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APPENDIX A: RISK ASSESSMENT - SUMMARY

A preliminary risk assessment was conducted to identify and analyse the risks involved with an automated / semi-automated system for the *eccentricity* test.

Guidelines provided in the Annex I of the Directive 2006/42/EC [6] were used to formulate the questions for the risk assessment.

The risk assessment was conducted in three parts:

- Part I - Operating environment related risk assessment: focused on identifying the possible risks perceived by the process owners according to their experience on the operating environment/ condition (section A.1).
- Part II - Engineering risk assessment: focused on identifying the possible risks due to constructional features of the machinery (section A.2).
- Part III - Post-construction risk evaluation: focused on assessing the improvement of the safety factor, and; identification of the residual risks that need to be addressed in future developments stages (section A.3).

A.1



Operating environment related risk assessment

The Part I of the risk assessment was conducted as a group survey, to identify and analyse the risks involved with an automated / semi-automated system for the *eccentricity* test.

The risk assessment survey schedule is as follows:

- Type of survey: Cross-sectional.
- Sample population: 7
- Population categories: Production Manager; Quality Control Manager; Quality Inspector; Production Line Supervisor; Team Leader; Operators (two).
- Medium: Brain storming/ discussion.

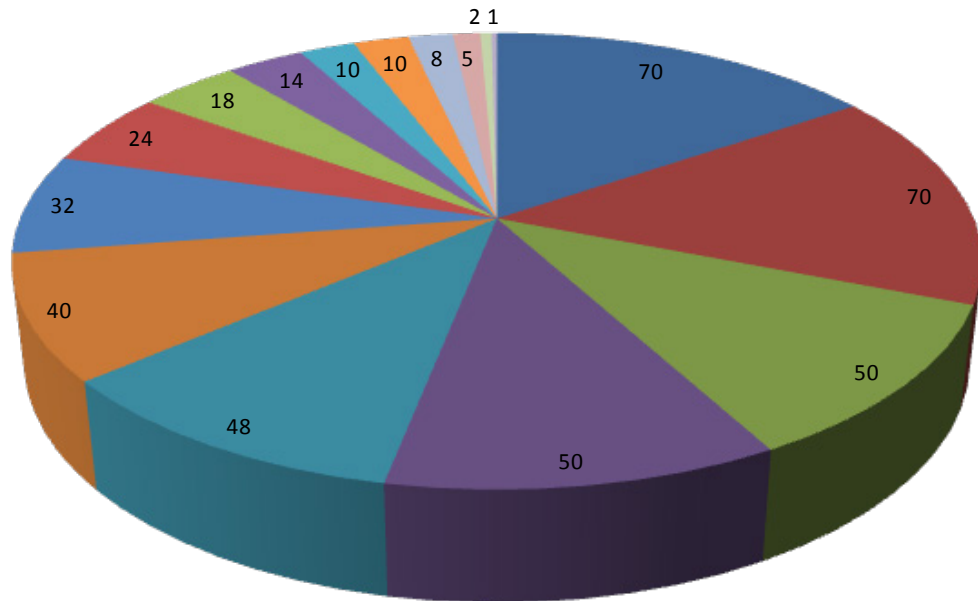
The results of the survey is summarised in Table A-1.

| Condition (Directive 2006/42/EC relevant clause is indicated within the brackets) | Risk | | |
|--|----------|-------------|-------------------|
| | severity | probability | cumulative factor |
| Principles of safe integration (Annex I - Clause 1.1.2) | | | |
| Usage by unskilled/ untrained operator. | 10 | 1 | 10 |
| Usage without PPE. | 10 | 1 | 10 |
| Materials and products (Annex I - Clause 1.1.3) | | | |
| Safety hazard due to material and by products of the machinery | 5 | 1 | 5 |
| Lighting (Annex I - Clause 1.1.4) | | | |
| Injury/ operational errors due to lighting | 2 | 1 | 2 |
| Handling of machinery (Annex I - Clause 1.1.5) | | | |
| Injury or damage due to internal transportation | 7 | 2 | 14 |
| Ergonomic considerations (Annex I - Clause 1.1.6) | | | |
| Operator inability to reach/ access | 1 | 1 | 1 |
| Operator position/ control panel layout (Annex I - Clause 1.1.7/ 1.2.2) | | | |
| Danger due to operator's location | 8 | 3 | 24 |
| Control system considerations (Annex I - Clause 1.2.3) | | | |
| Danger due to accidental start-up | 8 | 5 | 40 |

Table A-1 Operating environmental risk assessment (continued to next page)

| Condition (Directive 2006/42/EC relevant clause is indicated within the brackets) | Risk | | |
|--|----------|-------------|-------------------|
| | severity | probability | cumulative factor |
| Failure of power supply (Annex I - Clause 1.2.6) | | | |
| Hazard due to power interruptions, fluctuations and re-connection. | 8 | 6 | 48 |
| Risk of loss of stability (Annex I - Clause 1.3.1) | | | |
| Safety hazard due to falling, overturning and uncontrolled movement. | 9 | 2 | 18 |
| Risk due to falling or ejected objects (Annex I - Clause 1.3.3) | | | |
| Safety hazard due to drop of the <i>test weight</i> | 10 | 5 | 50 |
| Handling of machinery (Annex I - Clause 1.3.7) | | | |
| Safety hazard due to movement of the <i>test weight</i> | 10 | 7 | 70 |
| Safety hazard due to movement of the <i>actuators</i> | 10 | 7 | 70 |
| Operator position/ control panel layout (Annex I - Clause 1.5.1) | | | |
| Danger due to electrical supply | 8 | 4 | 32 |
| Control system considerations (Annex I - Clause 1.5.6) | | | |
| Danger due to fire | 8 | 1 | 8 |
| Maintenance considerations (Annex I - Clause 1.6) | | | |
| Hazardous conditions during maintenance | 10 | 5 | 50 |

Table A-1 Operating environmental risk assessment



Legend:

- Safety hazard due to movement of the test weight
- Safety hazard due to movement of the actuators
- Safety hazard due to drop of the test weight
- Hazardous conditions during maintenance
- Hazard due to power interruptions, fluctuations and reconnection.
- Danger due to accidental start-up
- Danger due to electrical supply
- Danger due to operator's location
- Safety hazard due to falling, overturning and uncontrolled movement.
- Injury or damage due to internal transportation
- Usage by unskilled/ untrained operator.
- Usage without PPE.
- Danger due to fire
- Safety hazard due to material and by products of the machinery
- Injury/ operational errors due to lighting
- Operator inability to reach/ access

Original graphic is in colour.

Figure A.1 Operating environment related risk perceptions

A.2 Machinery related technical risk assessment

The Part II of the risk assessment was conducted by the author, to identify and analyse the risks associated with the conceptual design for the *eccentricity* test.

Probability factor was determined with the inputs from the Part I of the risk assessment.

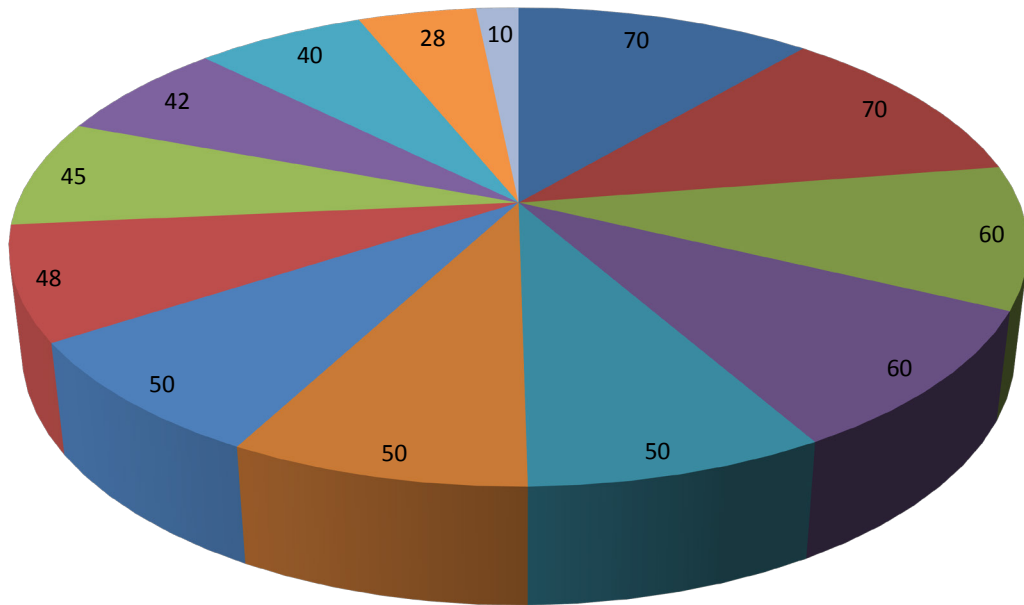
The results of the risk assessment is summarised in Table A-2.

| Condition (Directive 2006/42/EC relevant clause is indicated within the brackets) | Risk | | |
|--|----------|-------------|-------------------|
| | severity | probability | cumulative factor |
| Principles of safe integration (Annex I - Clause 1.1.2) Risk of loss of stability (Annex I - Clause 1.3.1) Risk of break-up during operation (Annex I - Clause 1.3.2) Risk due to falling or ejected objects (Annex I - Clause 1.3.3) | | | |
| Hazard due to fault in general structural integrity | | 1 | 10 |
| Danger due to failure of <i>test weight</i> lifting linkage/ drop of the <i>test weight</i> . | 10 | 7 | 70 |
| Design to facilitate handling (Annex I - Clause 1.1.5) | | | |
| Hazard during the internal movement of the machinery. | 7 | 4 | 28 |
| Ergonomics (Annex I - Clause 1.1.6) | | | |
| Excessive rate of movement (of weight). | 7 | 6 | 42 |
| Safety and reliability of the control system (Annex I - Clause 1.2.1) | | | |
| Unexpected start-up of the machine. | 9 | 5 | 45 |

Table A-2 Machinery related risk assessment (continued to next page)

| Condition (Directive 2006/42/EC relevant clause is indicated within the brackets) | Risk | | |
|--|----------|-------------|-------------------|
| | severity | probability | cumulative factor |
| Safety and reliability of the control system (Annex I - Clause 1.2.1) | | | |
| Risk related to moving parts (Annex I - Clause 1.3.7) | | | |
| Hazard due to movement of the <i>test weight</i> | 10 | 7 | 70 |
| Hazard due to movement of the <i>actuators</i> | 10 | 5 | 50 |
| Hazard due to movement of the <i>sliding table</i> | 10 | 6 | 60 |
| Hazard due to movement of the <i>test weigh carriage</i> | 10 | 6 | 60 |
| Control devices (Annex I - Clause 1.2.2) | | | |
| Hazard due to no status indication | 8 | 6 | 48 |
| Stopping (Annex I - Clause 1.2.4) | | | |
| Danger due to re-start, after an emergency stop | 10 | 5 | 50 |
| Risk due to surfaces, edges or angles (Annex I - Clause 1.3.4) | | | |
| Physical injury due to sharp edges and components | 8 | 5 | 40 |
| Machine maintenance (Annex I - Clause 1.6.1) | | | |
| Isolation of energy sources (Annex I - Clause 1.6.3) | | | |
| Hazardous conditions during maintenance | 10 | 6 | 60 |

Table A-2 Machinery related risk assessment



Legend:

- Danger due to failure of test weight lifting linkage/ drop of the test weight.
- Hazard due to movement of the test weight
- Hazard due to movement of the actuators
- Hazardous conditions during maintenance
- Hazard due to movement of the sliding table
- Hazard due to movement of the test weigh carriage
- Danger due to re-start, after emergency stop
- Hazard due to no status indication
- Unexpected start-up of the machine
- Excessive rate of movement (Test weight)
- Physical injury due to sharp edges and components
- Safety hazard during the internal movement of the machinery.
- Hazard due fault in general structural integrity.

Original graphic is in colour.

Figure A.2 Design concept based risk factor

A.3 Post-construction risk evaluation

The Part III of the risk assessment was conducted by the author, after the construction of the machinery in order to assess the level of risk mitigation and to identify residual risks which needs to be addressed during future development.

Probability factor was determined with the observation of the machine operation.

The results of the risk evaluation is summarised in Table A-3


| Condition (Directive 2006/42/EC relevant clause is indicated within the brackets) | Risk | | |
|--|----------|-------------|-------------------|
| | severity | probability | cumulative factor |
| Principles of safe integration (Annex I - Clause 1.1.2) Risk of loss of stability (Annex I - Clause 1.3.1) Risk of break-up during operation (Annex I - Clause 1.3.2) Risk due to falling or ejected objects (Annex I - Clause 1.3.3) | | | |
| Hazard due to  fault in general structural integrity | 10 | 1 | 10 |
| Danger due to failure of <i>test weight</i> lifting linkage/ drop of the <i>test weight</i> . | 10 | 1 | 10 |
| Design to facilitate handling (Annex I - Clause 1.1.5) | | | |
| Hazard during the internal movement of the machinery. | 7 | 1 | 7 |
| Ergonomics (Annex I - Clause 1.1.6) | | | |
| Excessive rate of movement (of weight). | 7 | 1 | 7 |
| Safety and reliability of the control system (Annex I - Clause 1.2.1) | | | |
| Unexpected start-up of the machine. | 9 | 1 | 9 |

Table A-3 Post-construction risk evaluation (continued to next page)

| Condition (Directive 2006/42/EC relevant clause is indicated within the brackets) | Risk | | |
|--|----------|-------------|-------------------|
| | severity | probability | cumulative factor |
| Safety and reliability of the control system (Annex I - Clause 1.2.1) | | | |
| Risk related to moving parts (Annex I - Clause 1.3.7) | | | |
| Hazard due to movement of the <i>test weight</i> | 10 | 1 | 10 |
| Hazard due to movement of the <i>actuators</i> | 10 | 1 | 10 |
| Hazard due to movement of the <i>sliding table</i> | 10 | 2 | 20 |
| Hazard due to movement of the <i>test weigh carriage</i> | 10 | 2 | 20 |
| Control devices (Annex I - Clause 1.2.2) | | | |
| Hazard due to no status indication | 0 | 0 | 0 |
| Stopping (Annex I - Clause 1.2.4) | | | |
| Danger due to re-start, after an emergency stop | 10 | 1 | 10 |
| Risk due to surfaces, edges or angles (Annex I - Clause 1.3.4) | | | |
| Physical injury due to sharp edges and components | 8 | 1 | 8 |
| Machine maintenance (Annex I - Clause 1.6.1) | | | |
| Isolation of energy sources (Annex I - Clause 1.6.3) | | | |
| Hazardous conditions during maintenance | 10 | 1 | 10 |

Table A-3 Post-construction risk evaluation

APPENDIX B: ERGONOMIC FACTOR APPROXIMATION

An ergonomic risk approximation was conducted to identify and analyse the risks involved with repetitive tasks present in the weighing instrument testing procedure.

Guidelines provided in the Annex C of the ISO 12338-3 [8] were used to formulate an relative approximation criteria for the risk assessment.

Due to the limited scope of the project,

- only the actions which are directly lying within the specific testing - *eccentricity* test - were considered.
- only the factors which can directly be estimated were considered during the calculations.

A test condition was defined for the approximation, based on the following assumptions:

Maximum capacity of the weighing instrument = 40 kg

Test weight value for the *eccentricity* test = 10 kg

Based on the above assumptions, the risk assessment approximation was conducted in three parts:



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- Part I - Relative ergonomic risk approximation for manual *eccentricity* test: focused on assessing the ergonomic risk factor involved with current *eccentricity* test conducted by the operator (section B.1).
- Part II - Relative ergonomic risk approximation for manual *pre-loading* test: focused on assessing the theoretical ergonomic risk factor involved with a full load test (section B.2).
- Part III - Relative ergonomic risk approximation for automated *eccentricity* test: focused on assessing the theoretical ergonomic risk factor involved with the automated *eccentricity* test (section B.3).

B.1 Ergonomic risk approximation - manual *eccentricity* test

The Part I of the risk approximation was conducted by the visual analysis of the movements and posture of an operator, during the conduct of the *eccentricity* test.

The results of the analysis are as follows:

$$\begin{aligned}
 \text{number of technical actions } (n_{ATA}), & & = & 21 \\
 \text{(15 load handling actions and 6 key strokes)} & & & \\
 \text{cycle time} & & = & 34 \text{ sec.} \\
 \text{Force multiplier } (F_M) & & = & 0.2 \\
 \text{Posture/ movement multiplier } (P_M) & & = & 0.7 \\
 \text{Repetitiveness multiplier } (R_{eM}) & & = & 0.7 \\
 \text{Relative Ergonomic Risk Index}_{\text{manual eccentricity test}} & & = & 21 \\
 & & & \frac{0.2 \times 0.7 \times 0.7}{21} \\
 & & = & 214.3 \quad \text{----- (1)}
 \end{aligned}$$

B.2 Ergonomic risk approximation - manual *maximum load* test



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The Part II of the risk approximation was conducted with a theoretical assumptions of the *maximum load* test.

The results of the analysis are as follows:

$$\begin{aligned}
 \text{number of technical actions } (n_{ATA}), & & = & 12 \\
 \text{(6 load handling actions and 6 key strokes)} & & & \\
 \text{cycle time} & & = & 45 \text{ sec.} \\
 \text{Force multiplier } (F_M) & & = & 0.65 \\
 \text{Posture/ movement multiplier } (P_M) & & = & 0.7 \\
 \text{Repetitiveness multiplier } (R_{eM}) & & = & 1.0 \\
 \text{Relative Ergonomic Risk Index}_{\text{manual max load test}} & & = & 12 \\
 & & & \frac{0.65 \times 0.7 \times 1.0}{12} \\
 & & = & 37.7 \quad \text{----- (2)}
 \end{aligned}$$

B.3 Ergonomic risk approximation - machine assisted *eccentricity* test

The Part III of the risk approximation was conducted with a theoretical assumptions of the machine assisted *eccentricity* test.

The results of the analysis are as follows:

$$\begin{aligned}
 \text{number of technical actions } (n_{ATA}), & & = & 6 \\
 \text{(0 load handling actions and 6 key strokes)} & & & \\
 \text{cycle time} & & = & 45 \text{ sec.} \\
 \text{Force multiplier } (F_M) & & = & 1 \\
 \text{Posture/ movement multiplier } (P_M) & & = & 1 \\
 \text{Repetitiveness multiplier } (R_{eM}) & & = & 1 \\
 \text{Relative Ergonomic Risk Index}_{\text{machine assisted eccentricity test}} & & = & 6 \\
 & & = & \frac{1 \times 1 \times 1}{6}
 \end{aligned}$$



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$$= 0.17 \quad \text{--- (3)}$$

B.4 Ergonomic gain factor analysis

With the results obtained in sections B1 to B3, following factors were determined .

$$\begin{aligned}
 \text{Ergonomic advantage of machine assisted test} & & = & \frac{214.3 - 0.17}{214.3} \quad \text{--- (1)-(3)} \\
 \text{over manual testing procedure (with the} & & & \\
 \text{assumption that any gain factor is inversely} & & & \text{--- (1)} \\
 \text{proportional to the associated risk)} & & = & 99.92\%
 \end{aligned}$$

$$\begin{aligned}
 \text{Ergonomic advantage of automating eccentricity} & & = & \frac{214.3}{214.3 + 37.7} \quad \text{--- (1)} \\
 \text{test over the full load test (with the assumption} & & & \text{--- (1)+(2)} \\
 \text{that any gain factor is inversely proportional to} & & & \\
 \text{the associated risk)} & & = & 85\%
 \end{aligned}$$