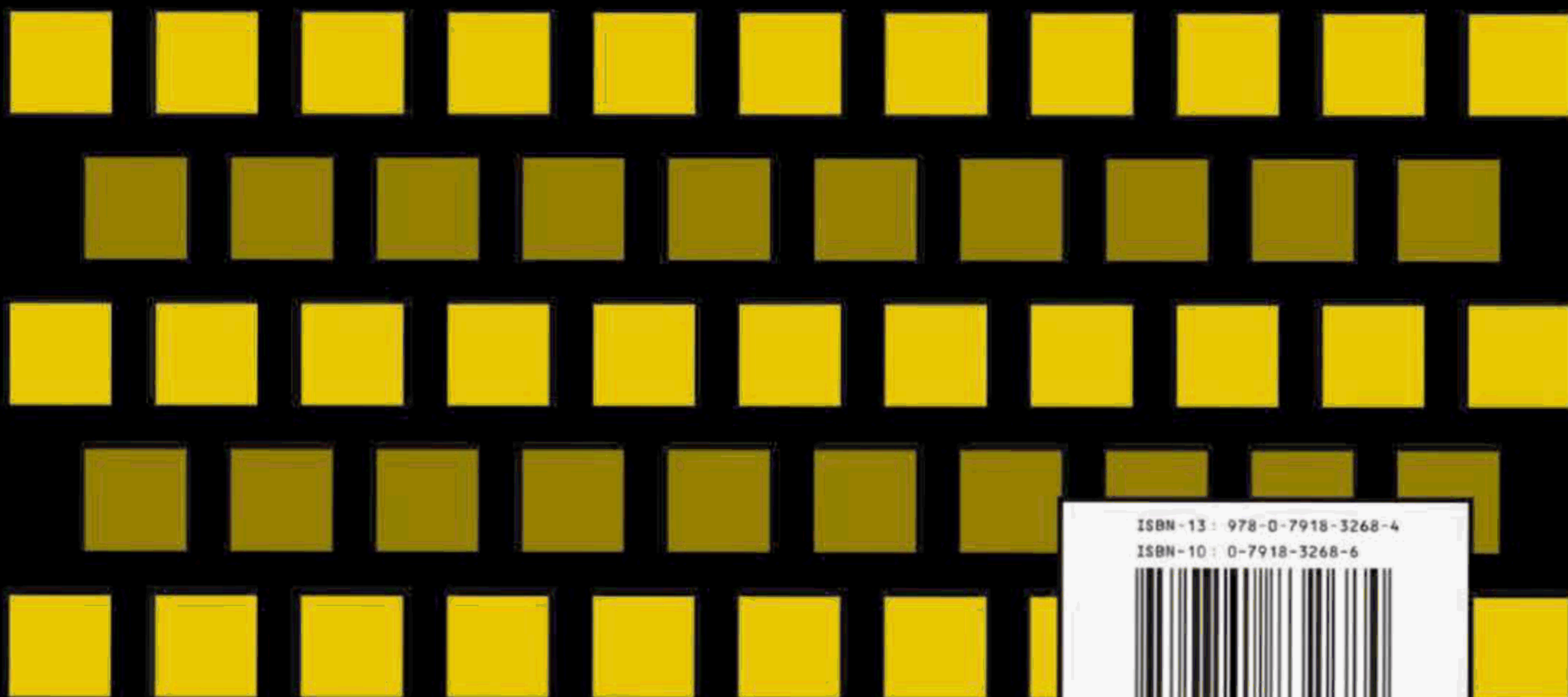
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ABBREVIATIONS AND ACRONYMS

AWS:	American Welding Society
ANSI:	American National Standards Institute
ASRS:	Automatic Storage and Retrieval System
AWS:	American Welding Society
CMAA:	Crane Manufacturers Association of America
EN:	European National
EOA:	End of Aisle
EOT:	End of Travel
FEA:	Finite Element Analysis
FEM:	Federation Europeenne de la Manutention
MHI:	Material Handling Institute of America
P&D:	Pick and Delivery
SKU:	Stock Keeping Unit
SR:	Storage and Retrieval
T-car(s):	Transfer car(s)
UIC:	International Union of Railways (European)

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