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Safety Control Systems for Machine Tools

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Introduction and Overview of the ANSI B11 Series</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Scope</td>
<td>15</td>
</tr>
<tr>
<td>2 References</td>
<td>15</td>
</tr>
<tr>
<td>3 Definitions</td>
<td>16</td>
</tr>
<tr>
<td>4 General Design Considerations for Mechanical, Fluid Power and Electrical Technologies</td>
<td>21</td>
</tr>
<tr>
<td>4.1 ANSI B11.TR6 Circuit Analysis Tables</td>
<td>21</td>
</tr>
<tr>
<td>4.2 Practical Use of TR6</td>
<td>22</td>
</tr>
<tr>
<td>4.2.1 General</td>
<td>22</td>
</tr>
<tr>
<td>4.2.2 Applying TR6 to a Sample Application</td>
<td>22</td>
</tr>
<tr>
<td>4.3 Reset Function of the Safety Circuit</td>
<td>24</td>
</tr>
<tr>
<td>4.4 Start Function</td>
<td>24</td>
</tr>
<tr>
<td>4.5 Testing &amp; Verification of the Safety Function</td>
<td>24</td>
</tr>
<tr>
<td>4.5.1 Category 2 Periodic Test</td>
<td>24</td>
</tr>
<tr>
<td>4.6 Fault Consideration</td>
<td>24</td>
</tr>
<tr>
<td>4.6.1 Fault Analysis</td>
<td>25</td>
</tr>
<tr>
<td>4.6.2 Fault Exclusion</td>
<td>25</td>
</tr>
<tr>
<td>4.7 Response Time</td>
<td>25</td>
</tr>
<tr>
<td>4.8 Mechanical Considerations (general)</td>
<td>25</td>
</tr>
<tr>
<td>4.9 Fluid Power (Pneumatics &amp; Hydraulics)</td>
<td>25</td>
</tr>
<tr>
<td>4.9.1 General Considerations</td>
<td>25</td>
</tr>
<tr>
<td>4.9.2 Basic Methodology for Safety Interfacing</td>
<td>25</td>
</tr>
<tr>
<td>4.9.3 Pressure Vessels and Accumulators</td>
<td>26</td>
</tr>
<tr>
<td>4.9.4 Stored Energy (Trapped Pressure)</td>
<td>26</td>
</tr>
<tr>
<td>4.9.5 Reapplication of Pressure</td>
<td>26</td>
</tr>
<tr>
<td>4.9.6 Hoses and Fittings</td>
<td>27</td>
</tr>
<tr>
<td>4.9.7 Fluid Power Valve Crossover Considerations</td>
<td>28</td>
</tr>
<tr>
<td>4.9.8 Single Channel Fluid Power Device</td>
<td>28</td>
</tr>
</tbody>
</table>
4.9.9 Single Channel Fluid Power Device with Monitoring .............................................. 28
4.9.10 Dual channel fluid power .................................................................................... 29
4.9.11 Dual Channel fluid power with Monitoring ......................................................... 29
4.9.12 Dual Channel Cross Monitoring Valve ................................................................. 29
4.9.13 Response Time Considerations ............................................................................ 29
4.9.14 Fault Reset Function ............................................................................................. 29
4.9.15 Position Fault ....................................................................................................... 29
4.9.16 Diminished Performance Fault ............................................................................ 29
4.9.17 Failure Modes to be Considered ........................................................................... 29
4.9.18 Non-Safety Devices ............................................................................................. 30

4.10 Pneumatics ........................................................................................................... 30
4.10.1 Basic Pneumatic System Considerations ............................................................... 30
4.10.2 Safety Shut-Off and Exhaust Valve .......................................................... 30
4.10.3 Filtration ............................................................................................................. 31
4.10.4 Regulator ............................................................................................................ 31
4.10.5 Lubrication ......................................................................................................... 31
4.10.6 Air Valve Mufflers ............................................................................................... 32
4.10.7 Environmental Influences .................................................................................... 32

4.11 Hydraulics ............................................................................................................. 32
4.11.1 Basic Hydraulic System Considerations ................................................................. 32
4.11.2 General ................................................................................................................ 32
4.11.3 Accumulators ....................................................................................................... 33
4.11.4 Fluid Management ............................................................................................... 33
4.11.5 Filtration ............................................................................................................. 34
4.11.6 Relief/Pressure Reducing Valve .......................................................................... 36

4.12 Electrical Interfacing Considerations (General) ...................................................... 36
4.12.1 Basic Methodology of Safety Interfacing .............................................................. 36
4.12.2 Protective Stop Circuits ....................................................................................... 36
4.12.2.1 Single-Channel Control ................................................................................... 36
4.12.2.2 Dual-Channel Control .................................................................................... 37
4.12.3 Safety Interface Module (SIM) ............................................................................ 37
4.12.4 Interfacing the Protective (Safety) Stop ............................................................... 38
4.12.4.1 Positive Logic ................................................................................................. 38
4.12.4.2 PES/PLC Interfacing ..................................................................................... 38
4.12.5 Electro-Mechanical Contact Considerations ...................................................... 39
4.12.6 Failure Modes ..................................................................................................... 39
4.12.7 Power Supplies .................................................................................................. 39
4.12.8 Environmental Influences ................................................................................... 39

4.13 Safety-Related Performance .................................................................................. 40

5 Input Devices (safeguarding devices and complementary equipment) .................... 42
5.1 Emergency Stop Devices

5.1.1 Lowest Risk Reduction (Category 1) ................................................................. 43
5.1.1.1 Single Channel E-Stop Using a Control Relay (Category 1) ......................... 43
5.1.2 Low / Intermediate Risk Reduction (Category 2) .............................................. 44
5.1.2.1 Dual Channel E-Stop Using Redundant Control Relays (Category 2) ......... 44
5.1.3 Intermediate / High Risk Reduction (Category 3) .............................................. 45
5.1.3.1 Dual Channel E-Stop Using FGR Relays and Cross Monitoring (Category 3) .............................................. 45
5.1.3.2 Multiple Dual Channel E-Stop with a Safety Relay Interface Module (Category 3) .............................................. 46
5.1.4 Highest risk reduction (Category 4) ................................................................. 47
5.1.4.1 Single Button Dual Channel E-Stop with a SIM (Category 4) ....................... 47
5.1.4.2 Single Button Dual Channel E-Stop* w/ Self Monitoring and a SIM (Category 4) .............................................. 48

5.2 Contact Interlocking

5.2.1 Description of Positive-Opening Interlock Switches ........................................... 49
5.2.2 Type 1 and Type 2 Considerations ...................................................................... 50
5.2.2.1 Failure Modes ................................................................................................ 50
5.2.2.1.1 Type 1 ........................................................................................................ 50
5.2.2.1.2 Type 2 ........................................................................................................ 50
5.2.2.2 Categories .................................................................................................... 50
5.2.3 General Considerations ...................................................................................... 50
5.2.3.1 Physical installation ...................................................................................... 50
5.2.3.2 Electrical interface ....................................................................................... 50
5.2.3.2.1 PES/PLC Control System Monitoring ...................................................... 51
5.2.3.2.2 Monitoring Series Connected Positive-Opening Interlocking Switches ............ 51
5.2.4 Basic Circuit (Category B) ................................................................................ 52
5.2.4.1 Basic Interlocked Guard Monitoring Circuit (Category B) ......................... 52
5.2.5 Lowest Risk Reduction (Category 1) .................................................................. 53
5.2.5.1 Interlocked Guard Monitoring Circuit – Single Channel (Category 1) ......... 53
5.2.6 Low / Intermediate Risk Reduction (Category 2) .............................................. 54
5.2.6.1 Series Connection of Interlocks to a SIM (Category 2) .............................. 54
5.2.6.2 Interlocked Guard Monitoring – Single Channel w/ a SIM and PES (Category 2) .............................................. 55
5.2.7 Intermediate / High Risk Reduction (Category 3) .............................................. 56
5.2.7.1 Single Interlock to a SIM (Category 3) ....................................................... 56
5.2.7.2 Series Connection of Interlocks to a SIM (Category 3) .............................. 57
5.2.8 Highest Risk Reduction (Category 4) ............................................................... 58
5.2.8.1 Interlocked Guard Monitoring – Dual Channel w/ Relay/Contactor and Reset Button (Category 4) .............. 58
5.2.8.2 Interlocked Guard Monitoring – Dual Channel w/ a SIM (Category 4) ........ 59

5.3 Guard Interlocking with Non-Contact Switches (without a Locking Function) ..... 60
5.3.1 Description of Non-Contact Interlock Switches ................................................. 60
5.3.2 General Considerations .................................................................................... 60
5.3.3 Inductive Switches ............................................................................................ 60
5.3.4 Optical Switches .............................................................................................. 60
5.3.5 Magnetic Switches ......................................................................................... 60
5.3.6 Transponder Switches ..................................................................................... 61
5.3.7 Basic Risk Reduction (Category B) .................................................................... 61
5.3.7.1 Non-Contact Interlocked Guard Monitoring using Standard Retro-Reflective Photo Sensor (Category B) .... 61
5.3.7.2 Non-Contact Interlocked Guard Monitoring using Standard Magnetic Sensor (Category B) .................. 62
5.3.8 Intermediate / High Risk Reduction (Category 3) .............................................. 63
5.3.8.1 Non-Contact Interlocked Guard Monitoring Circuit (Category 3) ......................................................... 63
5.3.8.2 Interlocked Guard Monitoring – Dual Channel with a SIM (Category 3) .................................................. 64
5.3.9 Highest Risk Reduction (Category 4) ........................................................................................................... 65
5.3.9.1 Interlocked Guard Monitoring – Dual Channel with a SIM (Category 4) .................................................. 65
5.3.9.2 Interlocked Guard Monitoring – Dual Channel with a SIM (Category 4) .................................................. 66
5.3.9.3 Interlocked Guard Monitoring – Dual Channel with a SIM (Category 4) .................................................. 67
5.3.9.4 Interlocked Guard Monitoring – Dual Channel with a SIM (Category 4) .................................................. 68

5.4 Guardlocking Interlocks ............................................................................................................................. 69
5.4.1 General Considerations ........................................................................................................................... 69
5.4.2 Low / Intermediate Risk Reduction (Category 2) ..................................................................................... 69
5.4.2.1 Power to Release, Inline Guardlocking Interlock (Category 2) ................................................................. 69
5.4.3 Intermediate / High Risk Reduction (Category 3) .................................................................................... 70
5.4.3.1 Power to Release, Dual Axis Guardlocking Interlock (Category 3) ............................................................. 70
5.4.4 Highest Risk Reduction (Category 4) ......................................................................................................... 71
5.4.4.1 Power to Release, Inline Guardlocking Interlock (Category 4) ................................................................. 71
5.4.4.2 Power to Release, Dual Axis Interlock Connected to a SIM (Category 4) .................................................. 72
5.4.4.3 Power to Release, Dual Axis Interlock Connected to a SIM (Category 4) .................................................. 73
5.4.4.4 Power to Release, Dual Axis Interlock Connected to a SIM (Category 4) .................................................. 74

5.5 Optical Presence Sensing Devices ............................................................................................................. 75
5.5.1 General Considerations ........................................................................................................................... 75
5.5.1.1 Light Curtains ........................................................................................................................................... 75
5.5.1.2 Single/Multiple Beam Devices (Point or Grid Devices) ........................................................................... 76
5.5.1.3 Scanners .................................................................................................................................................. 76
5.5.2 Lowest Risk Reduction (Category 1) ......................................................................................................... 77
5.5.2.1 IEC 61496 Type 2 Presence Sensing Device with Control Relay (Category 1) ............................................. 77
5.5.3 Low / Intermediate Risk Reduction (Category 2) .................................................................................... 78
5.5.3.1 IEC 61496 Type 2 Presence Sensing Device with Force-guided Relay (Category 2) ............................... 78
5.5.3.2 IEC 61496 Type 2 Presence Sensing Device with Force-guided Relay (Category 2) ............................... 79
5.5.4 Intermediate / High Risk Reduction (Category 3) ................................................................................... 80
5.5.4.1 IEC 61496 Type 3 Presence Sensing Device with Safety Interface Module (Category 3) ...................... 80
5.5.5 Highest Risk Reduction (Category 4) ....................................................................................................... 81
5.5.5.1 IEC 61496 Type 4 Presence Sensing Device with OSSD (Category 4) ....................................................... 81
5.5.5.2 IEC 61496 Type 4 Presence Sensing Device with Safety Interface Module (Category 4) ...................... 82

5.6 Mats / Edges ............................................................................................................................................... 83
5.6.1 General considerations ............................................................................................................................ 83
5.6.2 Low / Intermediate Risk Reduction (Category 2) .................................................................................... 83
5.6.2.1 Single Safety Mat Using a Safety Interface Module (Category 2) ............................................................ 83
5.6.3 Intermediate / High Risk Reduction (Category 3) ................................................................................... 84
5.6.3.1 Multiple Safety Mats Using a Safety Interface Module (Category 3) ...................................................... 84

5.7 Two-Hand Control ................................................................................................................................... 85
5.7.1 General Considerations ........................................................................................................................ 85
5.7.1.1 Minimum functional requirements for a Two-hand Control as required by NFPA 79 and IEC 60204-1 (Type III): ................................................................. 85
5.7.1.2 Physical Installation and Electrical Interface Considerations: ............................................................... 85
5.7.1.3 Two-Hand Control Safety Interface Modules ...................................................................................... 86
5.7.2 Lowest Risk Reduction Two Hand Control (Type IIIa Category 1) ........................................................ 86
5.7.2.1 Two Hand Control (Type IIIa Category 1) ......................................................................................... 86
5.7.2.2 Low / Intermediate Risk Reduction Two-Hand Control (Type IIIa Category 1) ................................. 87
5.7.3 Intermediate / High Risk Reduction Two-Hand Control (Type IIIb Category 3) ................................. 88
5.7.4.1 Two-Hand Control (Type IIIb Category 3) ......................................................... 89
5.7.5 Highest Risk Reduction Two-Hand Control (Type IIIc Category 4) ......................... 90

5.8 Zero (Stand Still) Speed Detection ........................................................................... 91
5.8.1 General Considerations ......................................................................................... 91
5.8.2 Lowest Risk Reduction (Category 1) ..................................................................... 92
5.8.2.1 Single Proximity Sensing (Category 1) ................................................................. 92
5.8.3 Intermediate / High Risk Reduction (Category 3) .................................................. 93
5.8.3.1 Dual Proximity Sensors to Timers and Force-guided Relay Monitoring (Category 3) .................................................................................................................. 93
5.8.3.2 Dual Proximity Sensors to Timers and Force-guided Relay Monitored by a SIM (Category 3) ........................................................................................................ 94
5.8.3.3 Dual Proximity Sensors to Dual Frequency Counters Monitored by a SIM (Category 3) ........................................................................................................ 95
5.8.3.4 Dual Proximity Sensors Plus Zero Speed or Stand Still SIM (Category 3 or 4) ............................................................................................................................... 96
5.8.3.5 Encoder Speed Monitoring (Category 3) .............................................................. 97
5.8.3.6 Motor Drive Back EMF Detection (Category 3 or 4) ........................................... 98

5.9 Enabling Devices ...................................................................................................... 99
5.9.1 General Considerations ......................................................................................... 99
5.9.2 Intermediate / High Risk Reduction (Category 3) .................................................. 101
5.9.3 Intermediate / High Risk Reduction (Category 3) .................................................. 102
5.9.3.1 Enabling device with overspeed (Category 3) ....................................................... 102
5.9.3.2 Enabling device with manual/auto switch (Category 3) ....................................... 103
5.9.3.3 Enabling device with manual mute enable (Category 3) ....................................... 104
5.9.4 Intermediate / High Risk Reduction (Category 4) .................................................. 105

6 Power Control Devices Interface (MPCE) .................................................................. 106
6.1 General Considerations .......................................................................................... 106

6.2 Relays and Contactors ............................................................................................ 107
6.2.1 Lowest Risk Reduction (Category 1) ..................................................................... 107
6.2.2 Low / Intermediate Risk Reduction (Category 2) .................................................. 108
6.2.3 Intermediate / High Risk Reduction (Category 3) .................................................. 109
6.2.4 Highest Risk Reduction (Category 4) ................................................................... 110

6.3 Variable Frequency Drives (VFD) .......................................................................... 111
6.3.1 Power Drive Systems - General Considerations .................................................. 111
6.3.2 Lowest Risk Reduction (Category 1) ..................................................................... 114
6.3.2.1 Single Channel Interlock Stop Category 0 of an AC Motor using Standard Rated AC Drive .................................................................................................................. 114
6.3.2.2 Single Channel Interlock Stop Category 1 of an AC Motor using Standard Rated AC Drive .................................................................................................................. 115
6.3.3 Intermediate / High Risk Reduction (Category 3) .................................................. 116
6.3.3.1 Stop Category 0 of an AC Motor using Safety Rated AC Drive (Category 3) ............................................................................................................................... 116
6.3.3.2 Stop Category 1 (Controlled) Stop of an AC Motor using Safety Rated AC Drive ............................................................................................................................... 117
6.3.4 Highest Risk Reduction (Category 4) ................................................................... 118
6.3.4.1 Dual Channel Interlock Stop Category 0 (Coast to Stop) of an AC Motor using Standard Rated AC Drive with Checking (Category 4) .................................................. 118

6.4 Pneumatic Systems ................................................................................................. 119
6.4.1 General Considerations ......................................................................................... 119
6.4.1.2 Pneumatic Component Selection Process ................................................................. 120
6.4.1.3 Air Preparation (Contamination Control) ................................................................. 122
6.4.1.4 Non-Lubricated (Preferred) ...................................................................................... 122
6.4.1.5 Lubricated (Not Recommended) ............................................................................... 122
6.4.1.6 Example Supply Circuit .......................................................................................... 123

6.4.2 Exhaust (Blocking, Dump) Valve .................................................................................. 124
6.4.2.1 Basic Risk Reduction (Category B) .......................................................................... 124
6.4.2.1.1 Spring Centered Three Position Open Center (Category B) ..................................... 124
6.4.2.1.2 Lowest Risk Reduction (Category 1) ..................................................................... 125
6.4.2.2 Low / Intermediate Risk Reduction (Category 2) ...................................................... 126
6.4.2.2.1 Single Monitored Directional Valve (Category 2) .................................................. 126
6.4.2.2.2 Spring Centered Three Position Open Center w/ Actuator Monitoring (Category 2) ... 127
6.4.2.3 Intermediate / High Risk Reduction (Category 3) ..................................................... 128
6.4.2.3.1 Series Dump Safety Valve with Spring Centered Three Position Open Center (Category 3) ... 128
6.4.2.3.2 Series Monitoring Circuit (Category 3) .................................................................. 129
6.4.2.4 Highest Risk Reduction Monitoring Circuit (Category 4) ........................................ 130
6.4.2.4.1 Dual Shift Time Monitored Valves (Category 4) ..................................................... 130
6.4.2.4.2 Safety Rated Valve – Manual Valve Reset (Category 4) ........................................... 131
6.4.2.4.3 Safety Rated Valve – Automatic Valve Reset (Category 4) ....................................... 132

6.4.3 Directional (Motion) Valve Selection ........................................................................... 133
6.4.3.1 Category B and 1 ...................................................................................................... 133
6.4.3.1.1 Single Solenoid – Two Position – Spring Offset (Category B and 1) ....................... 133
6.4.3.1.2 Double Solenoid – Two Position – Detented (Category B and 1) ............................. 134
6.4.3.1.3 3 Position – Spring Centered – Open Centered (Category B and 1) ....................... 135
6.4.3.1.4 3 Position – Spring Centered – Close or Blocked Center (Category B and 1) ......... 136
6.4.3.2 Low / Intermediate Risk Reduction (Category 2) ..................................................... 137
6.4.3.2.1 2 Position Spring Offset – Monitored Spool Position (Category 2) ....................... 137
6.4.3.3 Intermediate / High Risk Reduction (Category 3 and 4) ............................................ 138
6.4.3.3.1 Dual – 2 Position Spring Offset – Monitored Spool Position(s) (Category 3 and 4) ... 138

6.4.4 Pilot Operated Check Valves ....................................................................................... 139
6.4.4.1 Basic / Lowest Risk Reduction (Category B and 1) .................................................. 139
6.4.4.1.1 Pilot Operated Check Valve (Category B and 1) ...................................................... 139
6.4.4.2 Low / Intermediate Risk Reduction (Category 2) ..................................................... 140
6.4.4.2.1 Pilot Operated Check Valve (Category 2) .............................................................. 140
6.4.4.3 Intermediate / High Risk Reduction (Category 3) .................................................... 141
6.4.4.3.1 Pilot Operated Check (Category 3) ...................................................................... 141
6.4.4.3.2 Pilot Operated Check with Spring Centered Three Position Open Center (Category 3) ... 142
6.4.4.4 Highest Risk Reduction (Category 4) ...................................................................... 143
6.4.4.4.1 Pilot Operated Check (Category 4) ...................................................................... 143

6.4.5 Rod Locks and Brakes ................................................................................................. 144

6.4.6 Flow Controls ............................................................................................................ 145
6.4.6.1 Meter-IN – Controls the Fluid Flow Going into the Cylinder .................................... 146
6.4.6.2 Meter-OUT – Controls the Fluid Flow Coming Out of the Cylinder ....................... 147
6.4.6.3 Meter-IN Flow Control Example ............................................................................. 148
6.4.6.4 Meter-OUT Flow Control Example ....................................................................... 149

6.4.7 Pneumatic Air Logic Control Circuits ....................................................................... 150
6.4.7.1 E-Stop ..................................................................................................................... 150
6.4.7.1.1 Lowest Risk Reduction (Category 1) ..................................................................... 150
6.4.7.2 Two hand control .................................................................................................. 151
6.4.7.2.1 Lowest Risk Reduction (Category 1) ..................................................................... 151
6.4.7.2.2 Highest Risk Reduction (Category 4) ................................................................. 152
6.4.7.3 Velocity Fuse ......................................................................................................... 153

6.5 Hydraulic Systems ....................................................................................................... 154
6.5.1 General considerations ............................................................................................... 154
6.5.1.1 Hydraulic Component Selection Process ............................................................... 155
6.5.1.2 Fluid Preparation (Contamination Control) ........................................................... 157
6.5.2 Dump (Blocking) Valve .......................................................................................................... 157
  6.5.2.1 Basic Risk Reduction (Category B) .................................................................................... 157
  6.5.2.1.1 Spring Centered Three Position Exhaust Center (Category B) ......................................... 157
  6.5.2.1.2 Spring Centered Three Position Exhaust Center w/ Actuator monitoring (Category 1) .... 158
  6.5.2.2 Low / Intermediate Risk Reduction (Category 2) ................................................................ 159
  6.5.2.2.1 Monitored Two Way Valve (Category 2) ........................................................................ 159
  6.5.2.2.2 Spring Centered Three Position Exhaust Center w/ Control Circuit Functional Monitoring (Category 2) ........................................................................................................... 159
  6.5.2.3 Intermediate / High Risk Reduction (Category 3) .................................................................. 161
  6.5.2.3.1 Series Monitored Blocking Valve with Circuit Spring Centered Three Position Exhaust Center (Category 3) ................................................................. 161
  6.5.2.4 Highest Risk Reduction (Category 4) .................................................................................. 162
  6.5.2.4.1 Series Monitoring Circuit (Category 4) ............................................................................. 162

6.5.3 Directional (Motion) Valve Selection ................................................................................... 163
  6.5.3.1 Basic / Lowest Risk Reduction (Category B and 1) ................................................................. 163
  6.5.3.1.1 2 Position - Spring Offset (Category B and 1) ................................................................. 163
  6.5.3.1.2 2 Position – Detented (Category B and 1) ........................................................................ 163
  6.5.3.1.3 3 Position – Spring Centered – Open (Float) Centered (Category B and 1) ....................... 164
  6.5.3.1.4 3 Position – Spring Centered – Closed or Blocked Center (Category B and 1) ................. 165
  6.5.3.2 Low / Intermediate Risk Reduction (Category 2) .................................................................. 166
  6.5.3.2.1 2 Position Spring Offset – Monitored Spool Position (Category 2) .................................. 167

6.5.4 Pilot Operated Check Valves .................................................................................................. 168
  6.5.4.1 Basic / Lowest Risk Reduction (Category B and 1) ................................................................. 168
  6.5.4.1.1 Pilot Operated Check – Example 1 of 2 (Category B and 1) ............................................. 168
  6.5.4.2 Pilot Operated Check – Basic / Lowest Risk Reduction; Example 2 of 2 (Category B and 1) . 169
  6.5.4.3 Low / Intermediate Risk Reduction (Category 2) .................................................................. 170
  6.5.4.3.1 Pilot Operated Check – Low / Intermediate Risk Reduction (Category 2) ...................... 170
  6.5.4.4 Pilot Operated Check – Intermediate / High Risk Reduction (Category 3) ......................... 171
  6.5.4.4.1 Intermediate / High Risk Reduction (Category 3) ........................................................... 171
  6.5.4.4.2 Monitored Pilot Operated Check with Spring Centered Three Position Exhaust Center (Category 3) ........................................................................................................... 172
  6.5.4.5 Highest Risk Reduction (Category 4) .................................................................................. 173
  6.5.4.5.1 Pilot Operated Check (Category 4) .................................................................................. 173

6.5.5 Counter Balance Valve ........................................................................................................ 174

6.5.6 Rod Locks and Brakes ........................................................................................................ 175

6.5.7 Flow Controls ..................................................................................................................... 176

6.5.8 Velocity Fuse ...................................................................................................................... 177

ANNEX A – Analysis of circuit considerations .............................................................................. 178

ANNEX L – Safety-Related Performance Levels ........................................................................ 183

ANNEX M - External Device Monitoring by the Safety-Related Function ................................... 188

ANNEX S – Symbols .................................................................................................................... 190

ANNEX V – Valves ....................................................................................................................... 195
Foreword

Recognizing the need for a guidance document on the subject matter, the ANSI B11 Accredited Standards Committee for Machine Safety formed a subcommittee consisting of professionals that are involved in manufacturing, safety, design, integration and controls to develop a technical report giving guidance in understanding and implementing safety control functions when applied to machines covered by the ANSI B11 series of machine safety standards.

The intent is to illustrate safety control circuit design concepts to help mitigate the risks identified by a risk assessment. The following example circuits, explanations, and minimum fault exclusions are for educational purposes and do not contain complete information on electrical, fluid power, and mechanical design requirements. Substitutions, additions, or changes to the circuits, components, safety modules, or safeguarding devices should be thoroughly researched and examined as to the extent of the impact on the integrity, reliability, and the level of performance of the safety functions. The designer should refer to relevant standards, regulations, and codes to address all installation and safety requirements.

The B11.TR6 Subcommittee began with current industrial circuit applications and provided examples of common solutions in use at the time of creating this document; these are not intended to limit innovation or the advancement of technology.

Industry users expressed the desire that example circuits be depicted in a NEMA format. To provide clarity and enhance understanding the committee created symbols for safety components that previously did not exist. These new symbols distinguish safety rated components from their non-safety rated counterparts such as emergency stops and forced guided relays. This document also identifies the relationship between ANSI B11.TR3 risk level (now included within ANSI B11.0) and that of the Categories of ISO 13489.

The Circuit Analysis Table for each circuit diagram provides important guidance information on the performance of safety-related functions, identification and analysis of failures, and safety-related performance levels for categories B through 4 as referenced in section 4.13.

Publication of this Registered Technical Report has been approved by the Accredited Standards Developer. This document is registered as a Technical Report series of publications according to the procedures for the Registration of Technical Reports with ANSI. This document is not an American National Standard and the material contained herein is not normative in nature. Comments on the content of this document should be sent to the Accredited Standards Developer.
Summary of ISO 13849-1 Categories:

Category B Circuit
- Is designed in accordance with relevant standards.
- Can withstand the expected influences.
- The occurrence of a fault can lead to loss of the safety function.

Category 1 Circuit (includes Category B):
- Is designed in accordance with relevant standards.
- Well-tried components and well-tried safety principles are used.
- The occurrence of a fault can lead to loss of the safety function.

Category 2 Circuit (includes Category B and well tried safety principles):
- Safety function shall be checked at suitable intervals by the machine control system.
- The occurrence of a (single) fault can lead to loss of the safety function between the checks.
- The loss of safety function is detected by the check (automatic or manual).

NOTE: A suitable frequency of checking (periodic test interval) will be dependent on
the reliability of components and the probability of failure. A tolerable probability of
failure will be determined in the risk assessment.

Category 3 Circuit (includes Category B and well tried safety principles):
- A single fault does not lead to loss of the safety function, and whenever reasonably practicable the
  single fault is detected (i.e. some but not all faults will be detected).
- Accumulation of undetected faults can lead to loss of the safety function.

Category 4 Circuit (includes Category B and well tried safety principles):
- A single fault does not lead to loss of the safety function, and the single fault is detected at or before
  the next demand upon the safety function. If this is not possible, then an accumulation of faults
  shall not lead to loss of the safety function.
- The faults will be detected in time to prevent loss of the safety function.

Guide for using this document

Process steps needed to use this document:
- Conduct a risk assessment
- Determine the risk reduction required (e.g., Category, performance level, control reliability, SIL, etc.)
- Define the safety function (what needs to happen)
- Implement the safety function by selecting component(s) and designing the control circuit

Steps in the application of this document:
- Determine failure modes to be managed
- Select the safeguarding device and/or complementary equipment,
- Using the Table of Contents Clause 5 (Input devices (safeguarding devices complementary
  equipment)) subclause listings, choose the appropriate input device implementation
- Using the Table of Contents Clause 6 (Power controls and actuators) subclause listings, choose the
  appropriate output device implementation
- Evaluate the effectiveness of that system for the desired results

Publication of this Technical Report has been approved by the Accredited Standards Developer – B11
Standards, Inc. This document is registered as a Technical Report by ANSI according to the ANSI
Procedures for the Registration of Technical Reports. This document is not an American National Standard
and the material contained herein is not normative in nature.

While standards generally use the term shall to denote a requirement and the term should to denote a
recommendation, this document is written using those terms consistent with how they are used in a standard
(normative requirement vs. an informative recommendation). Nonetheless, nothing in this document is
normative; Technical Reports are considered “informative” or “guidance” documents.

This Technical Report was prepared by the B11.TR6 Subcommittee, processed by the B11 Accredited
Standards Committee (ASC) on Safety Standards for Machines, and submitted by its Secretariat for ANSI
registration.
At the time this Technical Report was processed and registered, the ANSI B11 Accredited Standards Committee was composed of the following member organizations:

John W. Russell, PE, CSP, Chairman
Gary D. Kopps, Vice-Chairman
David A. Felinski, Secretary

**Organizations Represented**

- Aerospace Industries Association of America
- Aluminum Extruders Council
- American Society of Safety Engineers
- Association For Manufacturing Technology
- Automotive Industry Action Group
- The Boeing Company
- Canadian Standards Association
- Deere & Co.
- Komatsu America Industries
- General Motors Corporation
- Metal Building Manufacturers Association
- Metal Powder Industries Federation
- National Institute for Occupational Safety & Health
- Occupational Safety & Health Administration
- Omron Scientific Technologies Incorporated
- Packaging Machinery Manufacturers Institute
- Pilz Automation Safety, LP
- Precision Metalforming Association
- Presence Sensing Device Manufacturers Association
- Property Casualty Insurers
- Robotic Industries Association
- Rockwell Automation
- Sheet Metal & Air Conditioning Contractors National Assn.
- System Safety Society
- Toyota Motor Manufacturing North America
- International United Automobile Workers

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The B11.TR6 Subcommittee on safety control systems which developed this TR had the following members:

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- Chris Bacon - Nexteer
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- Mike Carlson - Banner Engineering
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- Frank Webster - Omron STI
- Mark Witherspoon - Euchner
- Dave Felinski - B11 Standards, Inc.
- Cindy Haas - AMT
Introduction and Overview of the ANSI B11 Series

The primary purpose of every machine tool is to process parts. This is accomplished by the machine imparting process energy onto the workpiece. Inadvertent interference with, or accidental misdirection of the released energy during production, maintenance, commissioning and de-commissioning may result in injury.

The primary purpose of the ANSI B11 series of machine tool safety standards and technical reports is to devise and propose ways to minimize risks of the potential hazards. This can be accomplished either by an appropriate machine design or by restricting personnel or other individuals' access to hazard zones, and by devising work procedures to minimize personnel exposure to hazardous situations. This is the essence of the ANSI B11 series of safety standards and technical reports.

A general overview of the interaction between a typical ANSI B11 American National Standard and other standards / technical reports follows. Figure 1 provides a graphical overview of this scheme and in particular the responsibilities of and requirements for the manufacturer and user, including the user personnel. Numbers in parentheses denote the particular clause or subclause in the typical B11 standard.

The responsibility for the alleviation of these risks is divided between the equipment manufacturer, the user and the user's operating personnel, as follows (numbers in parentheses refer to the clause numbers in these "base" B11 standards which address that responsibility).

Notes for Figure 1:

1) Scope – Provides the boundaries or limits of the standard (i.e., what is/is not included).
2) Normative references – Other standards which in whole or in part provide additional requirements when referenced in the normative text (i.e., left-hand column of clauses 4 – 9) of this standard.
3) Definitions – Terms used in this standard, together with their definitions (terms used in the same context as are generally understood and commonly used in everyday English are not defined).
4) Responsibility – The general responsibilities of the manufacturer (builder), user, and the user personnel are listed in clause 4 together with which of the remaining clauses they have primary responsibility.
5) Hazard control (task/hazard identification & risk assessment/risk reduction) – Although clause 5 is intended to require a shared responsibility between manufacturer and user, the requirements of this clause may fall primarily on either entity (see ANSI B11.0 for further explanation of hazard/task identification and risk assessment/risk reduction).
6) Design and construction – It is assumed that the manufacturer will be responsible for the requirements of clause 6 with the understanding that the user may add to or modify these requirements through the purchase agreement.
7) Installation, testing and start-up – Although the requirements of clause 7 are predominantly the responsibility of the user, the manufacturer will normally provide assistance either directly (providing personnel) or indirectly (instruction materials).
8) Safeguarding – This is normally a shared responsibility but often, either the manufacturer or the user will provide and/or meet the requirements of clause 8.
9) Operation and maintenance – The user is normally responsible for the requirements of clause 9 with possible assistance from the manufacturer for training.
Figure 1 – Typical layout of B11 base standards showing the various responsibilities

The gray shading represents ANSI B11.0. A solid line between a block showing reference standard(s) and a block showing a normative clause denotes part of the requirements. A dashed line denotes an informative reference. See clause 2 for further information on standards referenced in Figure 1.
ANSI B11.TR6
Safety Control Systems for Machines

1 Scope
This Technical Report provides guidance in understanding and implementing safety-related control functions (functional safety) as they relate to electrical, electronic, mechanical, pneumatic, hydraulic components and systems for machines covered by the B11 series of safety standards.

NOTE 1: The terminology used in this document may not be used consistently throughout the industry, but this document does represent concepts which are important when using and designing safety-related control systems.

NOTE 2: Usage of [machine] in the following text means any of the specific machines/machine tools covered by the ANSI B11 ‘base’ series of safety standards.

NOTE 3: This document is not intended to address programmable electronic systems/programmable electronic devices (PES/PED). See B11.TR4.

2 References
ANSI B11.0 – 2010 Safety of Machinery; General Requirements and Risk Assessment
ANSI B11.19 – 2010 Performance Criteria for Safeguarding
ANSI / NFPA 79 – 2007 Electrical Standard for Industrial Machinery
ANSI B11.TR3 – 2000 Risk Assessment and Risk Reduction – A guide to estimate, evaluate and reduce risks associated with machine tools
ANSI / RIA R15.06 – 1999 Industrial Robots and Robot Systems – Safety Requirements
CSA Z434-03 – Industrial Robots and Robot Systems – General Safety Requirements
CSA Z432-04 – Safeguarding of Machinery
ISO 12100 – 2010 Safety of machinery—General principles for design—Risk assessment and risk reduction
ISO 13849-1:1999 Safety of machinery – Safety-related part of control systems – Part 1: General Principles for Design
IEC 60204-1 – Safety of electrical equipment of machinery used for general electrical safety aspects
IEC 61508 Parts 1-7 – Functional safety of E/E/PE safety-related systems used for the design of complex subsystems
IEC 62061 - Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems
ISO 1219-1 2006- Fluid power systems and components -- Graphic symbols and circuit diagrams -- Part 1: Graphic symbols for conventional use and data-processing applications
ISO 1219-2 1995 - Fluid power systems and components -- Graphic symbols and circuit diagrams -- Part 2: Circuit diagrams
IEC 617-7 - Graphical symbols for diagrams
ISO 1436 - Rubber hoses and hose assemblies -- Wire-braid-reinforced hydraulic types for oil-based or water-based fluids -- Specification
ISO 8573 2001 - Compressed air -- Part 1: Contaminants and purity classes
ISO 4414 1998 - Pneumatic fluid power -- General rules relating to systems
IEC 60947-5-8:2006 – Low voltage switchgear and control gear-- Part 5-8: Control circuit devices and switching elements – Three-position enabling switches
NFPA T2.25.1 R2-2005 - Pneumatic fluid power - Systems standard for industrial machinery - Supplement to ISO 4414:1998 - Pneumatic fluid power - General rules relating to systems (third edition)
EN 853 - Rubber hoses and hose assemblies. Wire braid reinforced hydraulic type. Specification
SAE 100Rx - Test and Test Procedures for SAE 100R Series Hydraulic Hose and Hose Assemblies