



SEMI AUX031-1114
S2 MAPPING INTO THE MACHINERY DIRECTIVE (2006/42/EC)
ESSENTIAL HEALTH AND SAFETY REQUIREMENTS

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S2 Mapping into the Machinery Directive (2006/42/EC) Essential Health and Safety Requirements



Introduction

Below is a table showing the output of the MD/S2 Mapping Task Force which had the goals stated below, and was working from a background stated in the following sections. The following matrix was created over the course of several years. During those years the SEMI standards referenced may have been revised, impacting the section references. We have made an effort to correct all S2 references to the S2-0712 publication.

Background Rationale

- Conformance to the Machinery Directive is an EU market entry requirement for most semiconductor and photovoltaic manufacturing equipment. Additionally, many equipment end users require Machinery Directive conformance for equipment going into regions other than the EU.
- Where a company typically must do S2 and Machinery Directive assessments, S2 is typically the higher priority as it is customarily done by a third party, and S2 has more specific criteria than the MD.
- Such companies often then use their S2 report as the basis for declaring conformance to much of the MD Annex I criteria. However, there is no industry accepted mapping of current S2 criteria into the MD Annex I criteria, so each company pursuing this route must argue its own mapping rationale.

Goal

Creation of an Related Information to S2, or an Auxiliary Information, to provide an informative mapping of S2 paragraphs onto Machinery Directive Annex I (essentially health and safety requirements) paragraphs typically relevant to equipment in the semi/photovoltaic industries and perhaps additional commentary on what might be missing if an S2 paragraph is found to partly, but not completely, address an MD Annex I paragraph.

Past, Somewhat Similar, SEMI Efforts

1. In Spring of 2001 the SEMI EHS committee published a comparison of the Korean Kosha S-mark regulation to SEMI S2-93. The S-mark regulation was substantially similar to parts of – but not all of – the EU Machinery Directive 98/37/EC in effect at that time.
2. In Fall of 2001 SEMI EHS committee published an auxiliary information document AUX005 which was a comparison of S2-93 to S2-0200.

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This New Project

Interpretations of the Machinery Directive for this project were primarily informed by the EU Commissions MD Guidance Document (2nd Edition). The Task Force limited their considerations to S2 and S-Type Normative references from S2. For example, the ergonomics concern of the MD could be answered by an S8 assessment because S8 is a normative reference from S2.

Not all of the MD Annex I sections were reviewed, because not all of them are relevant to SEMI Equipment. Only Section 1 (General) and Section 4 (“Supplementary Essential Health and Safety Requirements To Offset Hazards Due To Lifting Operations”) were considered.

With regard to S2, only sections that are points of assessment were used (e.g., S2 Section 6, Philosophy, was not used except where MD Annex 1 presented equivalently broad and general philosophical criteria)

General Work Method

Read an MD Annex I section, review MD Guidance as needed, compare the MD section to S2 and related S-type guidelines, and provide, in effect, one of the following conclusions.

- A. This topic is **not** addressed in SEMI S2 or other S-type guidelines that are typically used to support an S2 evaluation.
- B. This topic is **fully** addressed in SEMI S*___ with section(s)* _____
- C. This topic is **partially** addressed in SEMI S*___ with section(s)* _____, but this remaining aspect is not addressed _____

**add more references as appropriate*

Key Decisions

As work progressed, the task force made some key decisions to clarify and simplify the task. Note- the current S2 revision changed over the course of the project so some section references to S2 are off.

1. We have decided (e.g. with regard to use of equipment in potentially explosive atmospheres and marking) to frame our assessment of S2 towards “complete” machines. Though there may be companies in the industry that sell partly completed machines, expanding this document to that area is a different work product.
2. S2 is scoped to only equipment used to manufacture, assemble, measure and test semiconductor products. We **Think** this would exclude industry equipment such as ingot saws, so that type of equipment is not considered in this analysis.
3. We decided that we will not analyze the question of combined machinery (e.g., ref 155 in table below).
4. For many of the [MD] sections we looked at related to controls, while S2 did not explicitly address the issues, we suspect the typical electrical design standards used in the industry might. If we can survey those standards and show that they do, I think we can declare those sections covered, but this could take quite some effort. The electrical design standards we think we would have to assess are S22, NFPA 79, 60204-1, 60204-33, UL 508A, UL/EN 61010. It was proposed that “... we not try to claim the handful of issues not covered in S2 that might be covered by all reasonably used electrical design standards are therefore covered by S2, because we do not have the means to determine this. Therefore where we have made a notation about this in the past, the section will be changed, most likely, to status 3 (not

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covered), or perhaps 2 (partially covered). “ The TF agreed to the proposal with the additional thought that if S22 covers the topic we can claim partial coverage.

5. We really struggled with the MD’s guard criteria and our thoughts about general standard of care in the industry. [We strived to stay focused on what the words in the documents actually said but did use “standard of care” arguments occasionally when we felt the MD was being particularly in-specific/subjective in its requirements].
6. Exceptions to MD criteria are counted as 5 – not an assessment section (reference color and number code, below). Since this is an exercise to see what S2 criteria could “serve” MD criteria, MD exceptions do not need to be considered.
7. [also stated above] Issues covered by S22 can provide partial coverage at most since S22 is not required by S2 (except, of course, for the few S2 sections that require the use of particular S22 subsections such as S2 13.4.7)

Regarding the table codes and colors

Color code and numeric codes (for monochrome situations) for the following table

[1]	This chunk seems to be completely covered by the indicated S2+ section
[2]	This chunk seems to have partial coverage by an S2+ section.
[3]	This chunk is not addressed at all by S2+
[4]	A concern for machinery in general, but not a concern for typical wafer, solar or FPD manufacturing equipment.
[5]	This chunk provides background or is a heading, but is not an MD assessment section.

“+” → Indicates how S2+ has coverage of the topic

“-” → Indicates how S2+ does not have coverage of the topic.

“**G:**” is an excerpt from the Commission guidance for an MD criterion.

Text in {blue braces} is task force commentary on an MD criterion.

The first three columns are marker columns.

“ref” is an absolute row reference

“wrk” gives a count of the rows the task force set to review

“flg” was used to indicate when the row review was completed.

“§” → Indicates the Citation number in the EU’s ‘Guide to the application of the machinery directive 2006/42/EC’, 2nd Edition, June 2010

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ref	wrk	fig	ANNEX I Checklist	Outcome & Rationale
1			Essential health and safety requirements relating to the design and construction of machinery	[5]
2			GENERAL PRINCIPLES	[5]
3	1	¢	1. The manufacturer of machinery or his authorised representative must ensure that a risk assessment is carried out in order to determine the health and safety requirements which apply to the machinery. The machinery must then be designed and constructed taking into account the results of the risk assessment.	-] Section 6.8 of S2 recommends a hazard analysis with 6.8.2 calling for the risks associated with the hazards to be assessed per S10. But 6.8 is not assessable criteria. +] S2 section 8.5.1 bullet 4 requires a hazard analysis, referencing 6.8 in parens, be provided to or developed by the assessor (see 8.5). Since determining risk is a method of analyzing a hazard, and since section 6.8 is referenced in parentheses, it is reasonable to infer that the risk assessment mentioned in 6.8.2 must be part of the hazard analysis. +] While S2 does not have an assessable section saying the tool must be designed to mitigate risks identified in the hazard analysis to an acceptable level, this is implicit in how the industry works with S2. And in the sense that this MD section does not require the risks be reduced (only taken account of), they are equivalent. [1]
4			By the iterative process of risk assessment and risk reduction referred to above, the manufacturer or his authorised representative shall:	[5]
5			— determine the limits of the machinery, which include the intended use and any reasonably foreseeable misuse thereof,	[5]
6			— identify the hazards that can be generated by the machinery and the associated hazardous situations,	[5]
7			— estimate the risks, taking into account the severity of the possible injury or damage to health and the probability of its occurrence,	[5]
8			— evaluate the risks, with a view to determining whether risk reduction is required, in accordance with the objective of this Directive,	[5]
9			— eliminate the hazards or reduce the risks associated with these hazards by application of protective measures, in the order of priority established in section 1.1.2(b).	[5]

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ref	wrk	fig	ANNEX I Checklist	Outcome & Rationale	
10			2. The obligations laid down by the essential health and safety requirements only apply when the corresponding hazard exists for the machinery in question when it is used under the conditions foreseen by the manufacturer or his authorised representative or in foreseeable abnormal situations. In any event, the principles of safety integration referred to in section 1.1.2 and the obligations concerning marking of machinery and instructions referred to in sections 1.7.3 and 1.7.4 apply.	[5]	
11			3. The essential health and safety requirements laid down in this Annex are mandatory; However, taking into account the state of the art, it may not be possible to meet the objectives set by them. In that event, the machinery must, as far as possible, be designed and constructed with the purpose of approaching these objectives.	[5]	
12			4. This Annex is organised in several parts. The first one has a general scope and is applicable to all kinds of machinery. The other parts refer to certain kinds of more specific hazards. Nevertheless, it is essential to examine the whole of this Annex in order to be sure of meeting all the relevant essential requirements. When machinery is being designed, the requirements of the general part and the requirements of one or more of the other parts shall be taken into account, depending on the results of the risk assessment carried out in accordance with point 1 of these General Principles.	[5]	
13			1. ESSENTIAL HEALTH AND SAFETY REQUIREMENTS	[5]	
14			1.1. GENERAL REMARKS	[5]	
15			1.1.1. Definitions	[5]	
16			For the purpose of this Annex:	[5]	
17			(a) 'hazard' means a potential source of injury or damage to health;	[5]	
18			(b) 'danger zone' means any zone within and/or around machinery in which a person is subject to a risk to his health or safety;	[5]	
19			(c) 'exposed person' means any person wholly or partially in a danger zone;	[5]	
20			(d) 'operator' means the person or persons installing, operating, adjusting, maintaining, cleaning, repairing or moving machinery;	[5]	
21			(e) 'risk' means a combination of the probability and the degree of an injury or damage to health that can arise in a hazardous situation;	[5]	
22			(f) 'guard' means a part of the machinery used specifically to provide protection by means of a physical barrier;	[5]	

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23			(g) 'protective device' means a device (other than a guard) which reduces the risk, either alone or in conjunction with a guard;	[5]
24			(h) 'intended use' means the use of machinery in accordance with the information provided in the instructions for use;	[5]
25			(i) 'reasonably foreseeable misuse' means the use of machinery in a way not intended in the instructions for use, but which may result from readily predictable human behaviour.	[5]
26			1.1.2. Principles of safety integration <i>{The principles of safety integration are not a clearly assessable aspect of the MD per se. Rather they are principles that must underlie all other efforts to mitigate risks identified later. In this sense it is roughly equivalent in purpose to the S2 philosophy and general provisions sections 6 and 7. Note particularly that (a) thru (d) is a criterion 'assigned' to the machine design, while (b) is more of a background philosophy. }</i>	[5]

ref	wrk	fig	ANNEX I Checklist	Outcome & Rationale
27	2	ç	(a) Machinery must be designed and constructed so that it is fitted for its function, and can be operated, adjusted and maintained without putting persons at risk when these operations are carried out under the conditions foreseen but also taking into account any reasonably foreseeable misuse thereof. The aim of measures taken must be to eliminate any risk throughout the foreseeable lifetime of the machinery including the phases of transport, assembly, dismantling, disabling and scrapping.	+] S2 addresses operation, service and maintenance tasks which is essentially equivalent to the MD's "operation, adjustment and maintenance", perhaps a bit broader. +] Though S2 does not address "mis-use" per se, it does call for consideration of operational errors. (ref 6.5). +] The S2 philosophy does not rule out putting people or the environment at risk, but rather sets a scale for risk and recommends that Very High, High and Medium risks be mitigated at least to Low or Very Low (ref Note 8). +] The scope of S2 considerations is set in the philosophy section to "installation, operation, maintenance, service, and disposal of equipment" (ref 6.1) -] The philosophy section does not address the MD concern about "transportation." -] Thus, in general, a passing assessment to S2 would meet this principle requirement except for consideration of transportation. [2]
28			(b) In selecting the most appropriate methods, the manufacturer or his authorised representative must apply the following principles, in the order given: — eliminate or reduce risks as far as possible (inherently safe machinery design and construction), — take the necessary protective measures in relation to risks that cannot be eliminated, — inform users of the residual risks due to any shortcomings of the protective measures adopted, indicate whether any particular training is required and specify any need to provide personal protective equipment.	[5]

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29	3	ç	(c) When designing and constructing machinery and when drafting the instructions, the manufacturer or his authorised representative must envisage not only the intended use of the machinery but also any reasonably foreseeable misuse thereof. {this first part is a philosophy (a requirement to 'envisage'). It is not assessable in the product itself. The machinery must be designed and constructed in such a way as to prevent abnormal use if such use would engender a risk. Where appropriate, the instructions must draw the user's attention to ways — which experience has shown might occur — in which the machinery should not be used.	-]S2 does not explicitly ~~take into account or~~ discuss foreseeable unintended operation or abnormal operation. It only discusses abnormal operation as a result of a single point failure {potential examples of "intentional misuse" could be interlock bypassing, failure to follow PM schedules or procedures, failure to lock out according to instructions. } +] The idea misuse is adequately addressed for our industry by the criteria to consider "single point failure" [1]
30	4	ç	(d) Machinery must be designed and constructed to take account of the constraints to which the operator is subject as a result of the necessary or foreseeable use of personal protective equipment.	+] The S8 SESC checklist calls requires consideration of PPE in many instances. +] the sense of this requirement is conveyed in S8 section 6.9. -] S8 section 6.9 can be superceded by using the SESC checklist. +]S13 calls for PPE to be called out for tasks (ref sect. 12) but this is different from requiring the design to accommodate the PPE. [2]
31	5	ç	(e) Machinery must be supplied with all the special equipment and accessories essential to enable it to be adjusted, maintained and used safely.	+] S2 section 7.4 is essentially equivalent to this. -] S2 section 7.4 is not assessable, but it may nonetheless influence behavior. [2]
32			1.1.3. Materials and products	[5]

ref	wrk	flg	ANNEX I Checklist	Outcome & Rationale
33	6	¢	The materials used to construct machinery or products used or created during its use must not endanger persons' safety or health. In particular, where fluids are used, machinery must be designed and constructed to prevent risks due to filling, use, recovery or draining.	-] Hazardous solid materials of construction are anticipated in our industry such as lead for xray shielding, chromium 6 for metal plating, PVC in cables, etc... +]S2 addresses “chemicals anticipated to be used or generated in the equipment” (ref 23.1) -] S2+ does not address inherent hazards of materials of construction. +]S2 particularly addresses fluids and concerns of filling etc... (ref appendix 2) -]however, S2 criteria for exposure are focused on “breathing zones” and so do not necessarily robustly address contact hazards. [2]
34			1.1.4. Lighting	[5]
35	7	¢	Machinery must be supplied with integral lighting suitable for the operations concerned where the absence thereof is likely to cause a risk despite ambient lighting of normal intensity.	-] S8 SESC section 7.1 (may be moved and slightly reworded in recent ballots) calls for supply of a minimum amount of light (300 lux) for certain scenarios, but it allows that it could be provided by portable lights rather than having to be integral. S2 contains no criteria on lighting. [2]
36	8	¢	Machinery must be designed and constructed so that there is no area of shadow likely to cause nuisance, that there is no irritating dazzle and that there are no dangerous stroboscopic effects on moving parts due to the lighting.	-] S8 only address providing light for visibility. There is nothing in S2+ which address concerns like these about the quality of light or the potential risks of providing light in the wrong way. [3]
37	9	¢	Internal parts requiring frequent inspection and adjustment, and maintenance areas must be provided with appropriate lighting. G: Specifications for integral lighting are given in standard EN 1837 {no explanation in the guide about meaning of “frequent”}	+] The issue of integral is limited to ref35. Without other qualification in the MD or the guide, there seems to be no reason to assume 300lux is not appropriate. Therefore, this section is addressed by the S8 section noted in ref35 [1]
38			1.1.5. Design of machinery to facilitate its handling	[5]

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ref	wrk	fig	ANNEX I Checklist	Outcome & Rationale
39			Machinery, or each component part thereof, must: G: <i>Section 1.1.5 applies to 'machinery or each component part thereof'. This does not mean that all parts of machinery must be designed for safe handling, but only those parts of the machinery, or the machinery itself, which may have to be handled separately.</i> <i>{'Component' can be understood as something different than a 'part'. The obligation is not to assess each part to these criteria.}</i>	[5]
40	10	¢	— be capable of being handled and transported safely,	+] The assessment to S8, particularly MMH, would address handling concerns during O, M or S. +] S2 18.1 addresses stability during shipping and installation -] S2 does not address transportation of equipment for comprehensive general safety. See ref 27 [2]
41	11	¢	— be packaged or designed so that it can be stored safely and without damage.	-] S2 does not address packaging or design for storage and damage prevention. See ref 27 [3]
42	12	¢	=DELTA= During the transportation of the machinery and/or its component parts, there must be no possibility of sudden movements or of hazards due to instability as long as the machinery and/or its component parts are handled in accordance with the instructions.	+] S2 addresses shipping stability in sect. 18.2 [1]
43	13	¢	Where the weight, size or shape of machinery or its various component parts prevents them from being moved by hand, the machinery or each component part must: — either be fitted with attachments for lifting gear, or — be designed so that it can be fitted with such attachments, or — be shaped in such a way that standard lifting gear can easily be attached.	There is nothing in S8 or S2 that drives consideration of designing components intended for handling to be fitted for interfacing with lifting gear. Tradition, but no explicit criteria, limits lifting to 2 people. Regardless, the next progression if a multi-person lift cannot be done, would be to use lifting gear. The natural consequence of assessing a lifting task would most likely result in the fulfilling these criteria. [1]
44	14	¢	Where machinery or one of its component parts is to be moved by hand, it must: — either be easily moveable, or — be equipped for picking up and moving safely.	The S8 task assessment will address this concern. [1]

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ref	wrk	flg	ANNEX I Checklist	Outcome & Rationale
45	15	¢	Special arrangements must be made for the handling of tools and/or machinery parts which, even if lightweight, could be hazardous. <i>G; See section header at ref39</i> <i>Also – “When designing machinery or parts of machinery to be safely moved or lifted by hand, sharp edges must be avoided.”</i>	+] S2 addresses sharp edges and burrs regardless of weight. -] The MD expects consideration of all lifecycle stages, S2 only addresses in 6.1 installation, operation, maintenance, service, and disposal. S8 MMH only addresses operation, service and maintenance (SESC 1.1) +] S13 section 6.2 calls for instructions for “safe” install, operation, maintenance, decontamination, decommissioning. -] S8 requires manual material handling analysis only for objects over 5 or 10 pounds (2.2 or 4.4 kg) (under certain frequency conditions). There is nothing in S2 that calls for the assessment of small parts that will be handled for other hazards. +] Though other than sharp edges, it is not clear what the other hazards could be in our industry. The guide only seems to address sharp edges. +] For hazards such as toxic materials or hot and cold surfaces, S2 addresses these without consideration of the item size, and so these consideration would apply to lightweight and heavy objects alike. Furthermore the MD does not seem to be meaning chemical or temp issues here because there are other sections addressing them such as ref250 and ref225. -] small powerful magnets can be used in our industry and these can present a pinch or sudden movement hazard if not handled correctly. However the biologic impact of magnets is addressed (e.g., section 25.2, 25.5.1, Appendix 4 of S2) [2]
46			1.1.6. Ergonomics	[5]
47	16	¢	=DELTA= Under the intended conditions of use, the discomfort, fatigue and physical and psychological stress faced by the operator must be reduced to the minimum possible, taking into account ergonomic principles such as: — allowing for the variability of the operator's physical dimensions, strength and stamina, — providing enough space for movements of the parts of the operator's body, — avoiding a machine-determined work rate, — avoiding monitoring that requires lengthy concentration, — adapting the man/machinery interface to the foreseeable characteristics of the operators.	+] S8 covers physical dimension variability and body space considerations, adapting the interface to operator characteristics. -] S8 does not cover avoiding machine determined work rate (we are not certain this point is relevant to semiconductor manufacturing equipment), or lengthy concentration. [2]
48			1.1.7. Operating positions	[5]

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ref	wrk	fig	ANNEX I Checklist	Outcome & Rationale
49	17	¢	=DELTA= The operating position must be designed and constructed in such a way as to avoid any risk due to exhaust gases and/or lack of oxygen.	+] There generally are no reasonably foreseeable hazards of exhaust gas or lack of oxygen at operating positions. However in some limited cases (e.g., operator in from of a wet bench with fire suppression systems) they may be exposed. S2 sect. 14 addresses the concern of suppressants. There are occasional equipment designs that present a risk of asphyxiation (e.g., due to nitrogen flooding), but these are not foreseen at the “operating positions” of equipment. [1]
50	18	¢	=DELTA= If the machinery is intended to be used in a hazardous environment presenting risks to the health and safety of the operator or if the machinery itself gives rise to a hazardous environment, adequate means must be provided to ensure that the operator has good working conditions and is protected against any foreseeable hazards. <i>G: NOTE: from the guide, a hazardous environment is a broad range of concerns “Such risks may include, for example, exposure to hot and cold atmospheres, to risks due to noise, radiation, humidity, adverse weather conditions or atmospheres polluted by hazardous substances.”</i>	First clause is NA for our industry as we expect operator environment to be safe. The machine could give rise to hazards and S2 has elements which call for assessing these points for adequate operator protection, such as 1% chemical exposure requirement, noise, radiation, etc... [1]
51	19	¢	=DELTA= Where appropriate, the operating position must be fitted with an adequate cabin designed, constructed and/or equipped to fulfil the above requirements. The exit must allow rapid evacuation. Moreover, when applicable, an emergency exit must be provided in a direction which is different from the usual exit.	+] foreseeable conditions for semiconductor manufacturing equipment do not require cabins for the operating position. [4]
52			1.1.8. Seating	[5]
53	20	¢	Where appropriate and where the working conditions so permit, work stations constituting an integral part of the machinery must be designed for the installation of seats.	+] S8 addresses the heights of work surfaces which by consequence (if not by design) allows the use of commercially available seats. [1]

ref	wrk	fig	ANNEX I Checklist	Outcome & Rationale
54	21	¢	If the operator is intended to sit during operation and the operating position is an integral part of the machinery, the seat must be provided with the machinery.	NOTE: the MD guide clarifies (§183) that this applies where the location for the seat would be in/on the machine . Such a scenario is not typical for semiconductor manufacturing equipment but is not impossible. -] S2+ does not require the provision of seats at seated operator locations. [3]
55	22	¢	The operator's seat must enable him to maintain a stable position. Furthermore, the seat and its distance from the control devices must be capable of being adapted to the operator.	-] There are no criteria in S2+ related to the stability or adjustability of seats if provided by the supplier. [3]
56	23	¢	If the machinery is subject to vibrations, the seat must be designed and constructed in such a way as to reduce the vibrations transmitted to the operator to the lowest level that is reasonably possible.	It is not foreseeable that semiconductor manufacturing equipment would be subject to vibrations requiring such action. [4]
57	24	¢	The seat mountings must withstand all stresses to which they can be subjected. Where there is no floor beneath the feet of the operator, footrests covered with a slip-resistant material must be provided.	-] There are no criteria in S2+ related to the stability or adjustability of seats if provided by the supplier. [3]
58			1.2. CONTROL SYSTEMS	[5]
59			1.2.1. Safety and reliability of control systems	[5]
60	25	¢	Control systems must be designed and constructed in such a way as to prevent hazardous situations from arising. Above all, they must be designed and constructed in such a way that:	-] S2+ has no criteria targeted to “Control Systems” as a general concept. +] S2+ does have criteria targeted to some subset types of control systems e.g., 21.2.4.7. – Chemical mixing control systems, 14.4.4.2 – Fire protection control systems, 11.6.1 – Programmable Safety Control Systems, {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} [2] – for now

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61	26	ç	— they can withstand the intended operating stresses and external influences,	-] S2+ does not address this specific point. {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} [3] for now
62	27	ç	— a fault in the hardware or the software of the control system does not lead to hazardous situations,	-] S2 22.2 requires chemical ventilation to provide protection if there is a failure in software or hardware, but this is different from requiring the control system itself to be designed so that a fault in hardware or software does not lead to hazardous situations. +] S2 11.5 and 11.6 requires fault tolerant electromechanical safety systems or Fail-to-safe electronic safety systems. {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} [2] – for now
63	28	ç	— errors in the control system logic do not lead to hazardous situations,	+] S2 11.5 and 11.6 requires fault tolerant electromechanical safety systems or Fail-to-safe electronic safety systems. {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} [2] – for now

ref	wrk	fig	ANNEX I Checklist	Outcome & Rationale
64	29	ç	=DELTA= — reasonably foreseeable human error during operation does not lead to hazardous situations.	+] In many places S2 requires risk assessment which draws in the ideas of reasonably foreseeable human error. -] S2+ does not have a criteria for assessing the human error aspects of a control system in general. {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} [2] – for now
65			Particular attention must be given to the following points:	[5]
66	30	ç	— the machinery must not start unexpectedly,	+] S2 has a couple sections that discuss start up for certain types of control systems. E.g., 12.2.4. and 12.2.6 – start up on resetting EMO actuator, or 11.8 related to safety interlocks. -] S2 does not have a general concern about unexpected startup. {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} - section 13.2.2 addresses unexpected startup but it is tucked under “safety circuits” [2] for now

ref	wrk	fig	ANNEX I Checklist	Outcome & Rationale
67	31	ç	=DELTA= — the parameters of the machinery must not change in an uncontrolled way, where such change may lead to hazardous situations,	+] S2 address this for interlock setpoints at 11.5 -] S2+ does not have this as general requirement. {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} [2] for now
68	32	ç	— the machinery must not be prevented from stopping if the stop command has already been given,	+] S2 address the priority of the Emergency Stop command – 12.1. -] S2 is silent on “stop command” as a general concept. {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1}
69	33	ç	— no moving part of the machinery or piece held by the machinery must fall or be ejected,	+] S2 18.3 address the possibility of falling or ejected machine parts. However, this is already covered in ref151 below, so does not help this concern per se. -]S2+ does not address the falling or ejection of “pieces held by the machinery” which in our industry could be wafers, flat panel substrates, full FOUPS and cassettes. [3]
70	34	ç	— automatic or manual stopping of the moving parts, whatever they may be, must be unimpeded, {this could be referring to accessibility but this is under safety and reliability of control systems, so this must mean the certainty with which the stopping system will work given anticipated scenarios}	+] S2 12.5 on EMO accessibility +] manual stopping of moving parts is generally not anticipated (except where energy source is human effort which is outside stop) {this may well be already covered by emergency stopping and normal stopping criteria} See ref (68) for stopping {??? What types of impeding are envisioned that must be avoided?} [2]

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ref	wrk	fig	ANNEX I Checklist	Outcome & Rationale
71	35	ç	— the protective devices must remain fully effective or give a stop command,	+] S2 11.5 and 11.6 requires fault tolerant electromechanical safety systems or Fail-to-safe electronic safety systems. And S2 12.2.1 EMO circuit should not include controls that enable it to be defeated or bypassed; [1]
72	36	ç	— the safety-related parts of the control system must apply in a coherent way to the whole of an assembly of machinery and/or partly completed machinery.	+] S2 interlock criteria requires that safety interlocks, when triggered, must provide a notification on the operator interface. This implies a reasonable level of “coherence” is required. Likewise, for emergency off, there is a clause which allows particularly qualified subsystems to have independent EMO circuits/methods, and this implies a requirement of coherence otherwise. Could apply section 11 Safety Interlock Systems {combining things together, looking for hooks and documentation. This includes EMOs and safety interlocks} [1]
73	37	ç	=DELTA= For cable-less control, an automatic stop must be activated when correct control signals are not received, including loss of communication.	-] S2 has no criteria related to cable-less controls. They are anticipate in the industry for use in maintenance activities (e.g., wireless tablet computers). [3]

ref	wrk	fig	ANNEX I Checklist	Outcome & Rationale
74			1.2.2. Control devices <i>G: Control devices are parts of the control system which detect input signals given by the operators, usually by means of hand or foot pressure. There are many different kinds of control devices including, for example, push-buttons, levers, switches, knobs, sliders, joy-sticks, hand wheels, pedals, keyboards and tactile screens.</i> {The tone of the further guidance in the guide indicates that these are devices used to direct the operation of the machine from a system perspective. That is to say, it would include devices related to the operation of the machine for its intended use (e.g., what S2 might call operator tasks) and also for scheduled maintenance tasks such as interlock bypassing, or EMOs, etc..., but not necessarily all the controls that could be used in a service task such as an adjustment trim pot in a power supply}	R5 of S8 does discuss control topics but it is not required for assessment. [5]
75			Control devices must be:	[5]
76	38	¢	— clearly visible and identifiable, using pictograms where appropriate,	-] S2 is silent on “control devices”. +] A touch screen is a common control device in our industry, S8 address the visibility of control screens (e.g., height, stacking, readability). {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} [2] for now
77	39	¢	— positioned in such a way as to be safely operated without hesitation or loss of time and without ambiguity,	-] S2 is silent on “control devices”. +] S8 –required by S2 - discusses position requirements for frequently and infrequently used controls. [1]

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ref	wrk	fig	ANNEX I Checklist	Outcome & Rationale
78	40	ç	— designed in such a way that the movement of the control device is consistent with its effect,	-] S2 is silent on “control devices”. {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} [3] for now
79	41	ç	— located outside the danger zones, except where necessary for certain control devices such as an emergency stop or a teach pendant, {saying that the devices must be outside of dangers zones is an objective decision (e.g., identifying where danger zones are and ensure controls are outside of them), not related to risk. It is the following point that addresses the consideration of risk. }	-] S2 is silent on “control devices”. {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} } [3] for now
80	42	ç	— positioned in such a way that their operation cannot cause additional risk,	-] S2 is silent on “control devices”. +] S2 does say that EMO actuators should be operable without putting personnel at additional risk. (ref 12.5.3) {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} [2] for now
81	43	ç	— designed or protected in such a way that the desired effect, where a hazard is involved, can only be achieved by a deliberate action,	-] S2 is silent on “control devices”. +] S2 does discuss the need for deliberate actions for EMO resetting (ref 12.2.6), interlock set point changing (11.5), interlock bypassing (11.7.2), and interlock restoration (11.8). {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} [2] for now

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ref	wrk	fig	ANNEX I Checklist	Outcome & Rationale
82	44	ç	— made in such a way as to withstand foreseeable forces; particular attention must be paid to emergency stop devices liable to be subjected to considerable forces.	-] S2 is silent on “control devices”. -] S2 does not discuss force considerations for EMO actuators. {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} [3] for now
83	45	ç	Where a control device is designed and constructed to perform several different actions, namely where there is no one-to-one correspondence, the action to be performed must be clearly displayed and subject to confirmation, where necessary.	-] S2 is silent on “control devices”. {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} [3] for now
84	46	ç	Control devices must be so arranged that their layout, travel and resistance to operation are compatible with the action to be performed, taking account of ergonomic principles.	-] S2 is silent on “control devices”. -] S8 does not address issues such as device layout, travel and resistance to operation. {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} [3] for now
85	47	ç	Machinery must be fitted with indicators as required for safe operation. The operator must be able to read them from the control position.	-] S2 is silent on “control devices”. +] A common indicator in our industry is a video display terminal. S8 has many criteria for the positioning of video display terminals. -] Not all indicator types are addressed by S8. Particularly “frequently viewed” visual signals. {Needs additional study– see what typical Electrical Design standards say – SEMI S22, NFPA 79, EN 60204-1, EN 60204-33, UL 508A, UL/EN 61010-1} [2] for now

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ref	wrk	flg	ANNEX I Checklist	Outcome & Rationale
86	48	¢	=DELTA= From each control position, the operator must be able to ensure that no-one is in the danger zones, or the control system must be designed and constructed in such a way that starting is prevented while someone is in the danger zone. <i>{“control position” can be understood as “operator station” in S2}</i>	-] S2 has no requirement related to the visibility of danger zones from the control position(s) nor an explicit requirement about preventing starting if someone is in a danger zone. In ¶12.5 S2 requires EMO actuators to be “readily accessible” and ¶12.5.2, that they be no more than 3m from operation and maintenance locations, but there is nothing that drives assessment of where danger zones may be and how to prevent unexpected startup. +] However, it is implicit in the S2 interlock and HEI philosophies that there should be no active danger zones with people in them. Thus, S2 addresses the concern, by making it moot. +] often control positions for semi tools are elsewhere in the fab or the world because of remote control capabilities in the equipment. Our “remote control” work addressed this. [2]
87	49	¢	If neither of these possibilities is applicable, before the machinery starts, an acoustic and/or visual warning signal must be given. The exposed persons must have time to leave the danger zone or prevent the machinery starting up.	-] S2 does not have this provision, [3]
88	50	¢	If necessary, means must be provided to ensure that the machinery can be controlled only from control positions located in one or more predetermined zones or locations.	-] It is common for equipment in our industry to have more than one control position. Alternate control positions can occur near the machine, or very remotely. While S2 does discuss concerns of remote operation in RI 15, this is not a mandatory assessment point, and the reference to RI 15 is made from 6.8.1 which is itself a philosophy section, not an assessment section. [3]

ref	wrk	fig	ANNEX I Checklist	Outcome & Rationale
89	51	ç	Where there is more than one control position, the control system must be designed in such a way that the use of one of them precludes the use of the others, except for stop controls and emergency stops.	-] It is common for equipment in our industry to have more than one control position. Alternate control positions can occur near the machine, or very remotely. While S2 does discuss concerns of remote operation in RI 15, this is not a mandatory assessment point, and the reference to RI 15 is made from 6.8.1 which is itself a philosophy section, not an assessment section. [3]
90	52	ç	When machinery has two or more operating positions, each position must be provided with all the required control devices without the operators hindering or putting each other into a hazardous situation.	It is common for equipment in our industry to have more than one control position. Alternate control positions can occur near the machine, or very remotely. While S2 does discuss concerns of remote operation in RI 15, this is not a mandatory assessment point, and the reference to RI 15 is made from 6.8.1 which is itself a philosophy section, not an assessment section. [3]
91			1.2.3. Starting	[5]
92			It must be possible to start machinery only by voluntary actuation of a control device provided for the purpose. The same requirement applies:	This is really just an intro to the next two dashes. [5] {Note the following draft assessment was here -] S2 has no criteria for normal equipment starting. +} S2 interlock restart concern {defer to electrical design standard survey NFPA 79 section 9.2.5.2.4.}}
93	53	ç	— when restarting the machinery after a stoppage, whatever the cause,	-] S2+ has no criteria for normal equipment starting. +] S2 has a criteria related to restarting after a safety interlock trips (11.8) +]S22 13.2.2 provides a general caution against unexpected startup, but no detail like this in the MD [2]

ref	wrk	fig	ANNEX I Checklist	Outcome & Rationale
94	54	¢	— when effecting a significant change in the operating conditions.	-] S2+ has no criteria related to significant change in operating conditions. {e.g. transitioning in an implanter from no beam to beam (w/ xrays) or a laser from off to on} [3]
95			However, the restarting of the machinery or a change in operating conditions may be effected by voluntary actuation of a device other than the control device provided for the purpose, on condition that this does not lead to a hazardous situation.	This is permissive – not a restriction. [5]
96			For machinery functioning in automatic mode, the starting of the machinery, restarting after a stoppage, or a change in operating conditions may be possible without intervention, provided this does not lead to a hazardous situation.	This is permissive – not a restriction. [5]
97	55	¢	Where machinery has several starting control devices and the operators can therefore put each other in danger, additional devices must be fitted to rule out such risks. If safety requires that starting and/or stopping must be performed in a specific sequence, there must be devices which ensure that these operations are performed in the correct order.	-] S2+ has no criteria related to this topic +] RI15-6 speaks of multiple control points related to remote operation. [2]
98			1.2.4. Stopping	[5]
99			1.2.4.1. Normal stop	[5]
100	56	¢	Machinery must be fitted with a control device whereby the machinery can be brought safely to a complete stop.	-] S2+ has no criteria related to <u>normal</u> stopping [3]
101	57	¢	Each workstation must be fitted with a control device to stop some or all of the functions of the machinery, depending on the existing hazards, so that the machinery is rendered safe.	-] S2+ has no criteria related to <u>normal</u> stopping [3]
102	58	¢	The machinery's stop control must have priority over the start controls.	-] S2+ has no criteria related to <u>normal</u> stopping [3]
103		¢	Once the machinery or its hazardous functions have stopped, the energy supply to the actuators concerned must be cut off.	-] S2+ has no criteria related to <u>normal</u> stopping [3]
104			1.2.4.2. Operational stop	[5]

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ref	wrk	fig	ANNEX I Checklist	Outcome & Rationale
105	60	ç	=DELTA= Where, for operational reasons, a stop control that does not cut off the energy supply to the actuators is required, the stop condition must be monitored and maintained. <i>G: Section 1.2.4.2 recognises that, for operational reasons, for example, in order to permit an easier or more rapid restart of the machinery, it may be necessary to provide, in addition to the normal stop control required by section 1.2.4.1, a stop control that does not cut off the energy supply to the actuators. Since, in that case, a failure in the control system could lead to an unintended start, the control system must include the means of monitoring the stop condition in order to ensure that the machinery remains at a stop until it is intentionally restarted using the start control device.</i>	-] S2+ has no criteria related to operational stopping [3] {it is a little ambiguous how operational stopping is relevant in the semi arena, but it seems possible it could be. This is similar to a category 2 stop. }
106			1.2.4.3. Emergency stop	[5]
107	61	ç	Machinery must be fitted with one or more emergency stop devices to enable actual or impending danger to be averted. The following exceptions apply: — machinery in which an emergency stop device would not lessen the risk, either because it would not reduce the stopping time or because it would not enable the special measures required to deal with the risk to be taken, — portable hand-held and/or hand-guided machinery.	+] S2 requires an emergency off function (§12) with exception for low energy level equipment [1]
108			The device must:	
109	62	ç	— have clearly identifiable, clearly visible and quickly accessible control devices,	+] S2 requires EMO actuators be red on yellow (§12.3) and readily accessible (§12.5) [1]