

## **Annex 1**

Fault Trees for Tunnel  
Blasting

**2MIC Higher vibration due to 2 MIC detonated at the same time**

2MIC
Higher vibration due to 2 MIC detonated at the same time
2.90E-05

OR

2.1-WD	2.2-W-DETON	2.3-W-DETON-SC	2.4-W-SC	MD-DETON	MD-SC	OL-EMULSION
Wrong design in time delay of one detonator	1 detonator wrongly put into one sector which contains the same time delay detonator	One detonator of a sector connected wrongly to a surface connector of another sector	Use of a wrong surface connector	Manufacturer defect of one detonator such that time delay corresponds to another one	Manufacturer defect of one surface connector such that time delay corresponds to another one	Overcharge of emulsion more than required
1.26E-09	1.68E-14	1.33E-09	4.80E-09	2.40E-05	6.00E-07	4.39E-06
						OL-C-EMULSION
						Too much cartridged emulsion loaded into holes
						4.39E-06

**3MIC Higher vibration due to 3 MIC detonated at the same time**

3MIC
Higher vibration due to 3 MIC detonated at the same time
2.46E-07

OR

3.1-WD	3.2-W-DETON	3.3-W-DETON-SC	3.4-W-SC	3MIC-P-AD-DETON	3MIC-P-AD-SC	3MIC-ER-COMB
Wrong design in time delay of two detonators	Two detonators wrongly put into one sector which contains the same time delay detonator	Two detonators of other sectors connected wrongly to a surface connector of another sector	Use of two wrong surface connector	Incorrect time default of 2 detonators due to manufacturer defect	Surface connector fails to provide necessary delay due to manufacturer defect	3 MIC detonated at the same time (Due to combination of two types of errors)
1.26E-11	1.68E-16	1.33E-11	4.80E-11	2.40E-07	6.00E-09	2.45E-10

**4MIC**

**Higher than expected vibration due to 4 MIC detonated at the same time**

4MIC
Higher than expected vibration due to 4 MIC detonated at the same time
2.57E-09

OR

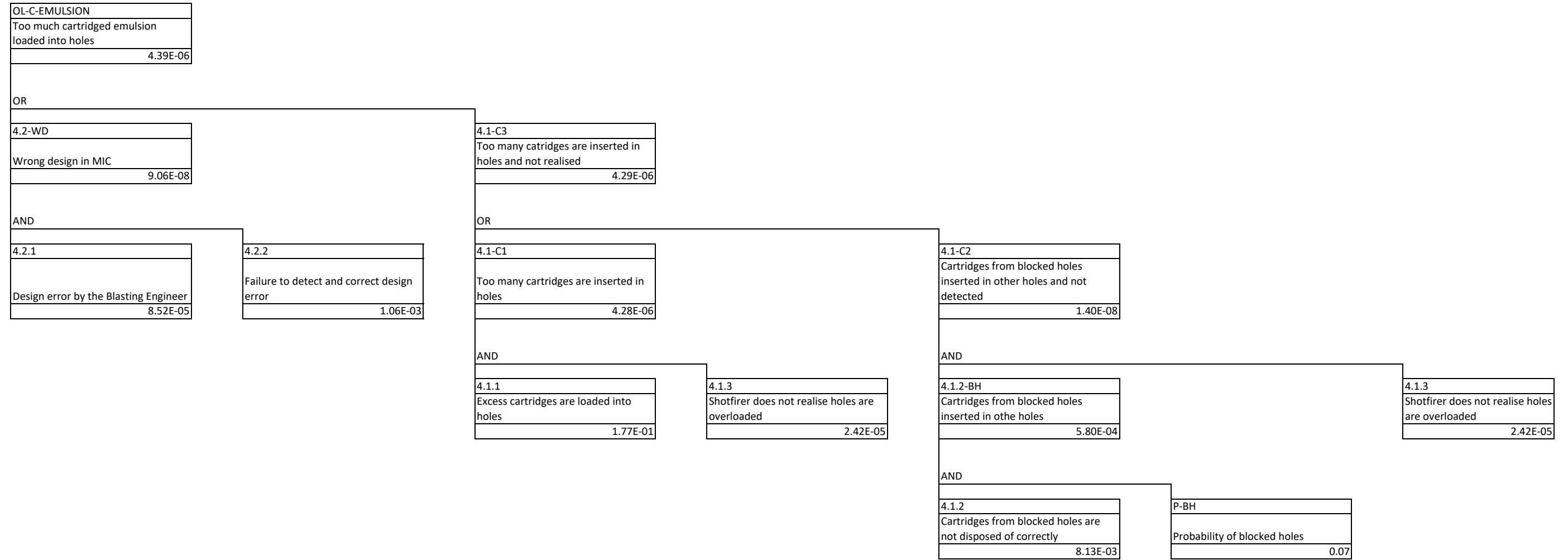
4MIC-COMB-1
4 MIC detonated (due to same error occurred three times) at the same time
2.46E-09

4MIC-COMB-2
4 MIC detonated (due to same error occurred two times and one other error) at the same time
1.37E-12

4MIC-COMB-3
4 MIC detonated (due to three different errors occur at the same time) at the same time
3.84E-16

4MIC-COMB-4
4 MIC detonated (due to charge overload and one other error occur at the same time) at the same time
1.08E-10

**OL-C-EMULSION**      **Too much cartridge emulsion loaded into holes**



**4.1-WD Wrong design in time delay of three detonators**

4.1-WD
Wrong design in time delay of three detonators
1.26E-13

AND

3.1-WD
Wrong design in time delay of two detonators
1.26E-11

P-AD-DETON
Wrong design in time delay of additional detonator
0.01

AND

2.1-WD
Wrong design in time delay of one detonator
1.26E-09

P-AD-DETON
Wrong design in time delay of additional detonator
0.01

**4.2-W-DETON**

**Three detonator wrongly put into one sector which contains the same time delay detonator**

4.2-W-DETON
Three detonator wrongly put into one sector which contains the same time delay detonator
1.68E-18

AND

3.2-W-DETON
Two detonators wrongly put into one sector which contains the same time delay detonator
1.68E-16

P-AD-DETON
Additional detonator wrongly put into one sector which contains the same time delay detonator
0.01

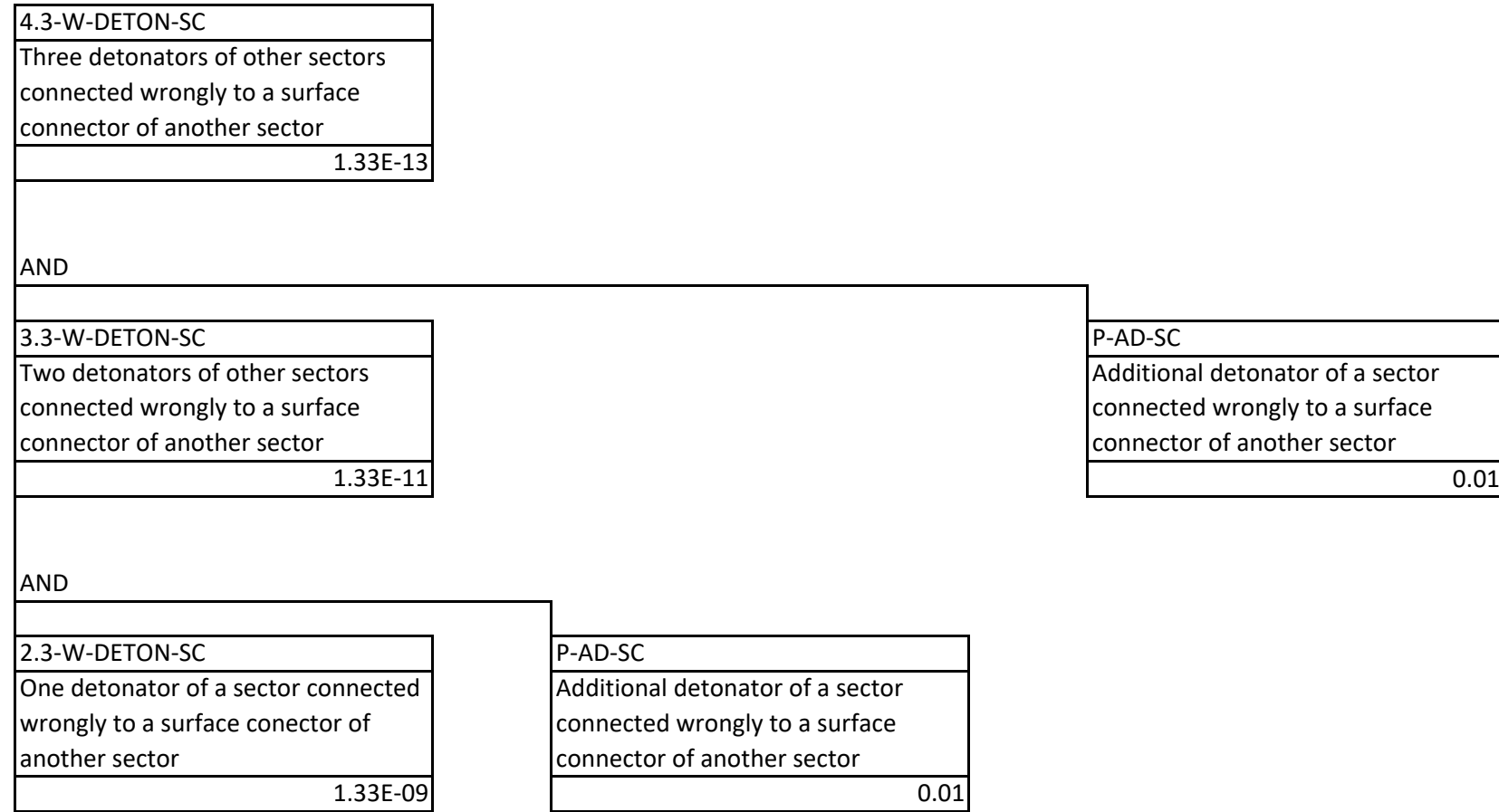
AND

2.2-W-DETON
One detonator wrongly put into one sector which contains the same time delay detonator
1.68E-14

P-AD-DETON
Additional detonator wrongly put into one sector which contains the same time delay detonator
0.01

**4.3-W-DETON-SC**

**Two detonators of othe sectors connected wrongly to a surface connector of another sector**





**4.4-W-SC**

**Use of three wrong surface connector**

4.4-W-SC
Use of three wrong surface connector
4.80E-13

AND

3.4-W-SC
Use of two wrong surface connector
4.80E-11

P-AD-SC
Additional use of wrong surface connector
0.01

AND

2.4-W-SC
Use of a wrong surface connector
4.80E-09

P-AD-SC
Additional use of wrong surface connector
0.01

**4MD-DETON**

**Incorrect time default of 3 detonators due to manufacturer defect**

4MD-DETON
Incorrect time default of 3 detonators due to manufacturer defect
2.40E-09

AND

3MD-DETON
Manufacturer defect of two detonator such that time delay corresponds to another one
2.40E-07

P-AD-DETON
Manufacturer defect of another detonator such that time delay corresponds to another one
0.01

AND

MD-DETON
Manufacturer defect of one detonator such that time delay corresponds to another one
2.40E-05

P-AD-DETON
Manufacturer defect of another detonator such that time delay corresponds to another one
0.01

**4MD-SC**

**Surface connector fails to provide necessary delay due to manufacturer defect**

4MD-SC
Surface connector fails to provide necessary delay due to manufacturer defect
6.00E-11

3MD-SC
Manufacturer defect of one surface connector such that time delay corresponds to another one
6.00E-09

P-AD-SC
Manufacturer defect of another surface connector such that time delay corresponds to another one
0.01

AND

MD-SC
Manufacturer defect of one surface connector such that time delay corresponds to another one
6.00E-07

P-AD-SC
Manufacturer defect of another surface connector such that time delay corresponds to another one
0.01

**4-MIC-COMB-1**

**4 MIC detonated (due to same error occurred three times) at the same time**

4-MIC-COMB-1
4 MIC detonated (due to same error occurred three times) at the same time
2.46E-09

OR

4.1-WD
Wrong design in time delay of three detonators
1.26E-13

4.2-W-DETON
Three detonator wrongly put into one sector which contains the same time delay detonator
1.68E-18

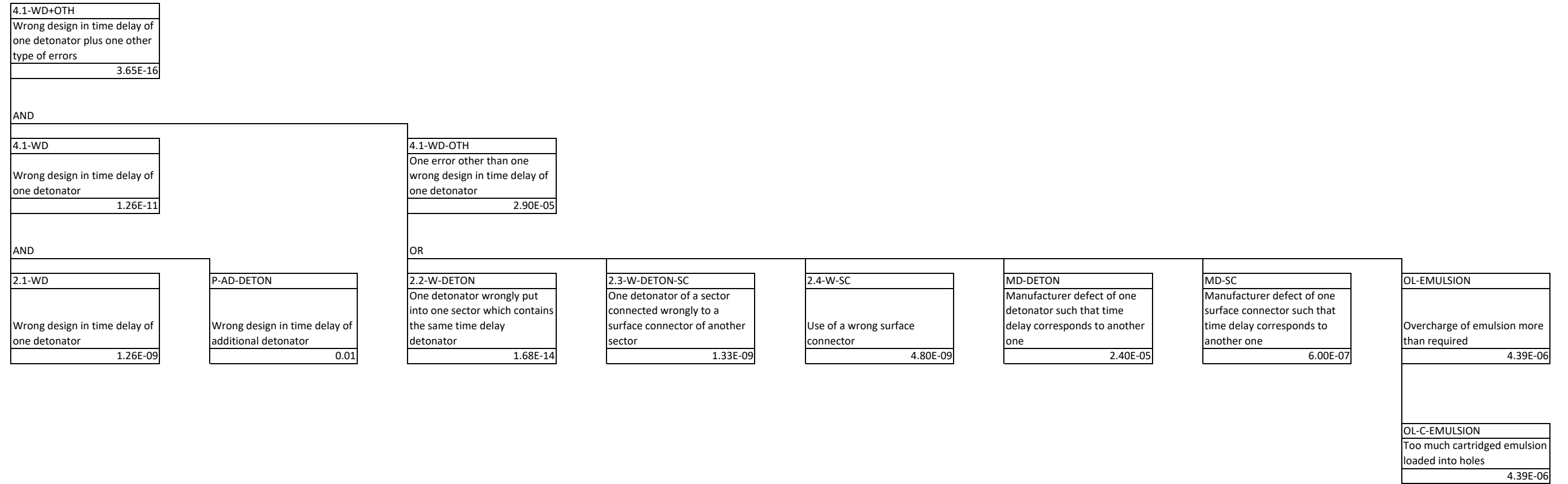
4.3-2-DETON
Three detonators of other sectors connected wrongly to a surface connector of another sector
1.33E-13

4.4-W-SC
Use of three wrong surface connector
4.80E-13

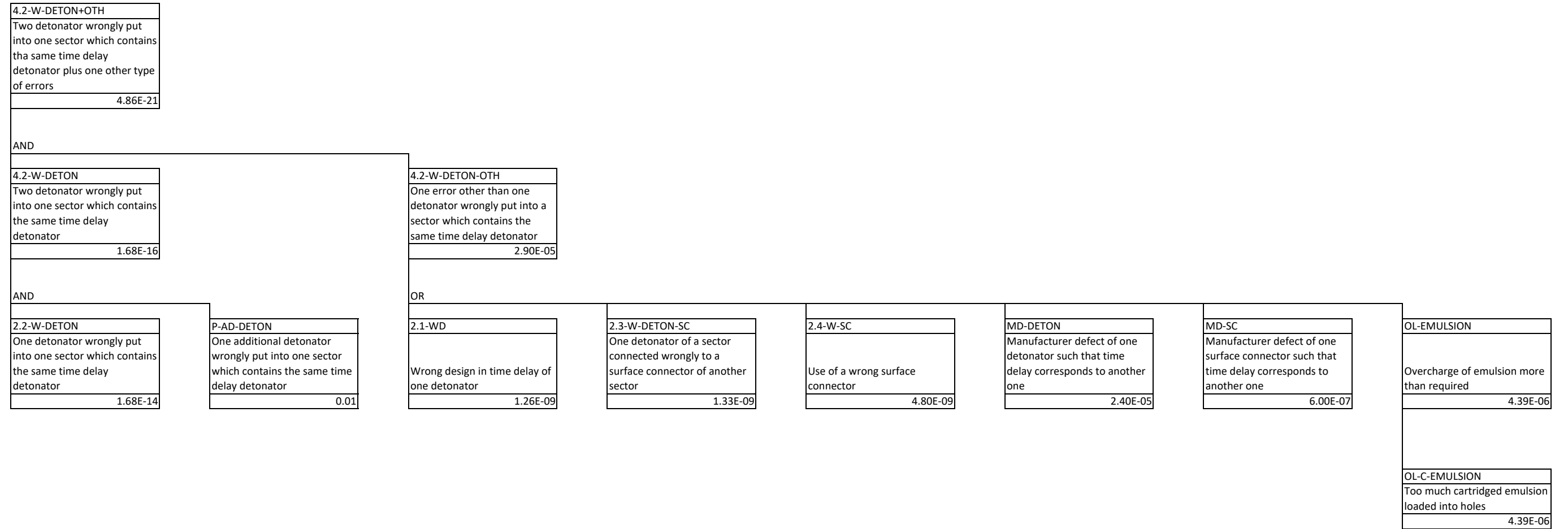
4MIC-P-AD-DETON
Incorrect time default of 3 detonators due to manufacturer defect
2.40E-09

4MIC-P-AD-SC
Surface connector fails to provide necessary delay due to manufacturer defect
6.00E-11

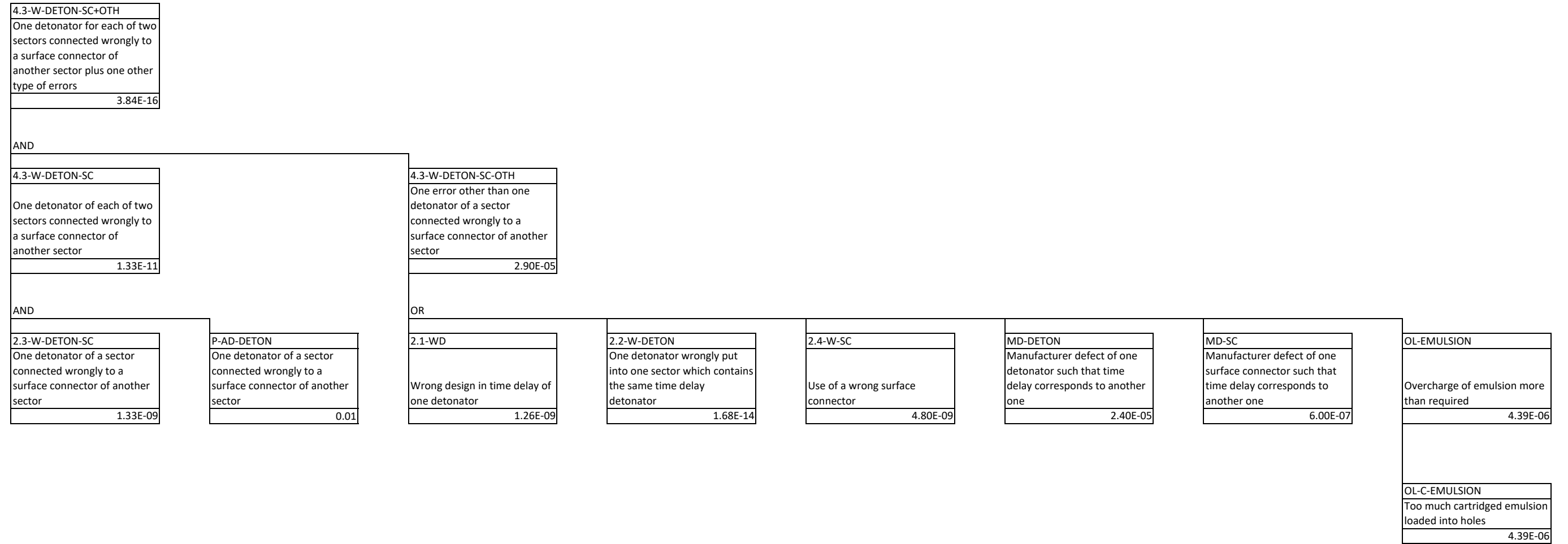
**4.1-WD+OTH Wrong design in time delay of two detonator plus one other type of error:**



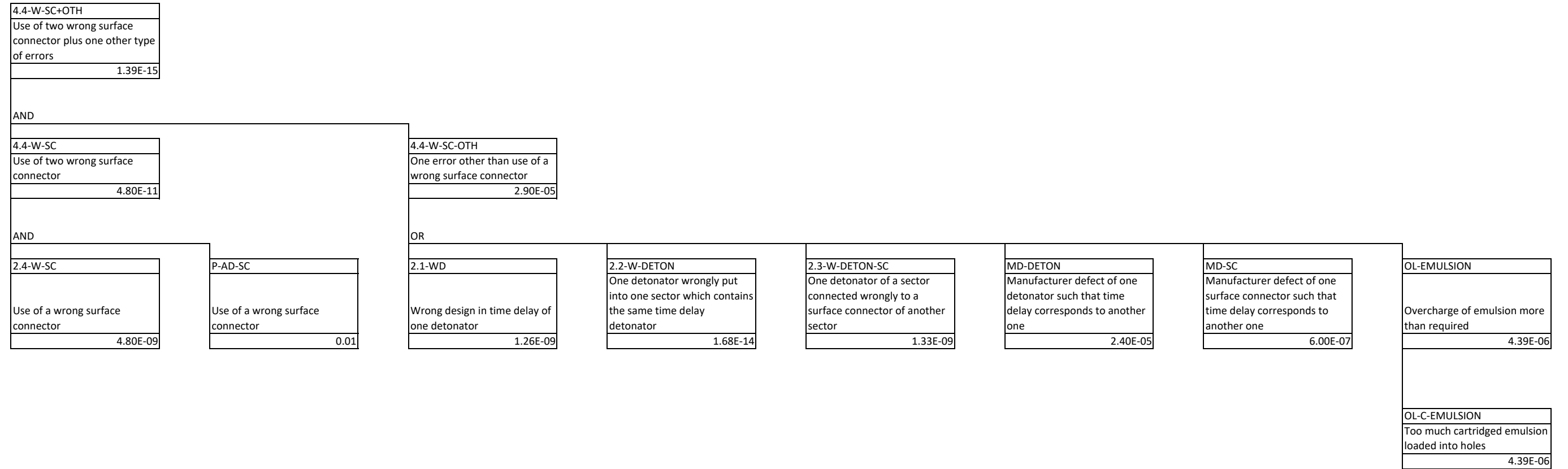
**4.2-W-DETON+OTH Two detonator wrongly put into one sector which contains the same time delay detonator plus one other type of error:**



**4.3-W-DETON-SC+OTH One detonator for each of two sectors connected wrongly to a surface connector of another sector plus one other type of error:**

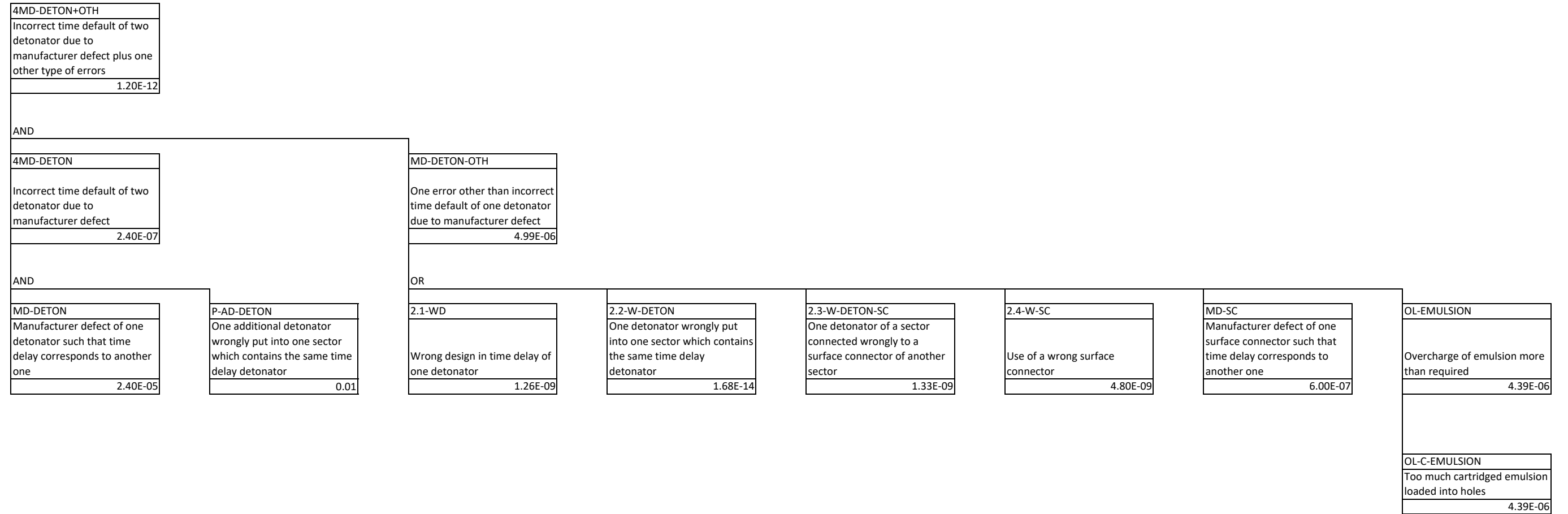


**4.4-W-SC+OTH Use of two wrong surface connector plus one other types of errors**

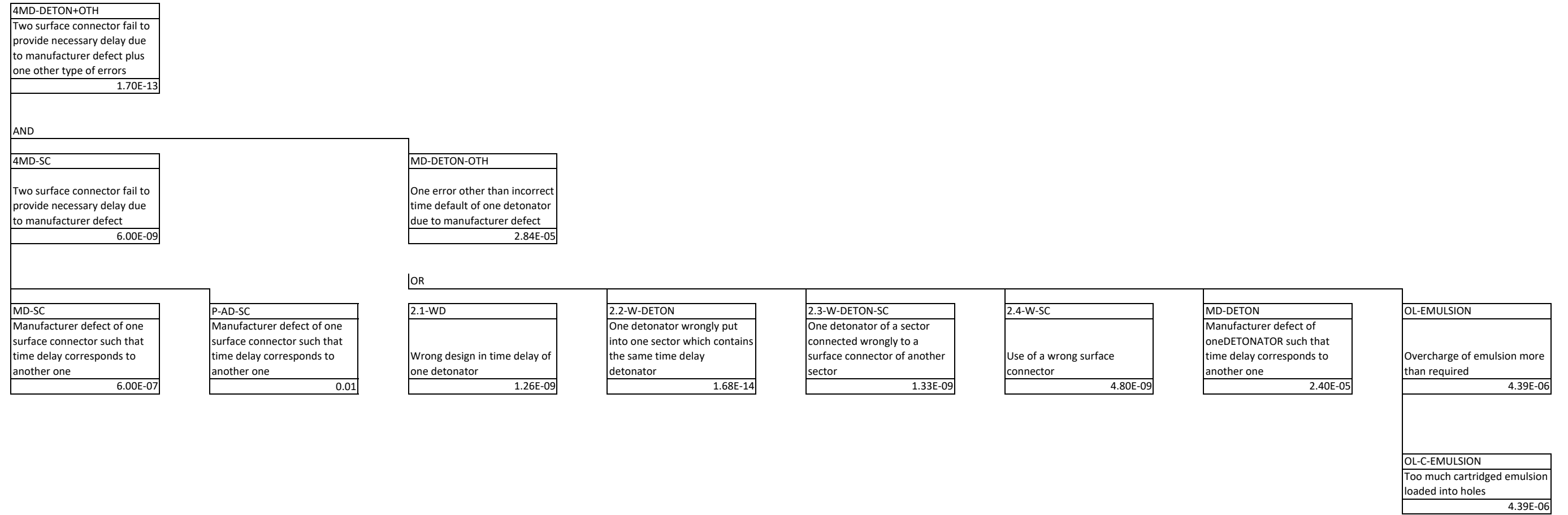




**4MD-DETON+OTH** Incorrect time default of two detonator due to manufacturer defect plus one other type of error:



**4MD-SC+OTH Two surface connector fail to provide necessary delay due to manufacturer defect plus one other type of errors:**



**4MIC-COMB-2**

**4 MIC detonated (due to same error occurred two times and one other error) at the same time**

4MIC-COMB-2
4 MIC detonated (due to same error occurred two times and one other error) at the same time
1.37E-12

OR

4.1-WD+OTH
Wrong design in time delay of one detonator plus one other type of errors
3.65E-16

4.2-W-DETON+OTH
Two detonator wrongly put into one sector which contains the same time delay detonator plus one other type of errors
4.86E-21

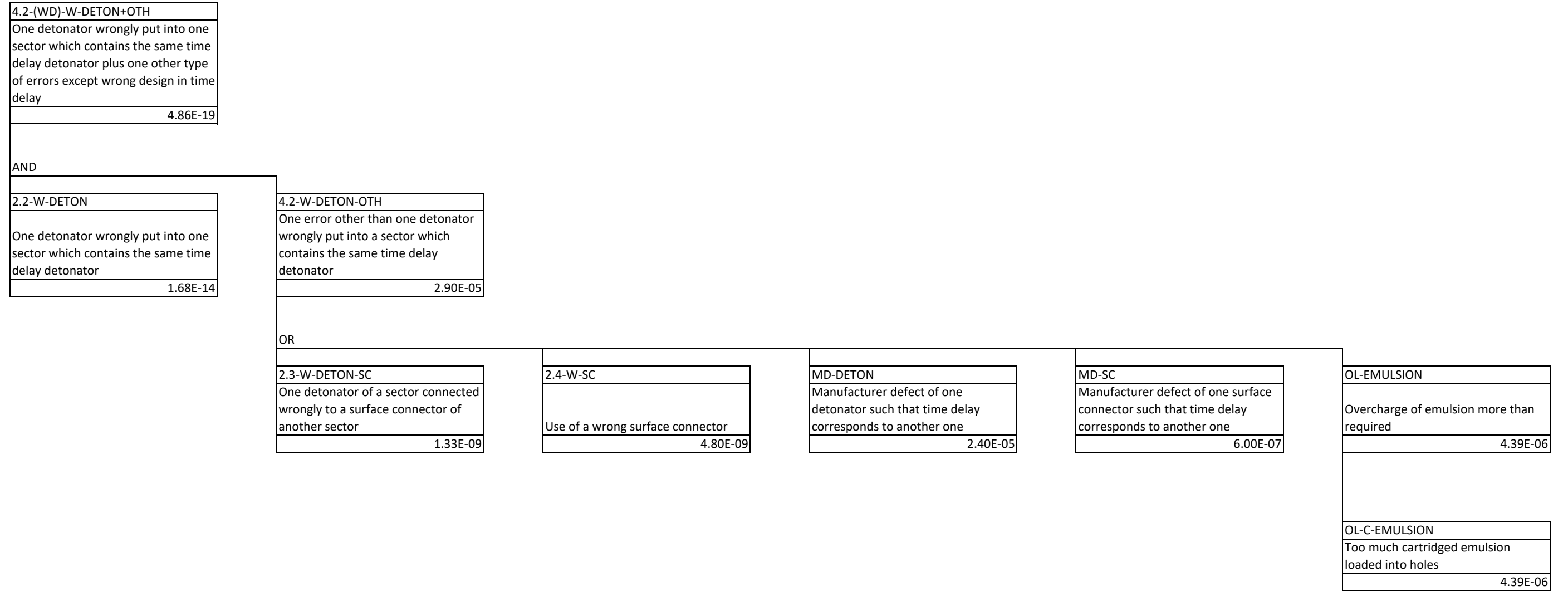
4.3-W-DETON-SC+OTH
One detonator for each of two sectors connected wrongly to a surface connector of another sector plus one other type of errors
3.84E-16

4.4-W-SC+OTH
Use of two wrong surface connector plus one other type of errors
1.39E-15

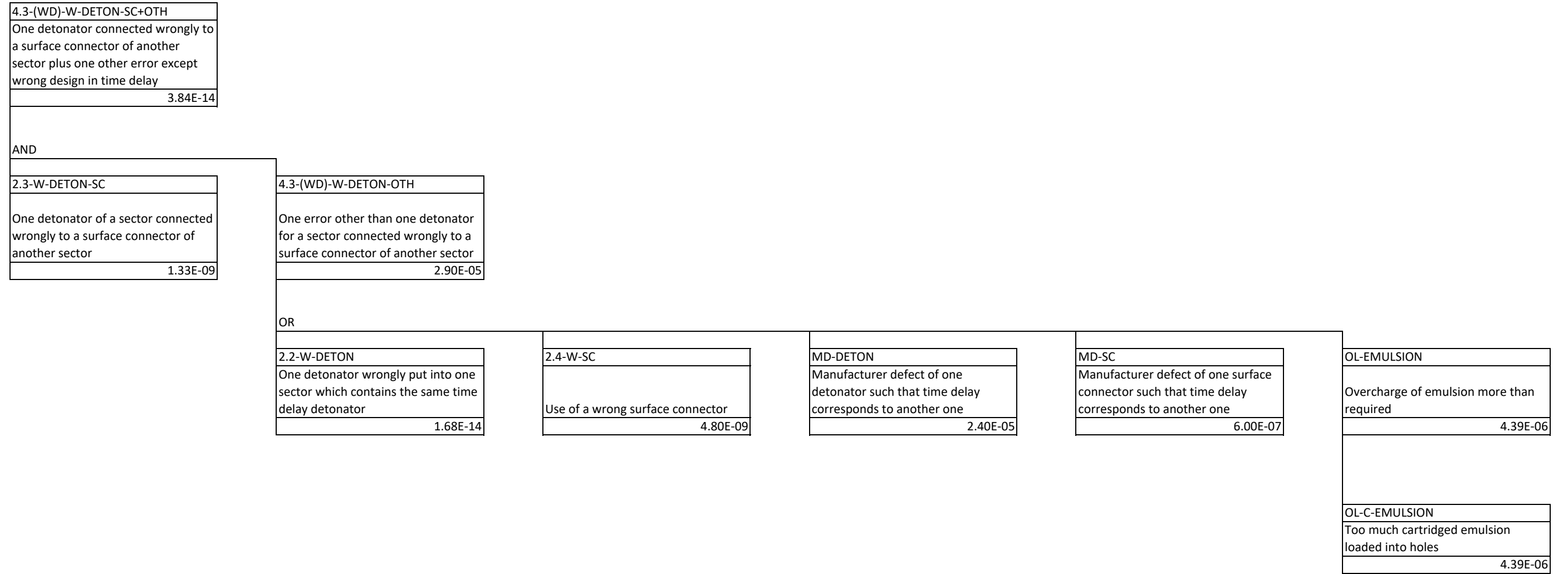
4MD-DETON+OTH
Incorrect time default of two detonator due to manufacturer defect plus one other type of errors
1.20E-12

4MD-SC+OTH
Two surface connector fail to provide necessary delay due to manufacturer defect plus one other type of errors
1.70E-13

**4.2-(WD)-W-DETON+OTH One detonator wrongly put into one sector which contains the same time delay detonator plus one other type of errors except wrong design in time delay**

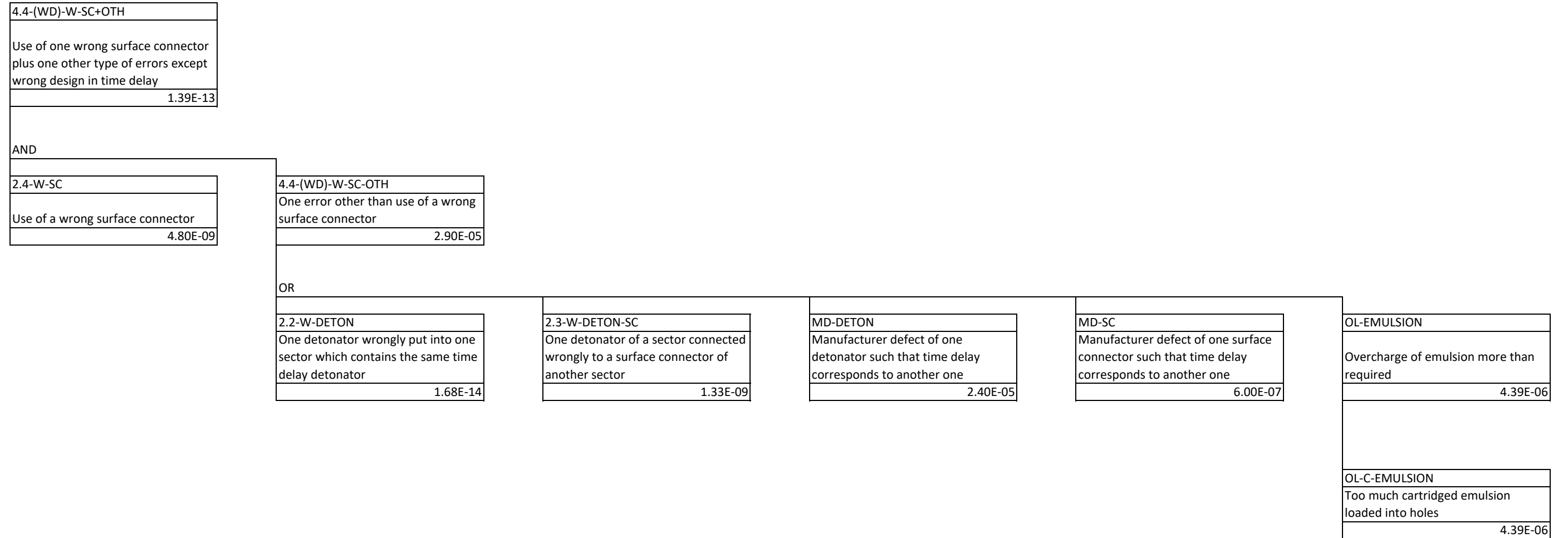


**4.3-(WD)-W-DETON-SC+OTH One detonator connected wrongly to a surface connector of another sector plus one other error except wrong design in time delay**

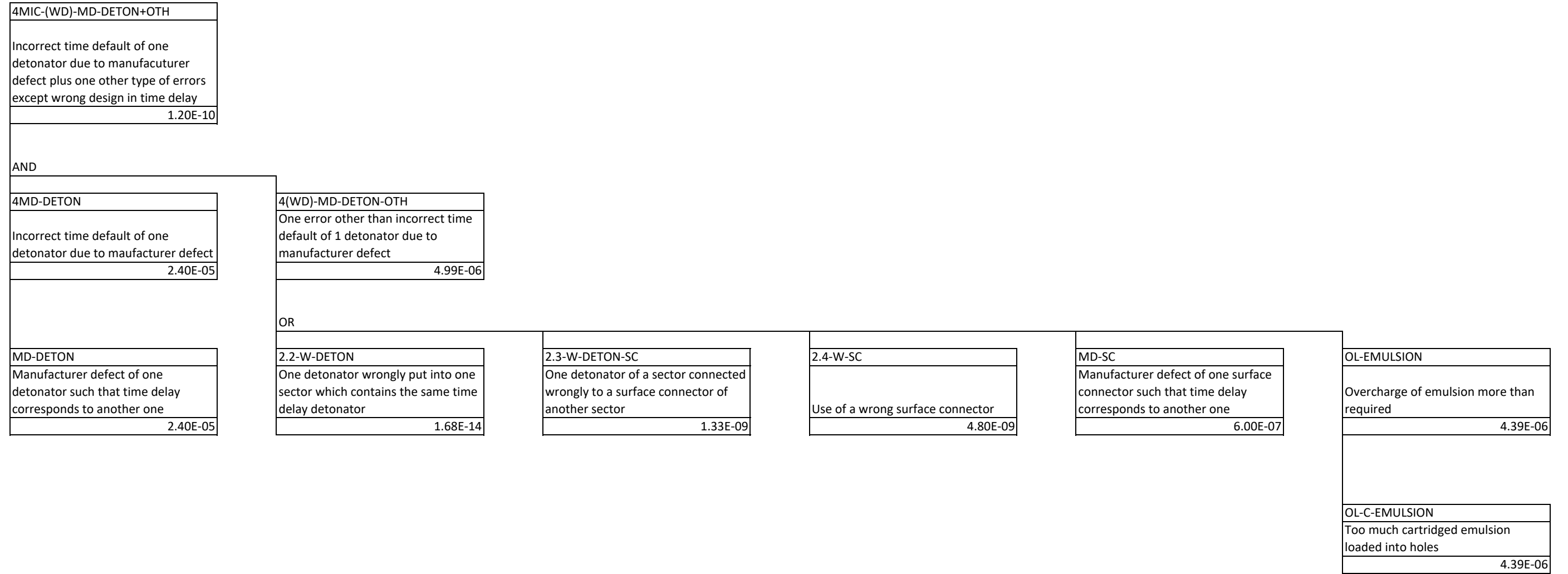


**4.4(WD)-W-SC+OTH**

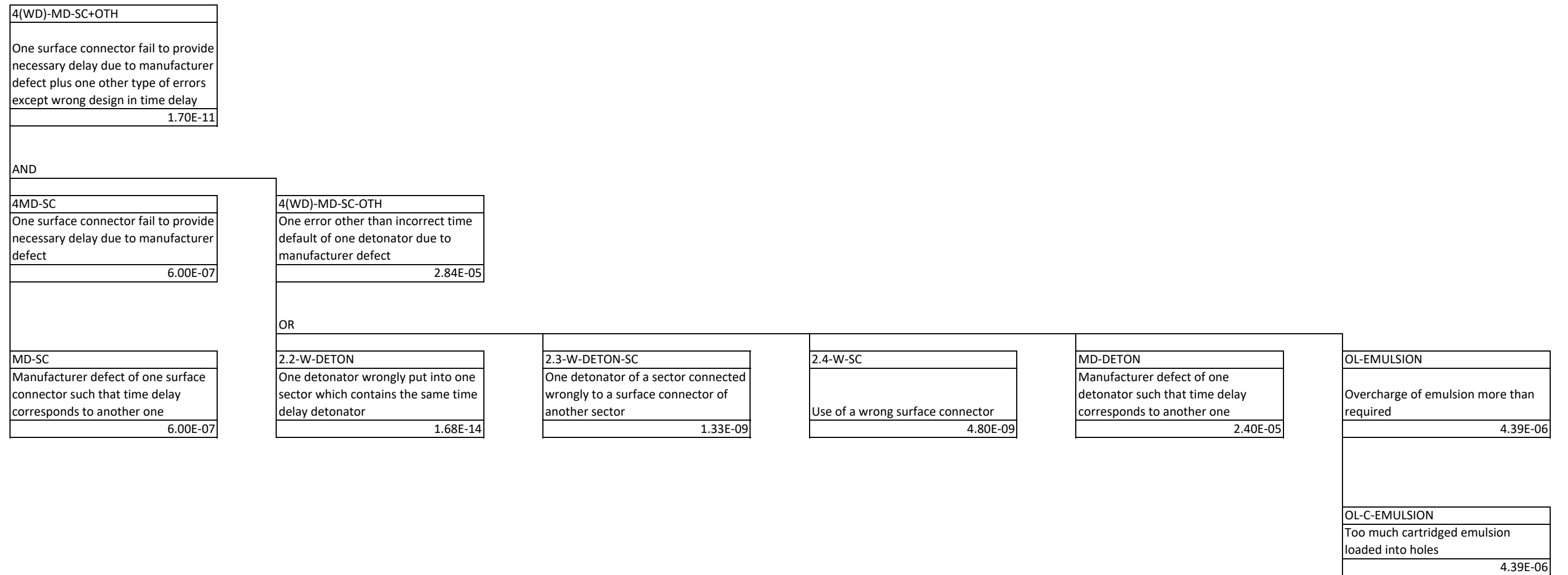
**Use of one wrong surface connector plus one other type of errors except wrong design in time delay**



**4(WD)-MD-DETON+OTH Incorrect time default of one detonator due to manufacturer defect plus one other type of errors except wrong design in time delay**

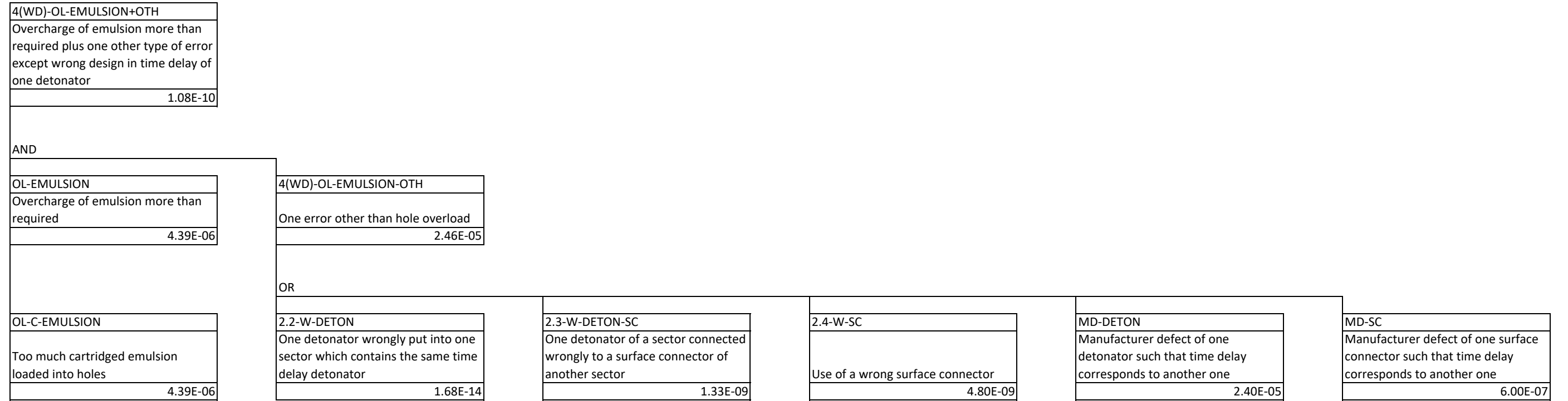


**4(WD)-MD-SC+OTH One surface connector fail to provide necessary delay due to manufacturer defect plus one other type of errors except wrong design in time delay**

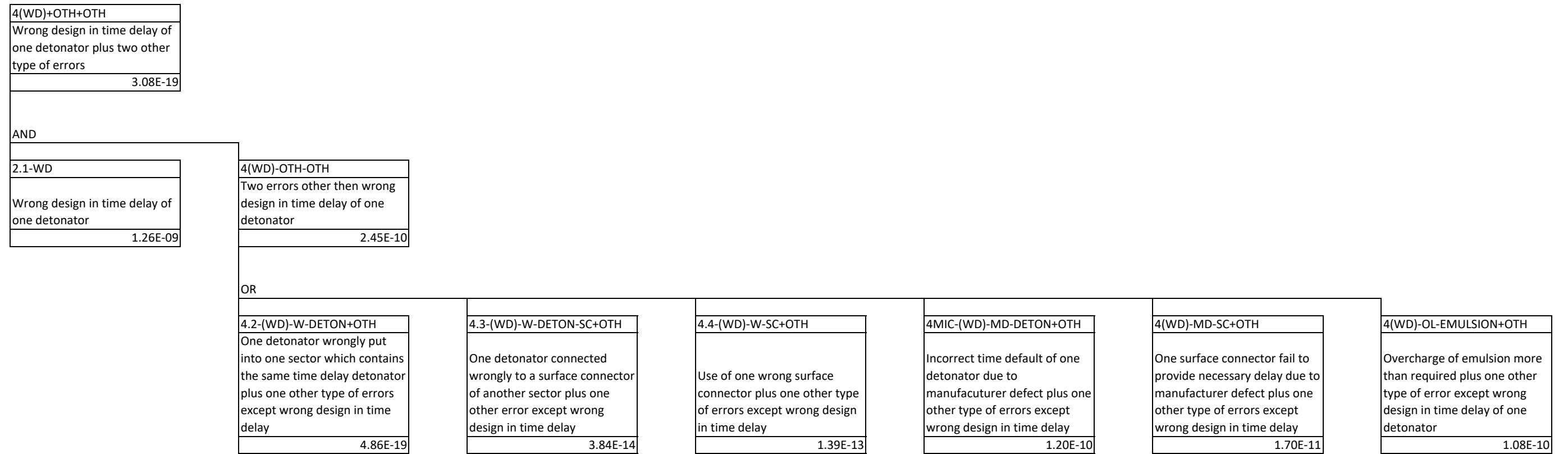




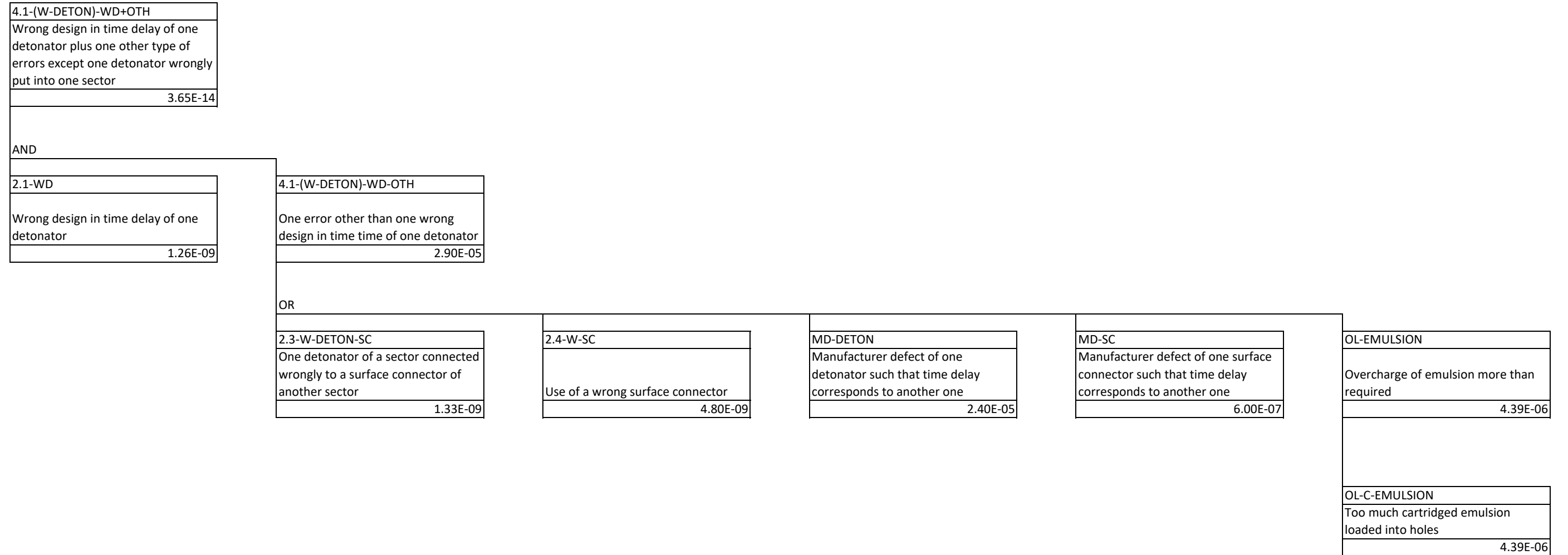
**4(WD)-OL-EMULSION+OTH Overcharge of emulsion more than required plus one other type of error except wrong design in time delay of one detonator**



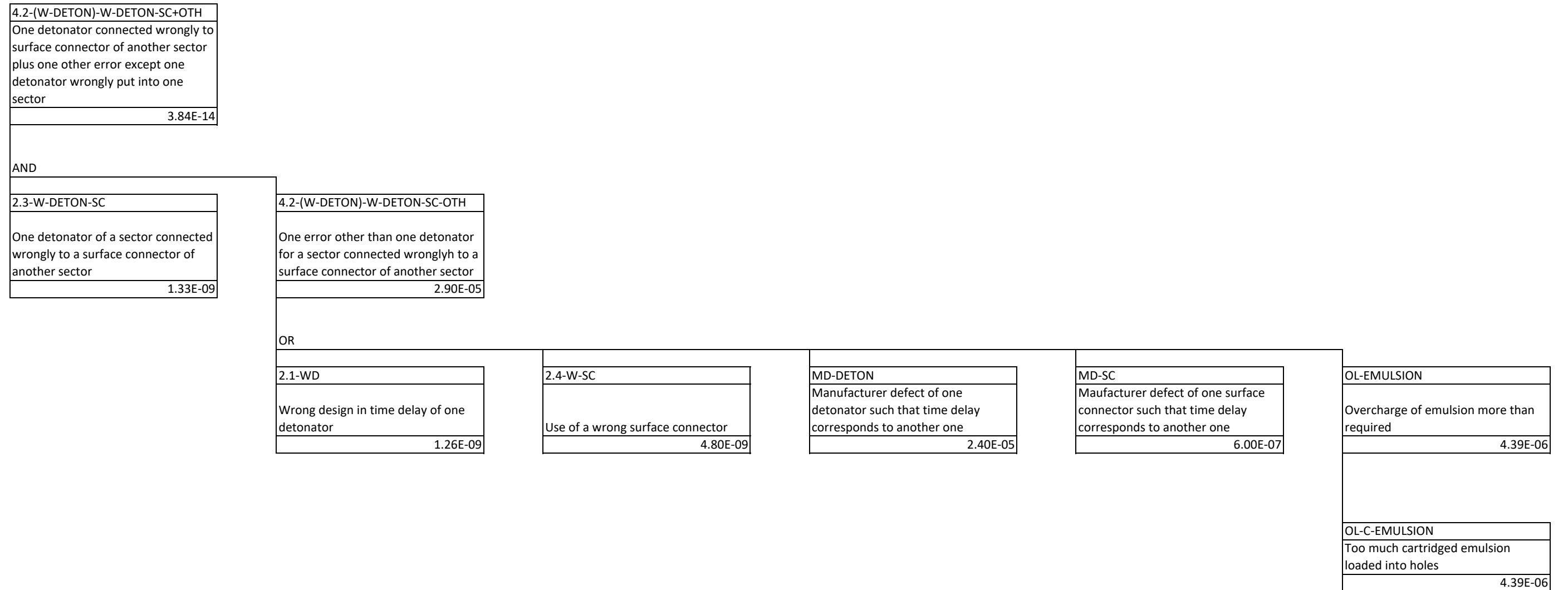
**4(WD)+OTH+OTH Wrong design in time delay of one detonator plus two other type of errors**



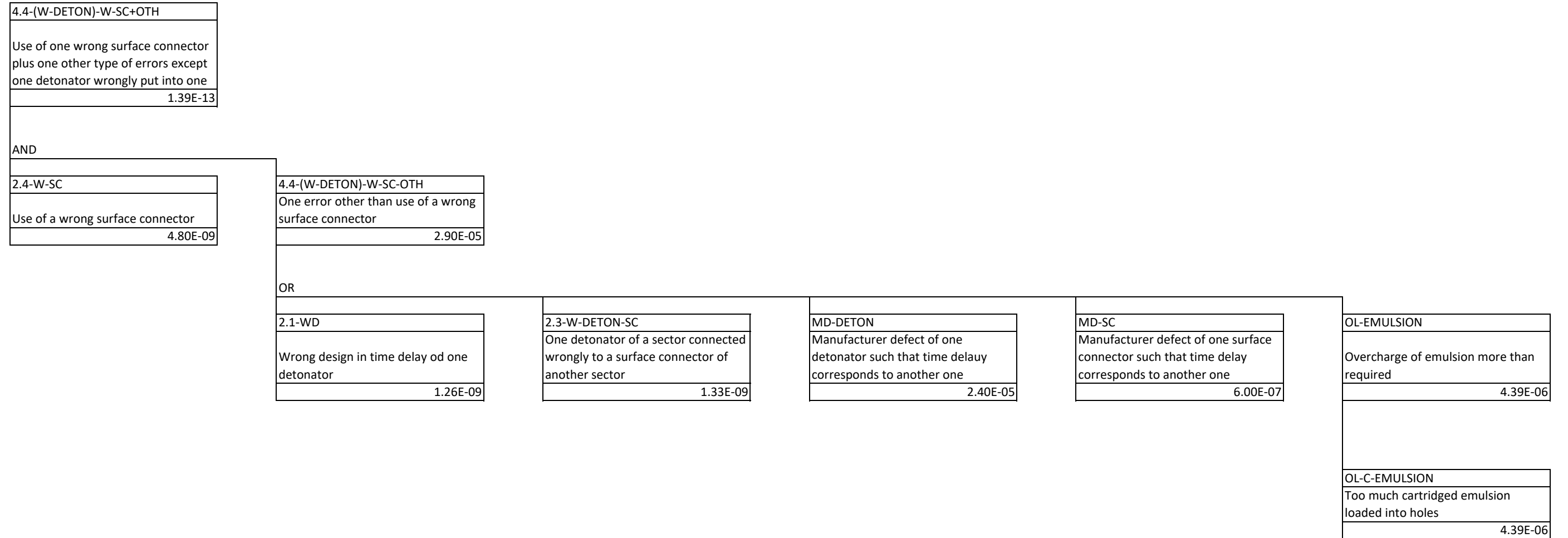
**4.1-(W-DETON)-WD+OTH Wrong design in time delay of one detonator plus one other type of errors except one detonator wrongly put into one sector**



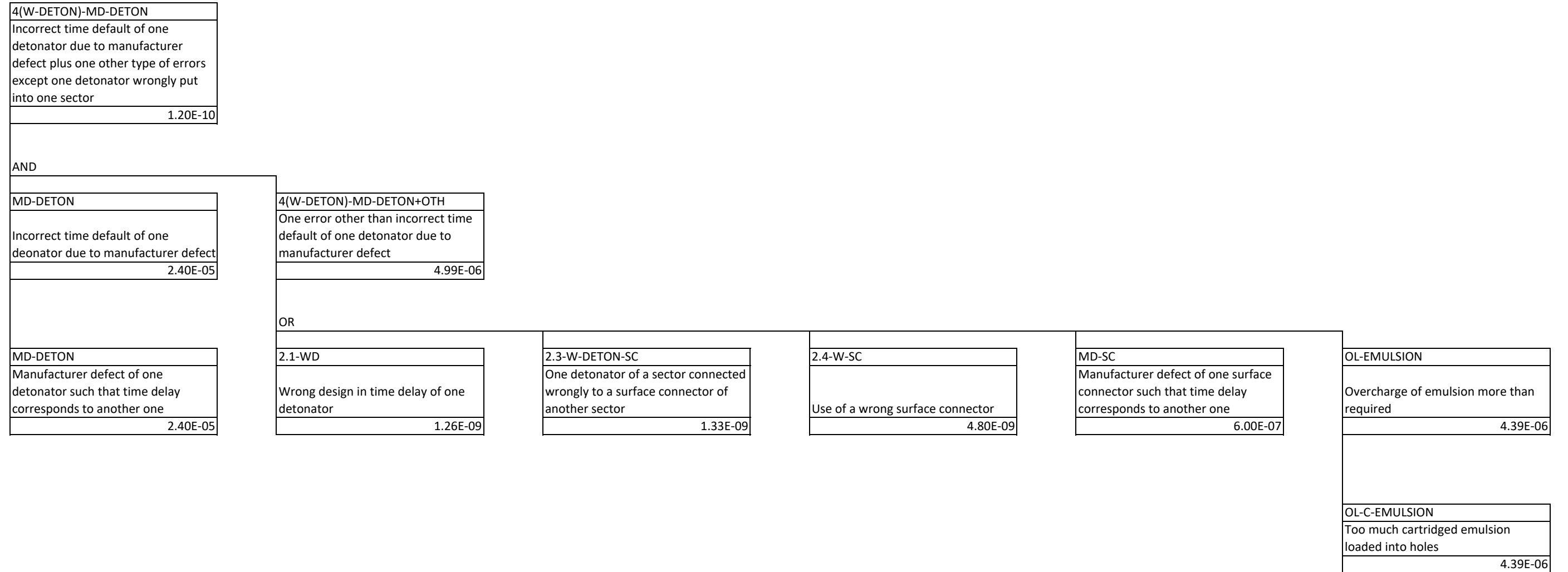
**4.3-(W-DETON)-W-DETON-SC+OTH One detonator connected wrongly to a surface connector of another sector plus one other error except one detonator wrongly put into one sector**



**4.4-(W-DETON)-W-SC+OTH Use of one wrong surface connector plus one other type of errors except one detonator wrongly put into one**

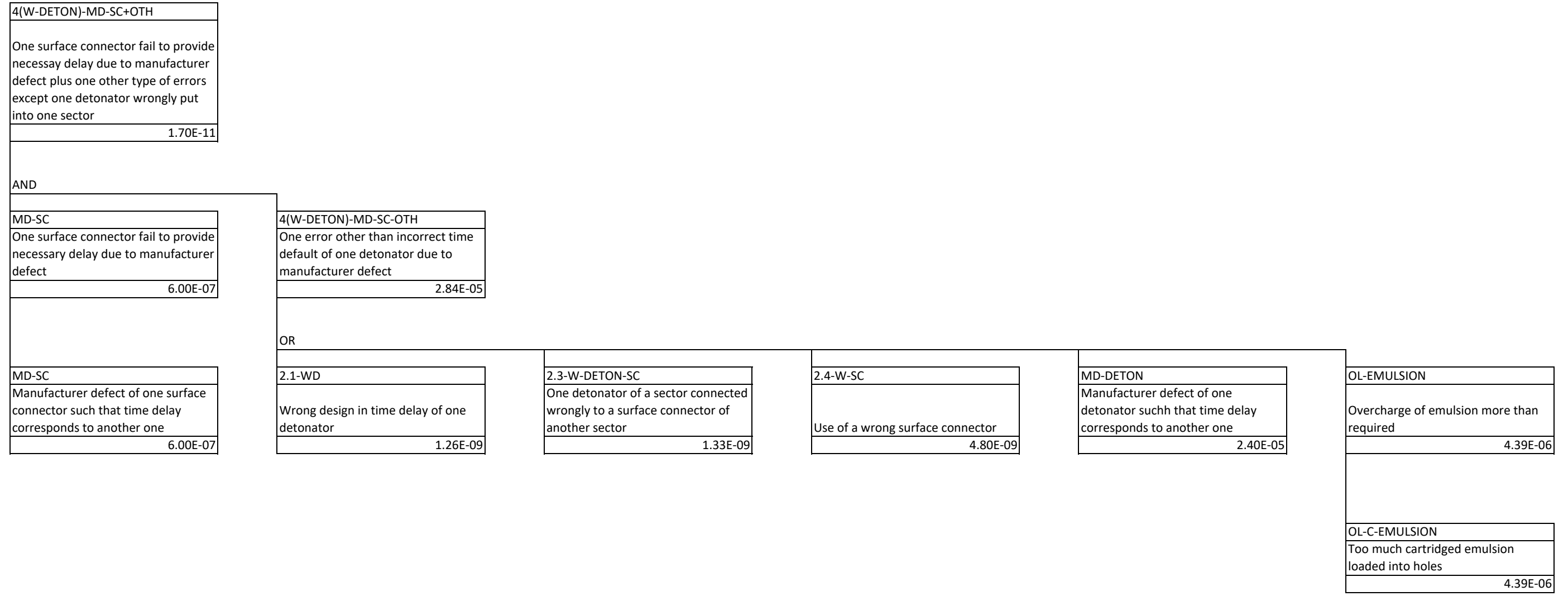


**4(W-DETON)-MD-DETON+OTH Incorrect time default of one detonator due to manufacturer defect plus one other type of errors except one detonator wrongly put into one sector**

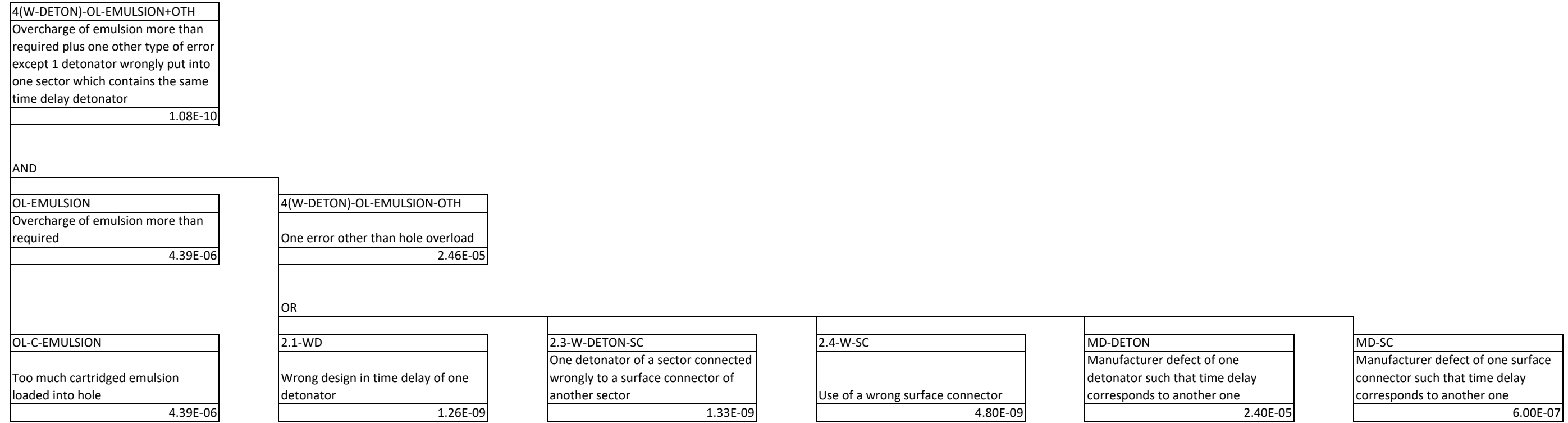


**4(W-DETON)-MD-SC+OTH**

**One surface connector fail to provide necessary delay due to manufacturer defect plus one other type of errors except one detonator wrongly put into one sector**

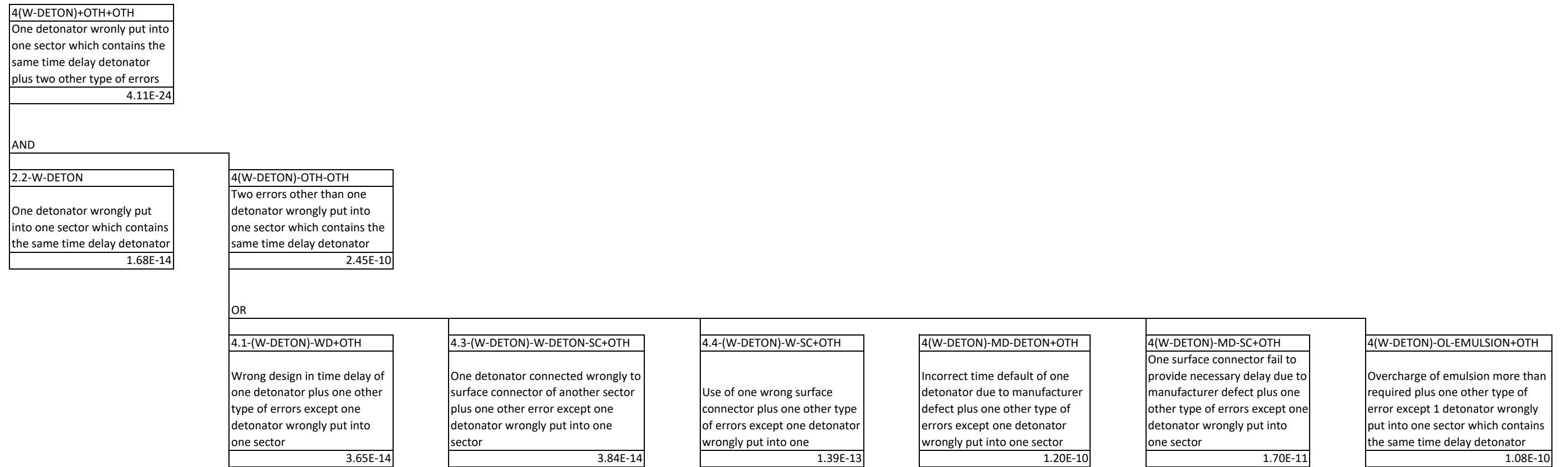


**4(W-DETON)-OL-EMULSION+OTH Overcharge of emulsion more than required plus one other type of error except 1 detonator wrongly put into one sector which contains the same time delay detonator**

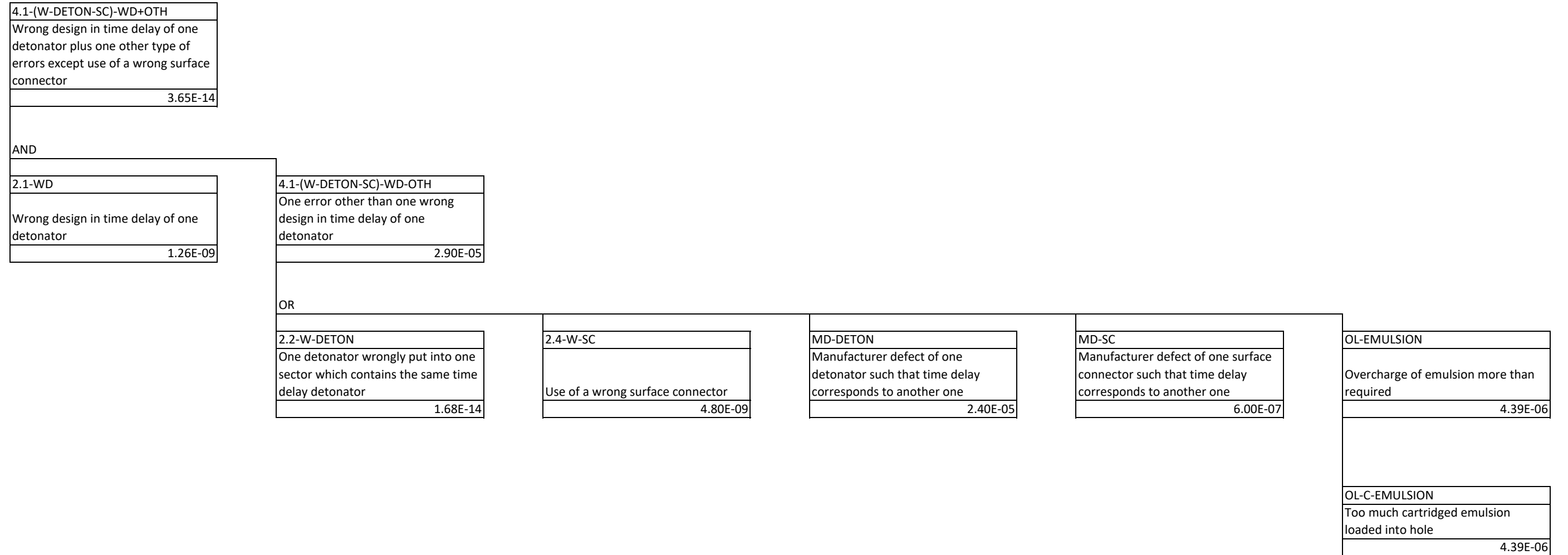




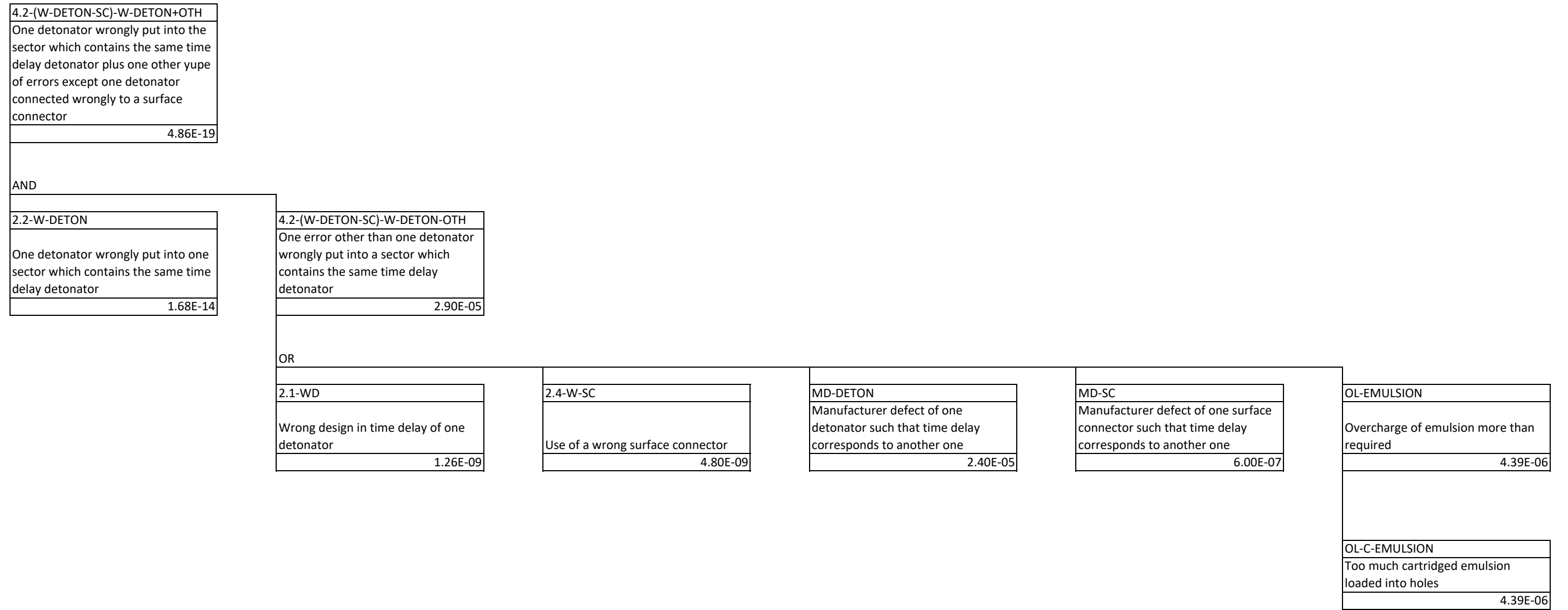
**4(W-DETON)+OTH+OTH One detonator wrongly put into one sector which contains the same time delay detonator plus two other type of errors**



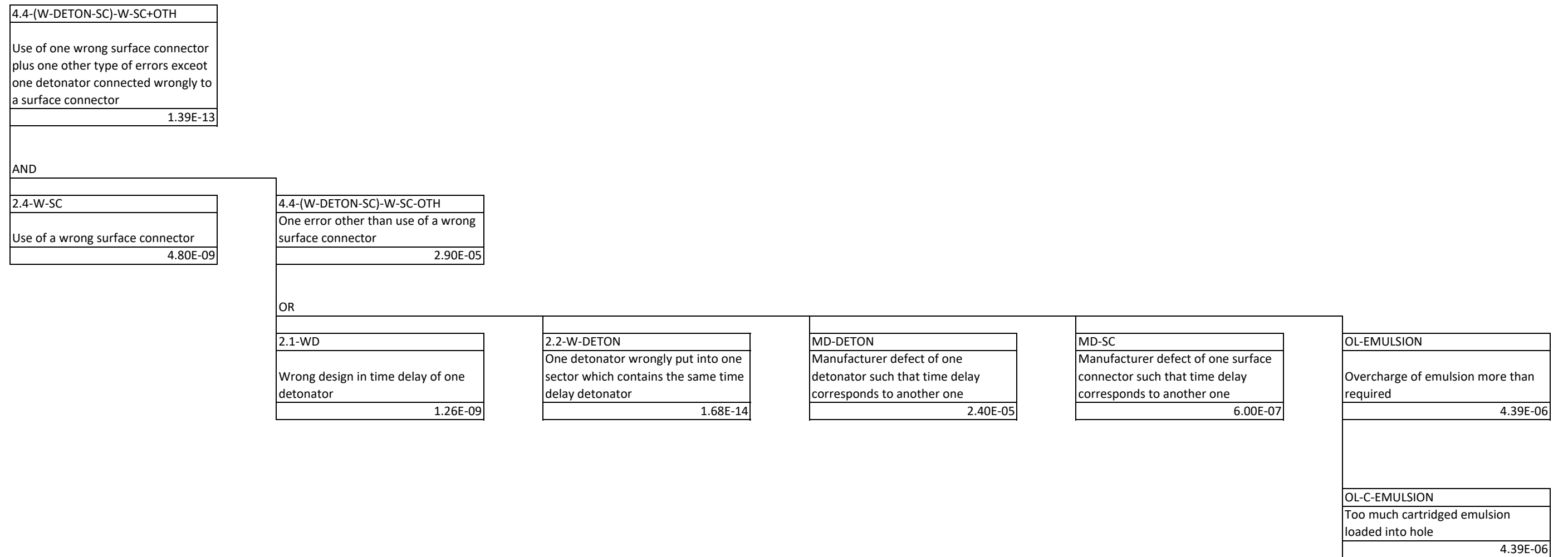
**4.1-(W-DETON-SC)-WD+OTH Wrong design in time delay of one detonator plus one other type of errors except use of a wrong surface connector**



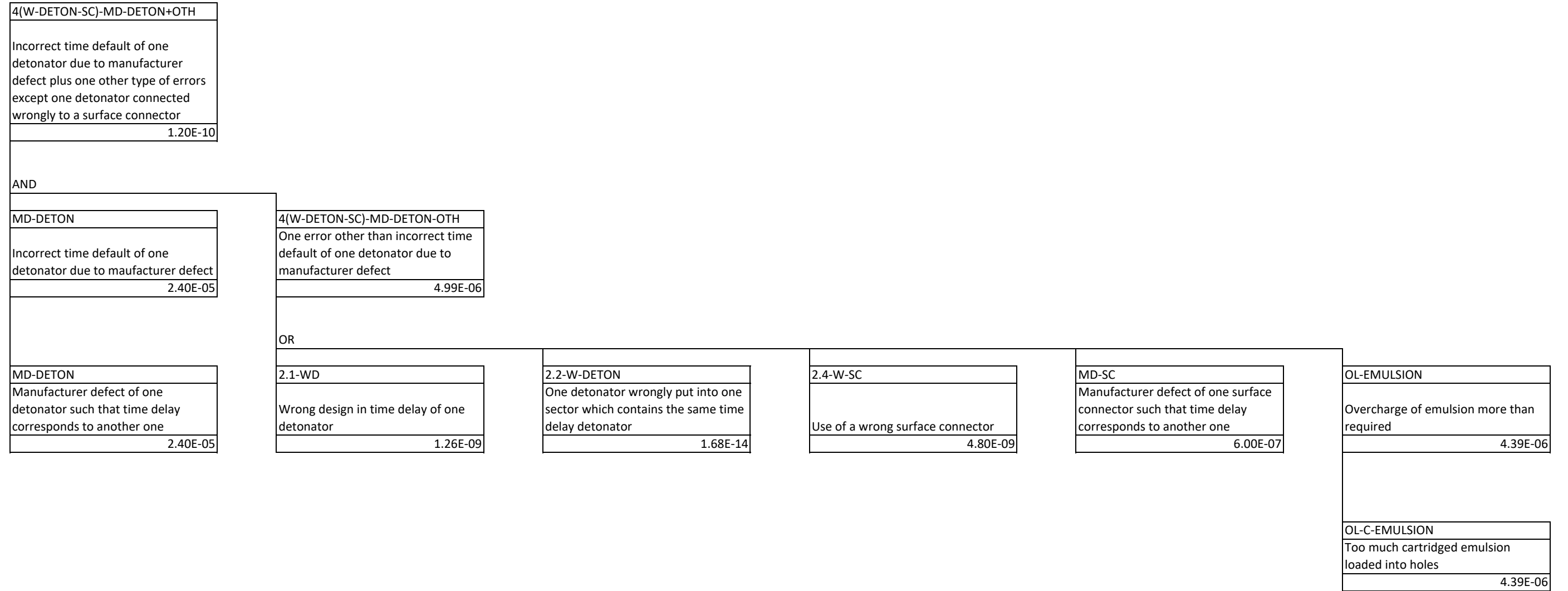
**4.2-(W-DETON-SC)-W-DETON+OTH One detonator wrongly put into the sector which contains the same time delay detonator plus one other yupe of errors except one detonator connected wrongly to a surface connector**



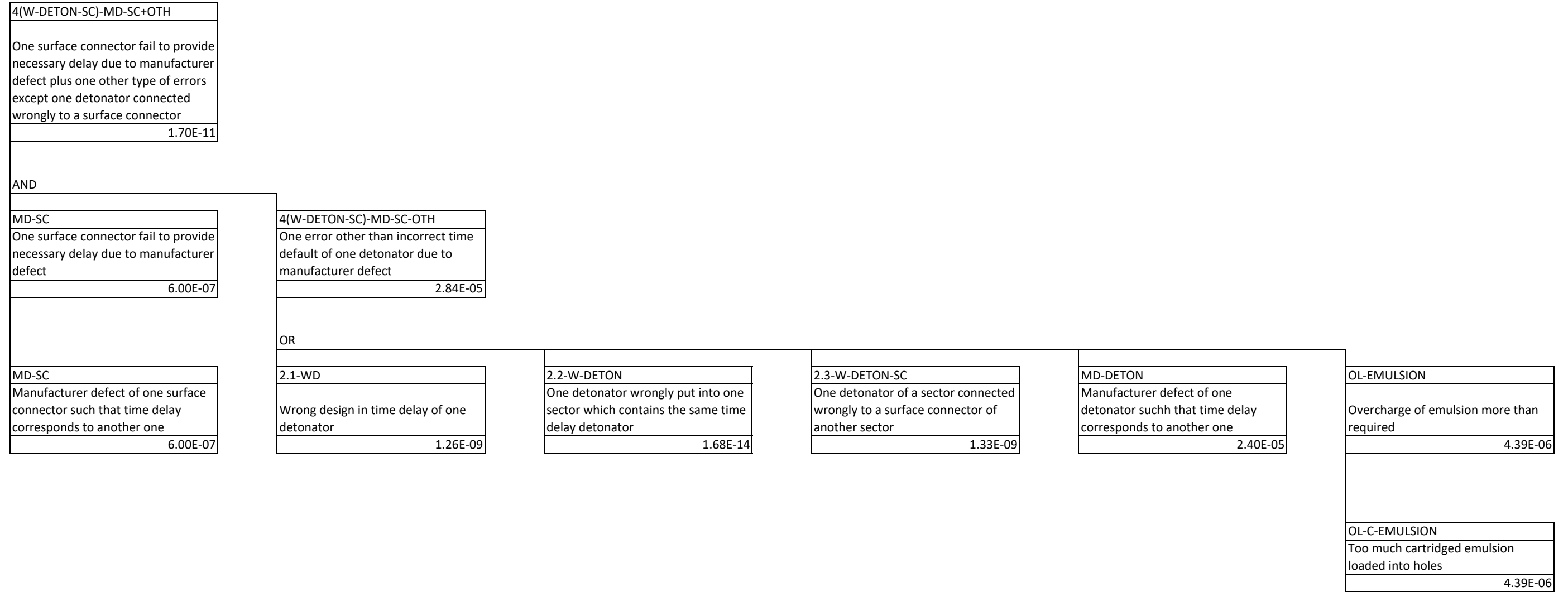
**4.4-(W-DETON-SC)-W-SC+OTH Use of one wrong surface connector plus one other type of errors except one detonator connected wrongly to a surface connector**



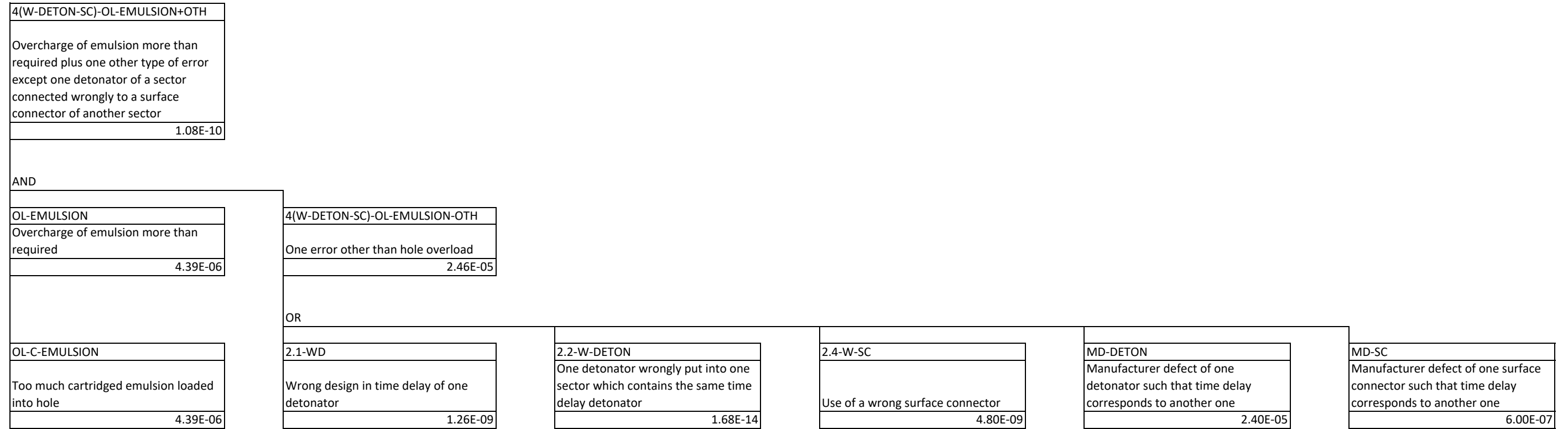
**4(W-DETON-SC)-MD-DETON+OTH Incorrect time default of one detonator due to manufacturer defect plus one other type of errors except one detonator connected wrongly to a surface connector**



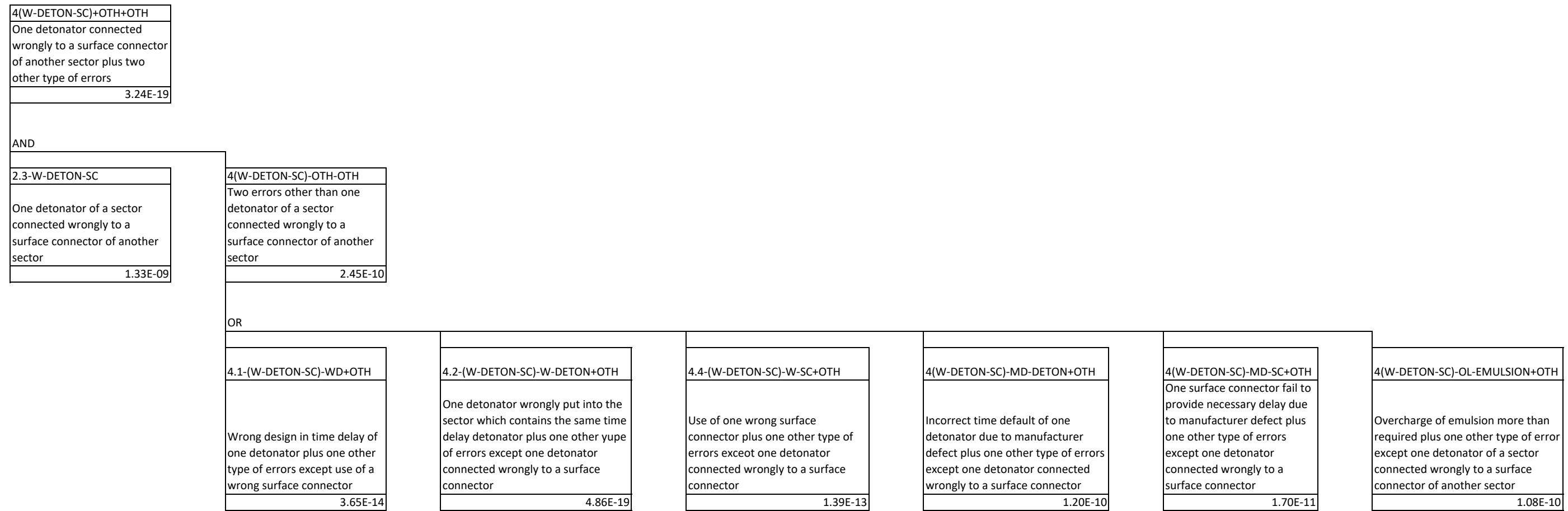
**4(W-DETON-SC)-MD-SC+OTH One surface connector fail to provide necessary delay due to manufacturer defect plus one other type of errors except one detonator connected wrongly to a surface connector**



**4(W-DETON-SC)-OL-EMULSION+OTH Overcharge of emulsion more than required plus one other type of error except one detonator of a sector connected wrongly to a surface connector of another sector**

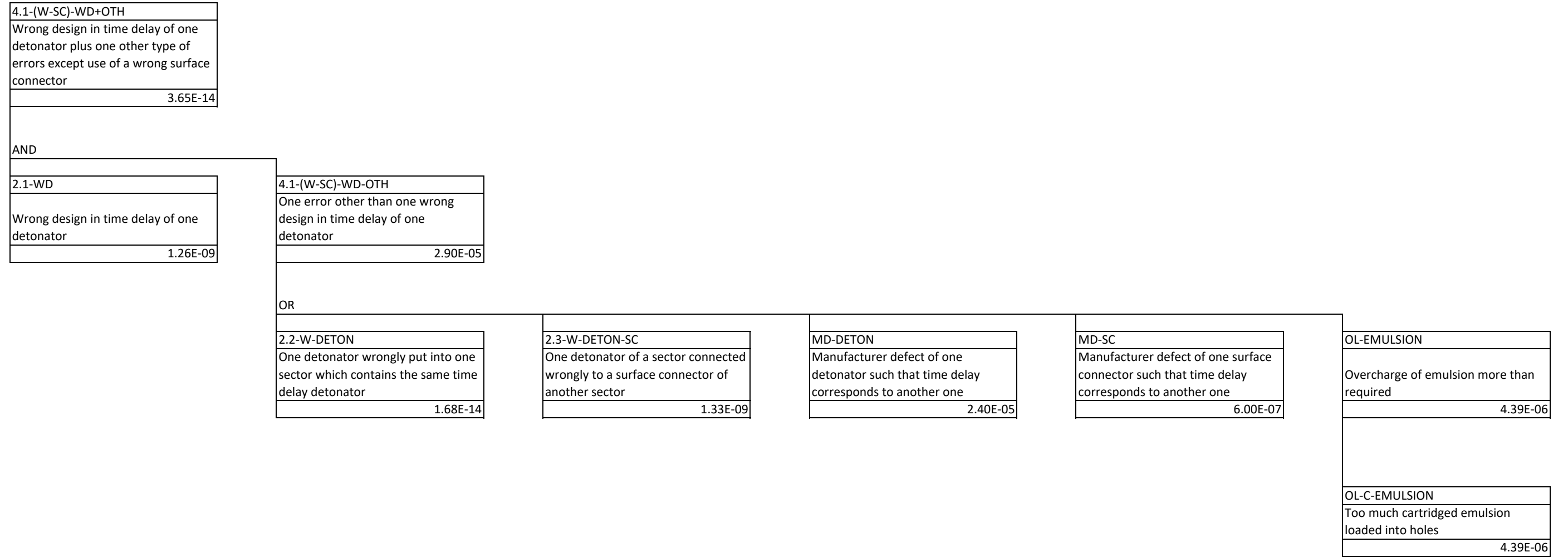


**4(W-DETON-SC)+OTH+OTH One detonator connected wrongly to a surface connector of another sector plus two other type of errors**



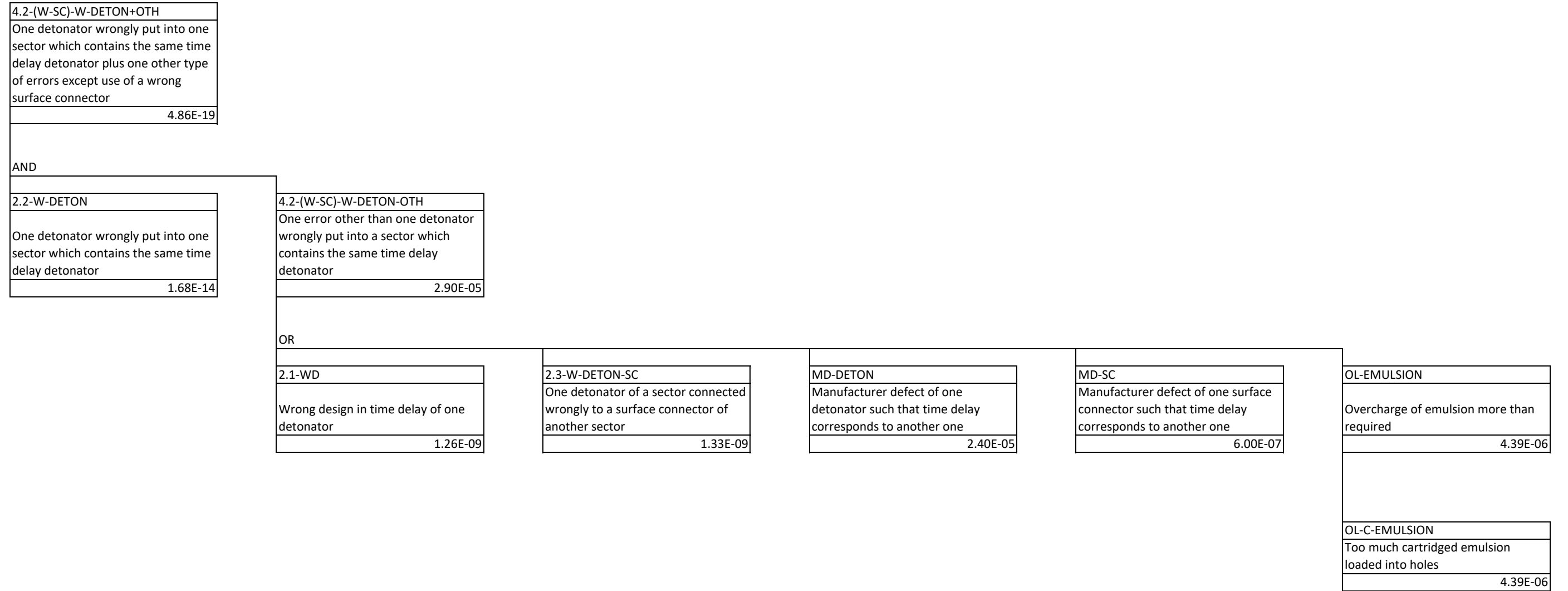


**4.1-(W-SC)-WD+OTH Wrong design in time delay of one detonator plus one other type of errors except use of a wrong surface connector**

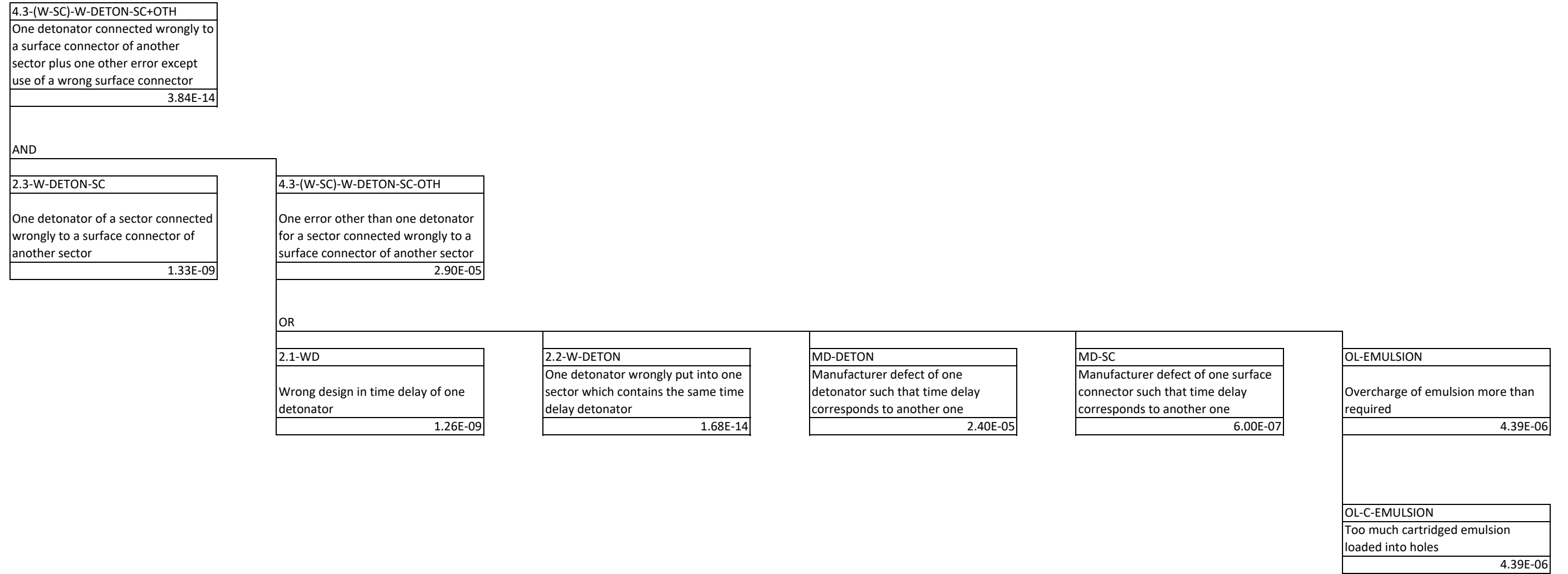


**4.2-(W-SC)-W-DETON+OTH**

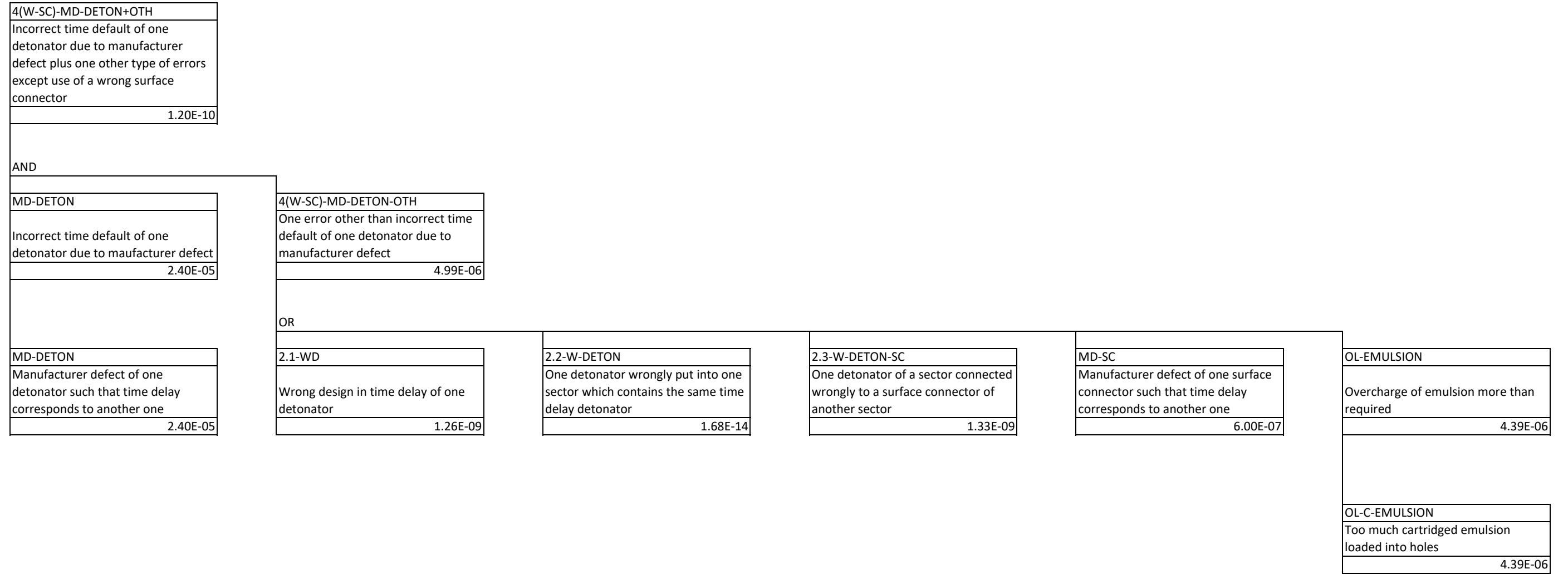
**One detonator wrongly put into one sector which contains the same time delay detonator plus one other type of errors except use of a wrong surface connector**



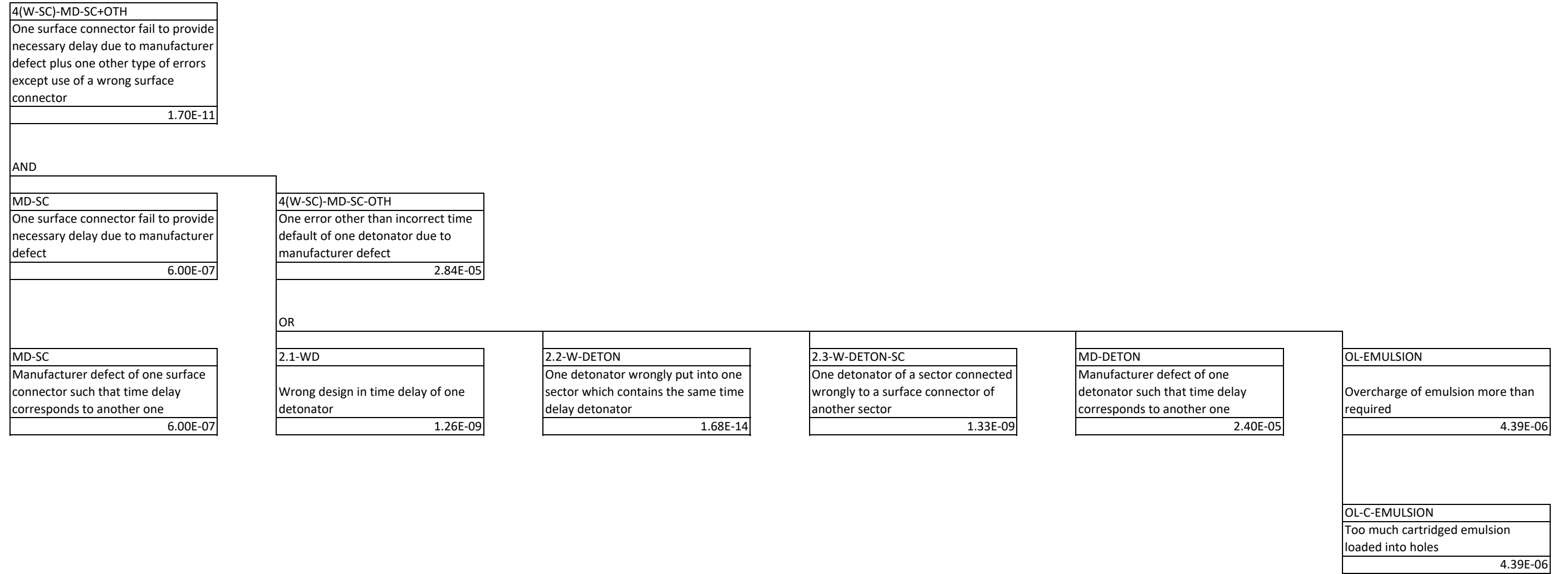
**4.3-(W-SC)-W-DETON-SC+OTH One detonator connected wrongly to a surface connector of another sector plus one other error except use of a wrong surface connector**



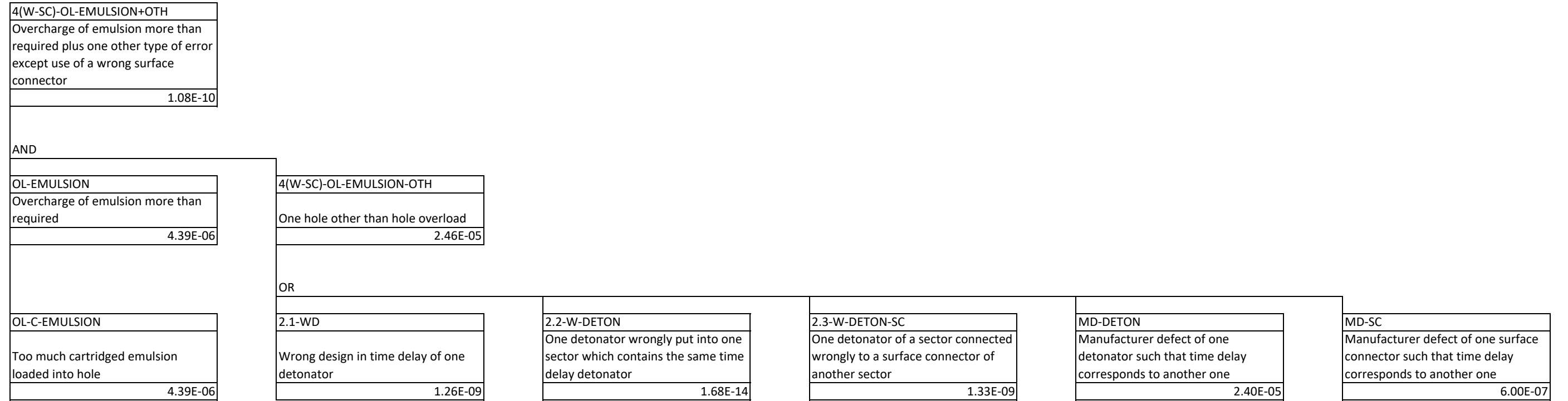
**4(W-SC)-MD-DETON+OTH**      **Incorrect time default of one detonator due to manufacturer defect plus one other type of errors except use of a wrong surface connector**



**4(W-SC)-MD-SC+OTH One surface connector fail to provide necessary delay due to manufacturer defect plus one other type of errors except use of a wrong surface connector**



**4(W-SC)-OL-EMULSION+OTH Overcharge of emulsion more than required plus one other type of error except use of a wrong surface connector**



**4(W-SC)+OTH+OTH Use of a wrong surface connector plus two other type of errors**

4(W-SC)+OTH+OTH
Use of a wrong surface connector plus two other type of errors
1.17E-18

AND

2.4-W-SC
Use of a wrong surface connector
4.80E-09

4(W-SC)-OTH-OTH
Two errors other than use of a wrong surface connector
2.45E-10

OR

4.1-(W-SC)-WD+OTH
Wrong design in time delay of one detonator plus one other type of errors except use of a wrong surface connector
3.65E-14

4.2-(W-SC)-W-DETON+OTH
One detonator wrongly put into one sector which contains the same time delay detonator plus one other type of errors except use of a wrong surface connector
4.86E-19

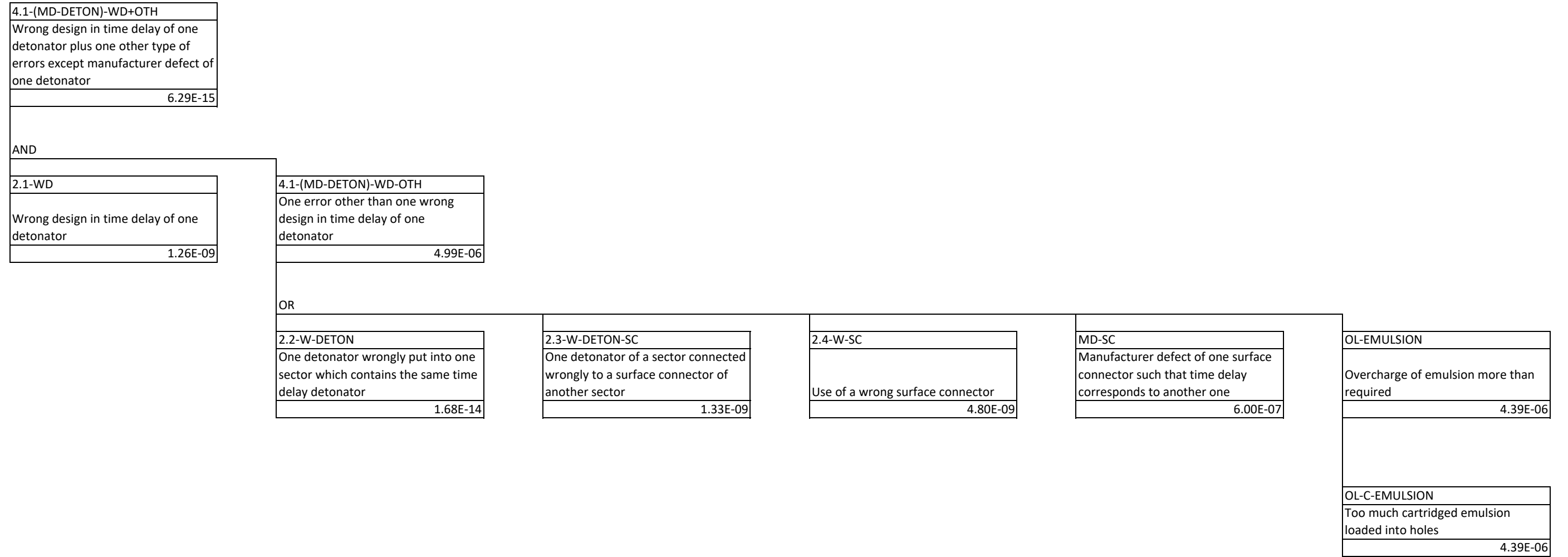
4.3-(W-SC)-W-DETON-SC+OTH
One detonator connected wrongly to a surface connector of another sector plus one other error except use of a wrong surface connector
3.84E-14

4(W-SC)-MD-DETON+OTH
Incorrect time default of one detonator due to manufacturer defect plus one other type of errors except use of a wrong surface connector
1.20E-10

4(W-SC)-MD-SC+OTH
One surface connector fail to provide necessary delay due to manufacturer defect plus one other type of errors except use of a wrong surface connector
1.70E-11

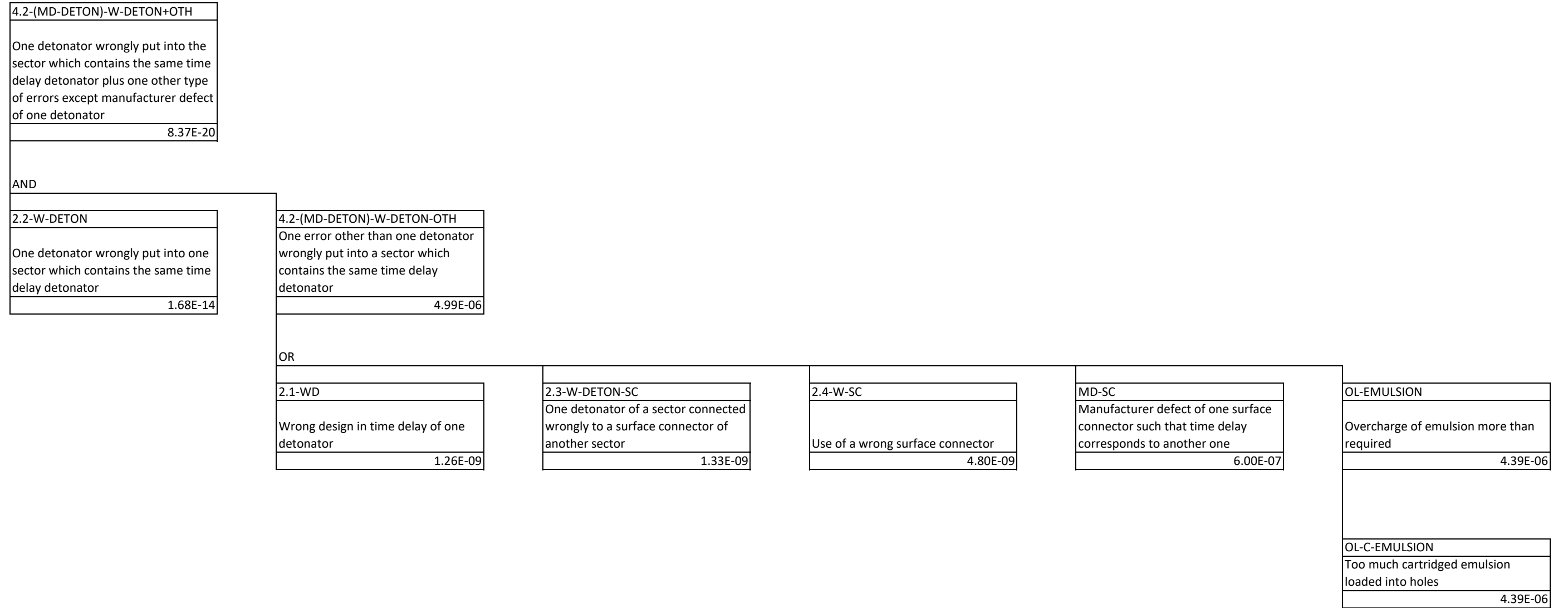
4(W-SC)-OL-EMULSION+OTH
Overcharge of emulsion more than required plus one other type of error except use of a wrong surface connector
1.08E-10

**4.1-(MD-DETON)-WD+OTH Wrong design in time delay of one detonator plus one other type of errors except manufacturer defect of one detonator**

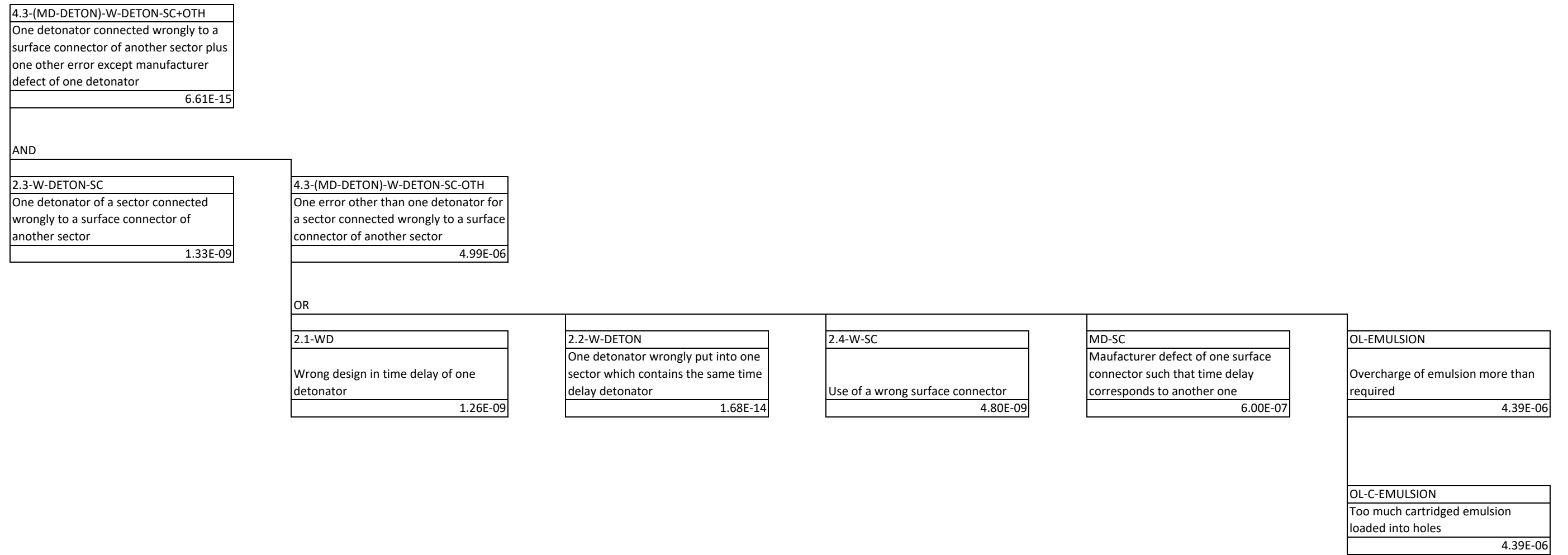




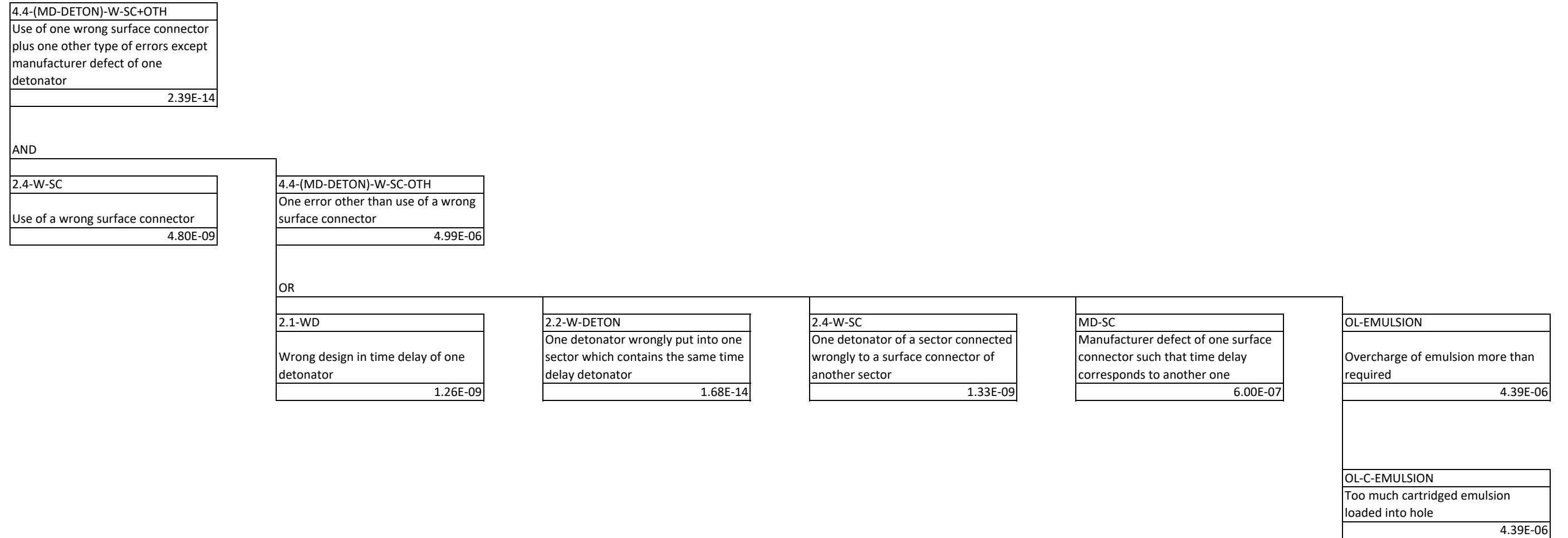
**4.2-(MD-DETON)-W-DETON+OTH One detonator wrongly put into the sector which contains the same time delay detonator plus one other type of errors except manufacturer defect of one detonator**



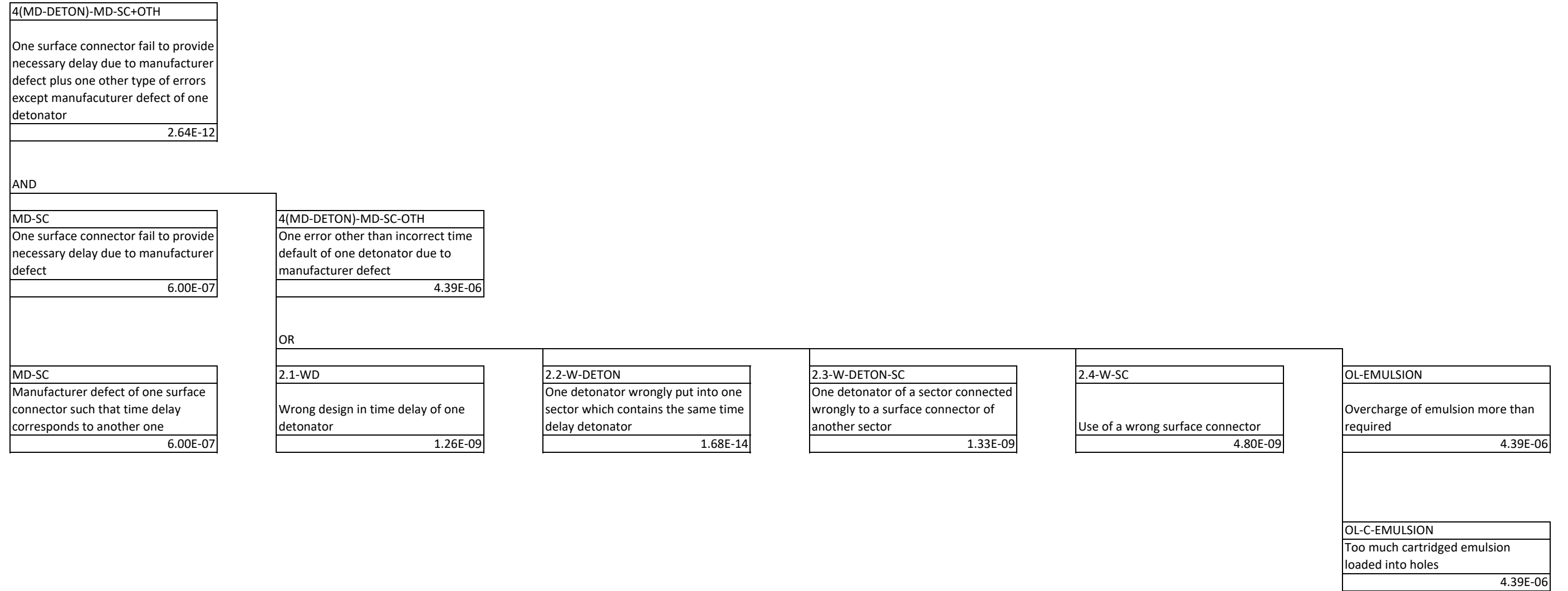
**4.3-(MD-DETON)-W-DETON-SC+OTH One detonator connected wrongly to a surface connector of another sector plus one other error except manufacturer defect of one detonator**



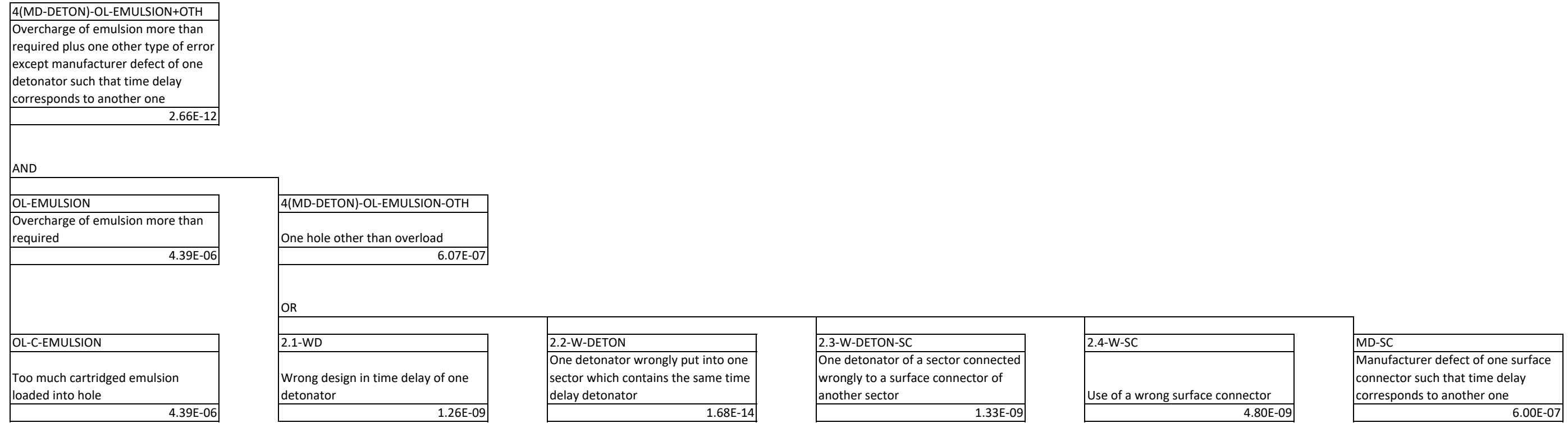
**4.4-(MD-DETON)-W-SC+OTH Use of one wrong surface connector plus one other type of errors except manufacturer defect of one detonator**



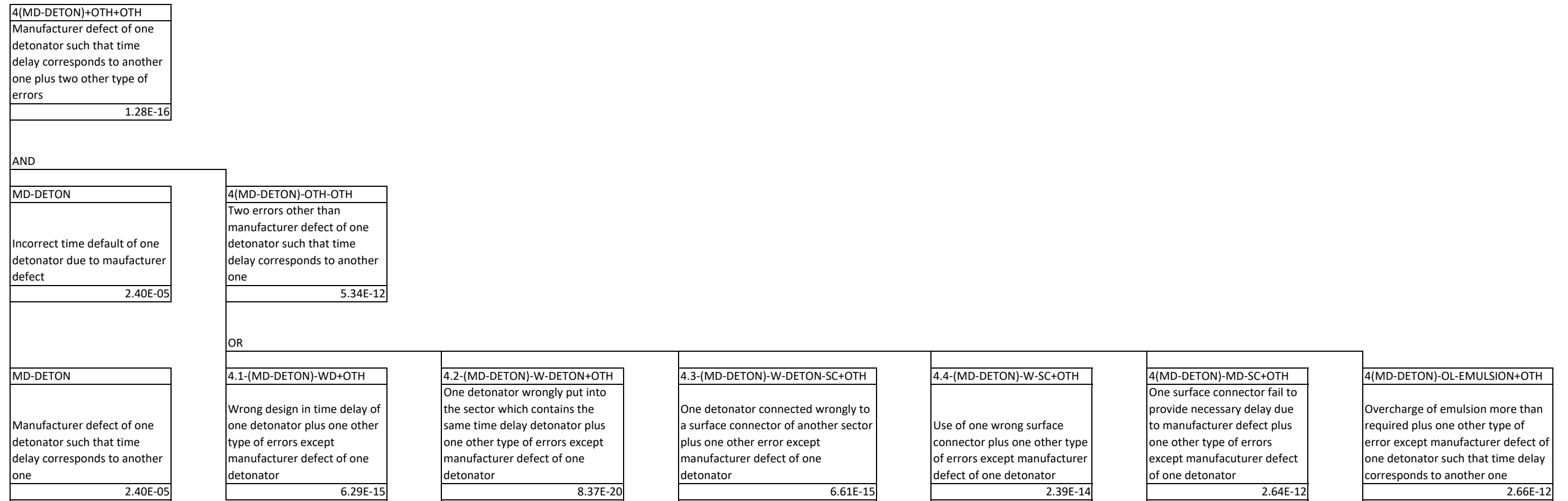
**4(MD-DETON)-MD-SC+OTH One surface connector fail to provide necessary delay due to manufacturer defect plus one other type of errors except manufacturer defect of one detonator**



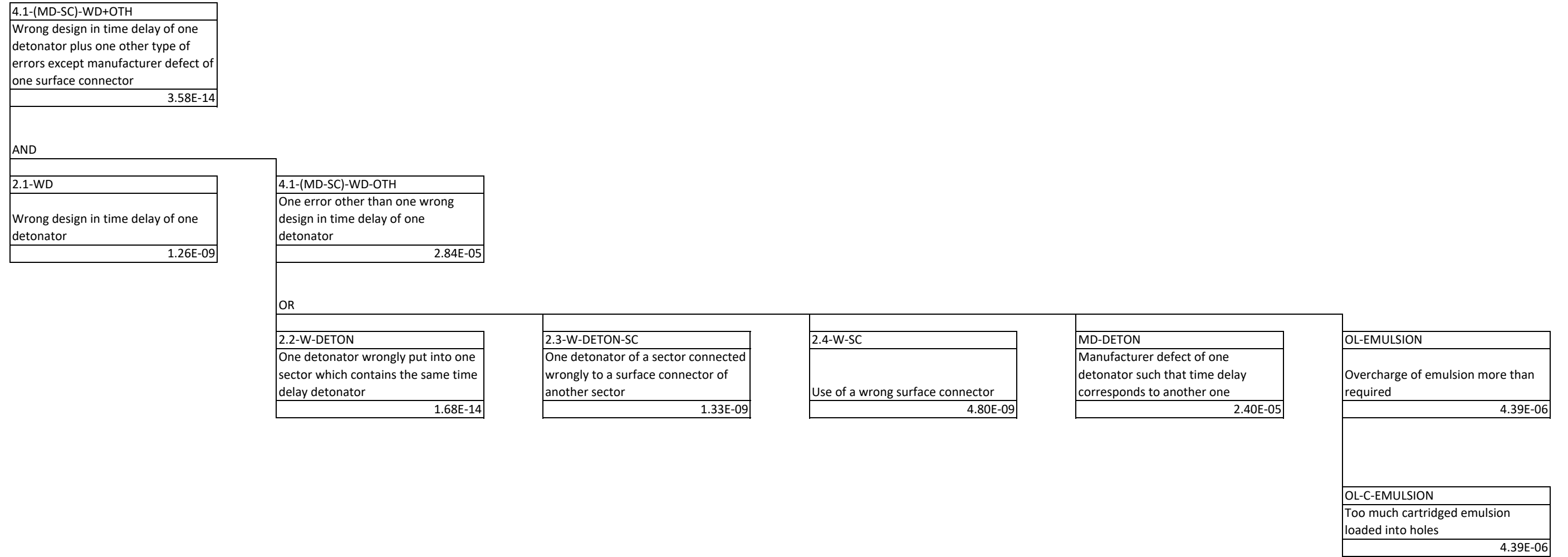
**4(MD-DETON)-OL-EMULSION+OTH Overcharge of emulsion more than required plus one other type of error except manufacturer defect of one detonator such that time delay corresponds to another one**



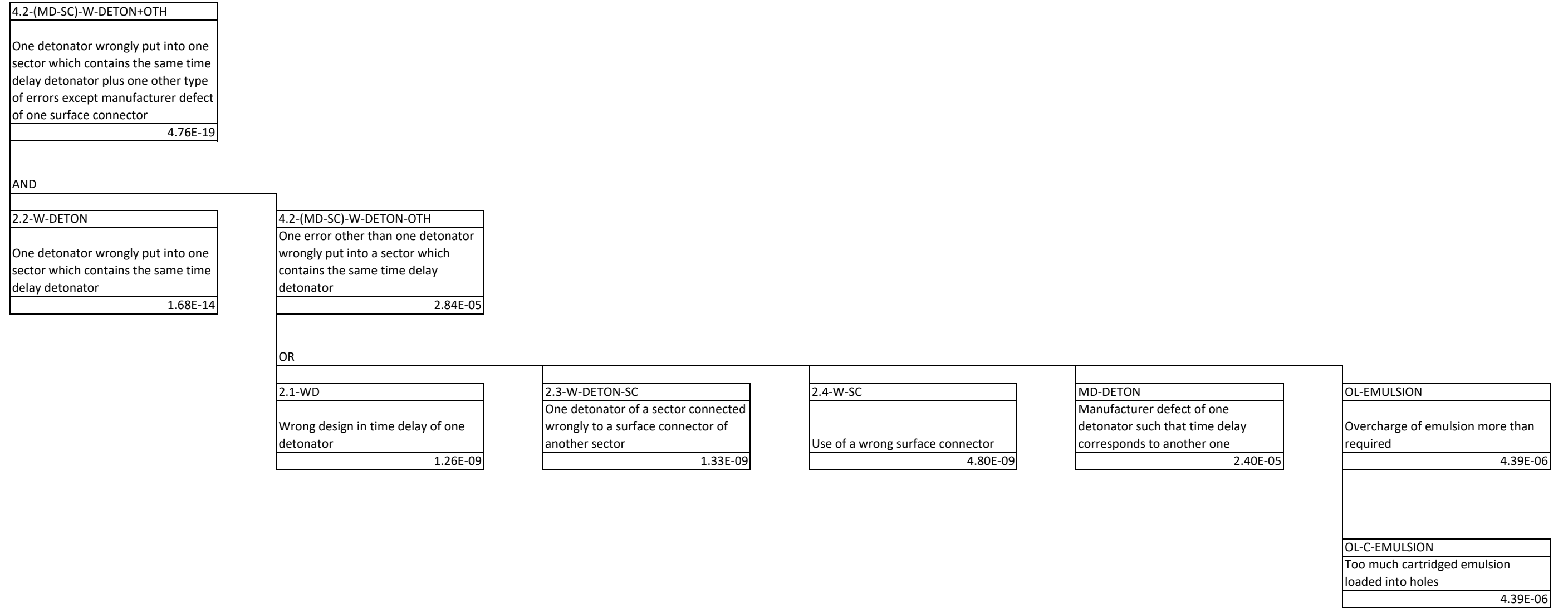
**4(MD-DETON)+OTH+OTH Manufacturer defect of one detonator such that time delay corresponds to another one plus two other type of errors**



**4.1-(MD-SC)-WD+OTH Wrong design in time delay of one detonator plus one other type of errors except manufacturer defect of one surface connector**

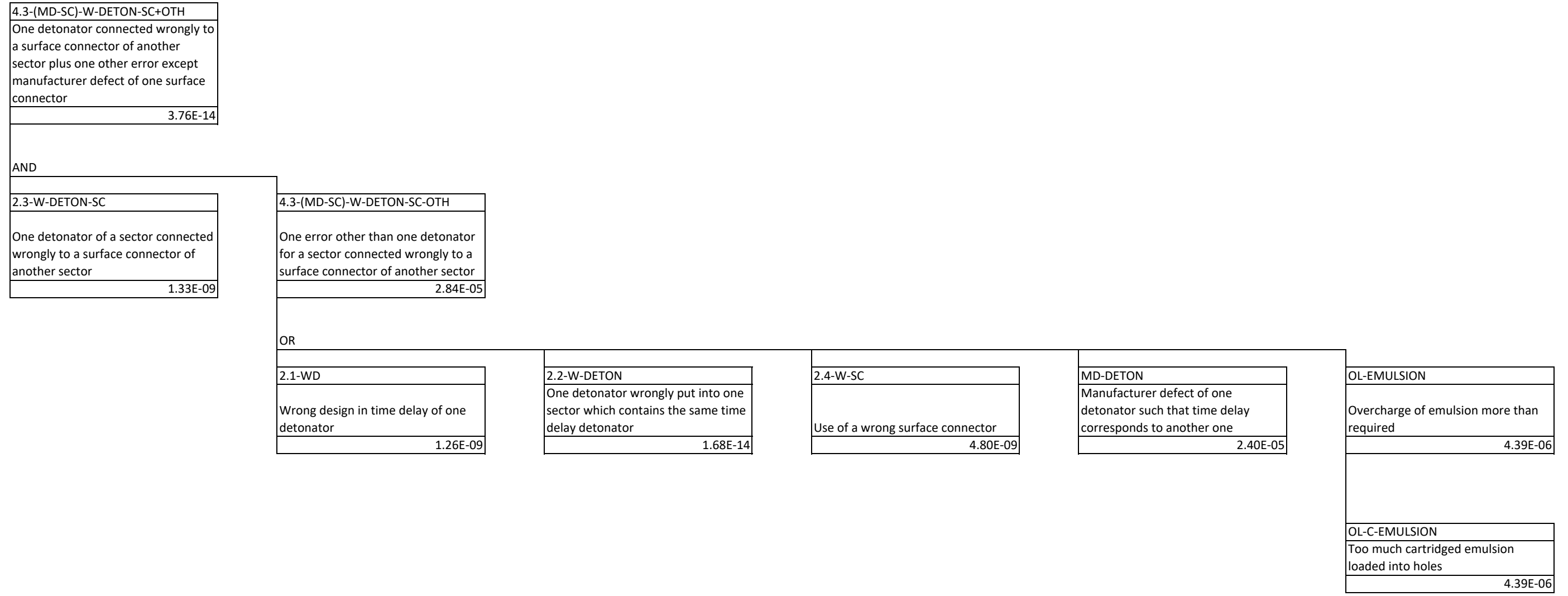


**4.2-(MD-SC)-W-DETON+OTH One detonator wrongly put into one sector which contains the same time delay detonator plus one other type of errors except manufacturer defect of one surface connector**

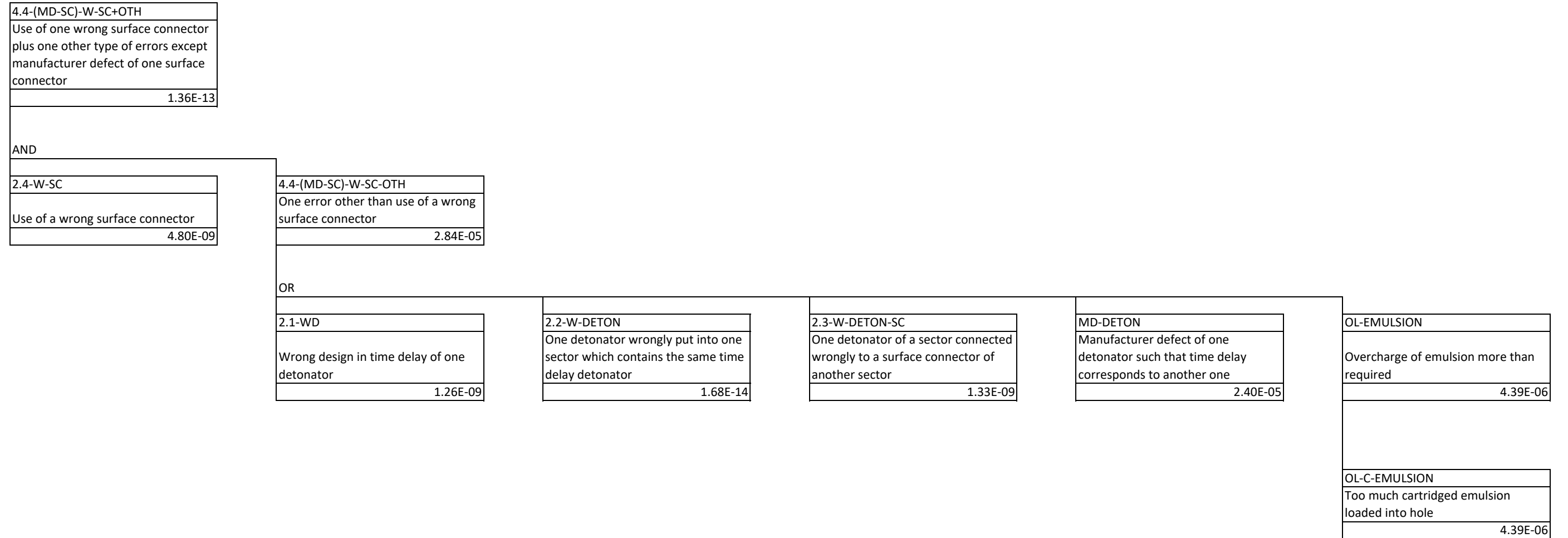




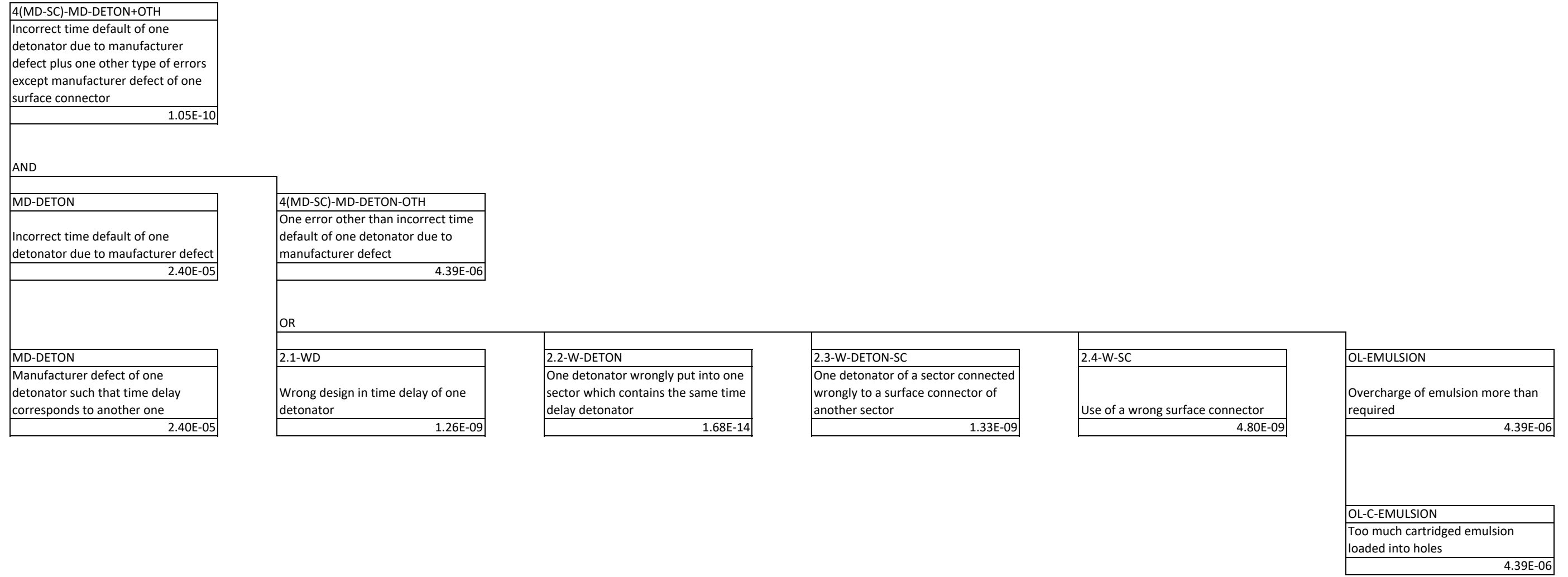
**4.3-(MD-SC)-W-DETON-SC+OTH One detonator connected wrongly to a surface connector of another sector plus one other error except manufacturer defect of one surface connector**



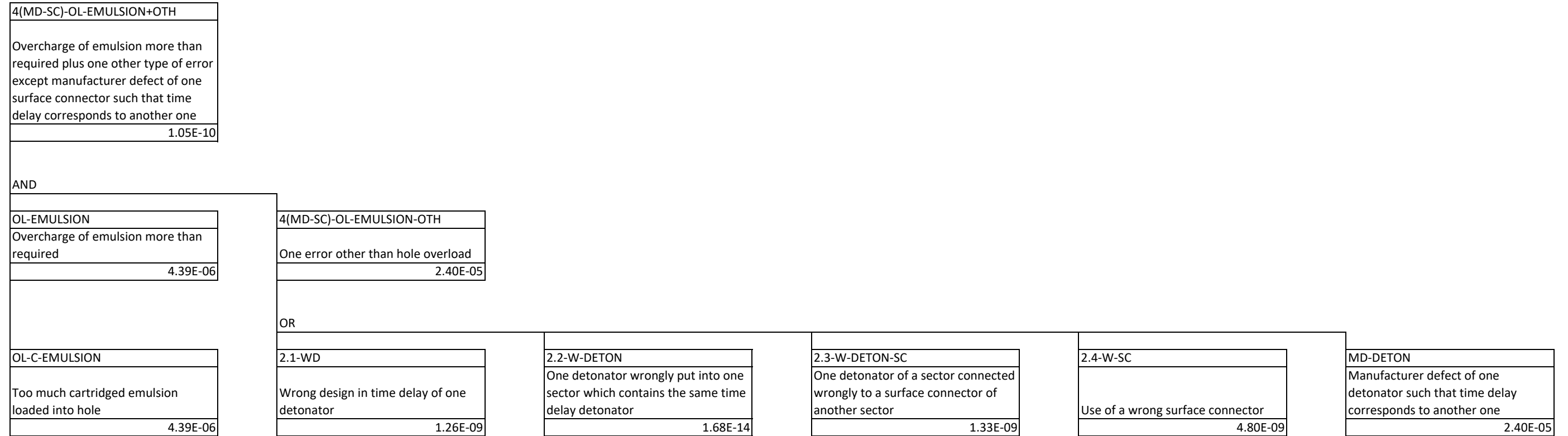
**4.4-(MD-SC)-W-SC+OTH Use of one wrong surface connector plus one other type of errors except manufacturer defect of one surface connector**



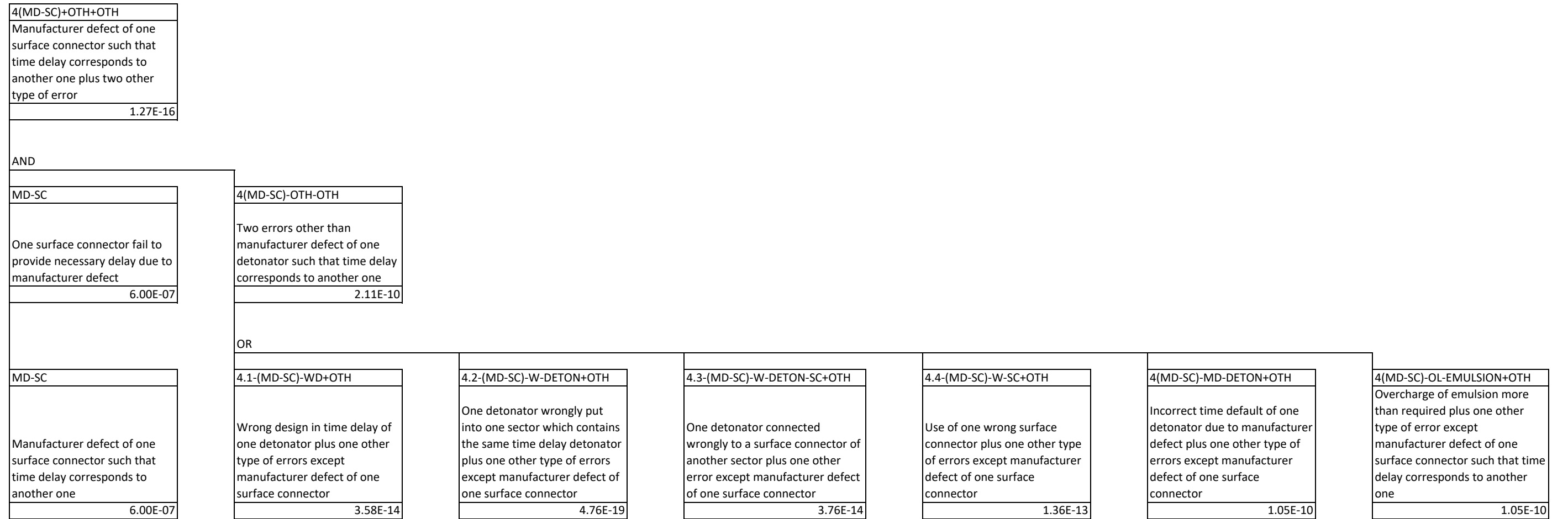
**4(MD-SC)-MD-DETON+OTH Incorrect time default of one detonator due to manufacturer defect plus one other type of errors except manufacturer defect of one surface connector**



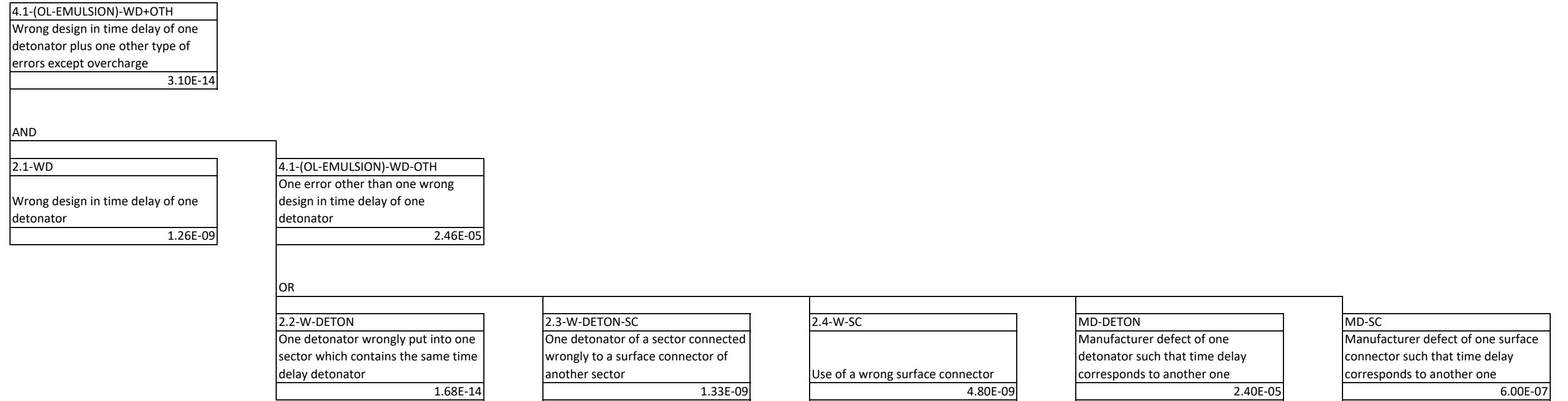
**4(MD-SC)-OL-EMULSION+OTH Overcharge of emulsion more than required plus one other type of error except manufacturer defect of one surface connector such that time delay corresponds to another one**



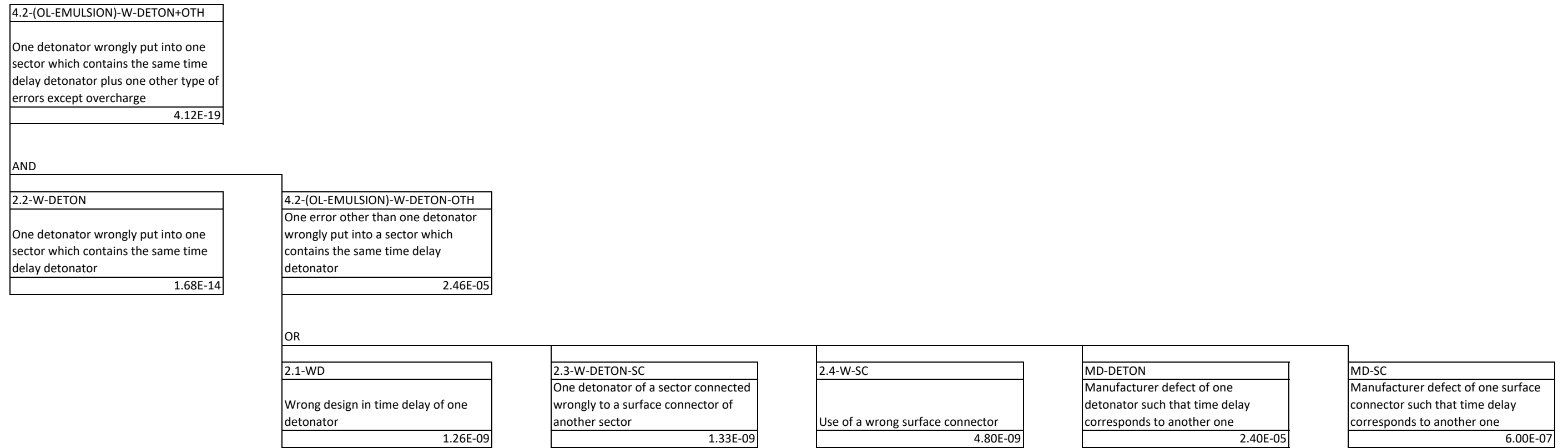
**4(MD-SC)+OTH+OTH Manufacturer defect of one surface connector such that time delay corresponds to another one plus two other type of error**



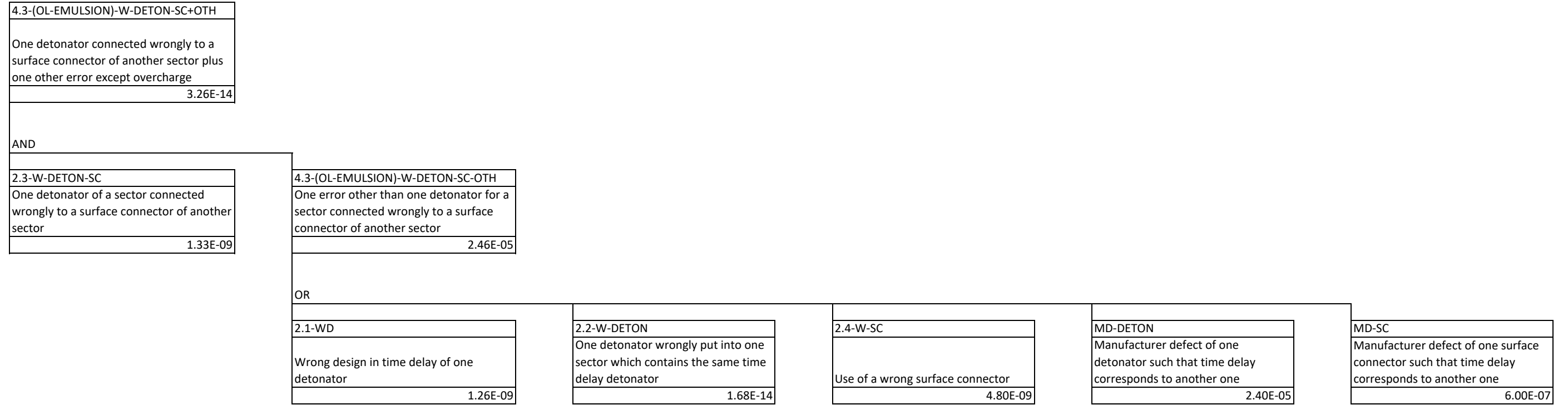
**4.1-(OL-EMULSION)-WD+OTH Wrong design in time delay of one detonator plus one other type of errors except overcharge**



**4.2-(OL-EMULSION)-W-DETON+OTH One detonator wrongly put into one sector which contains the same time delay detonator plus one other type of errors except overcharge**

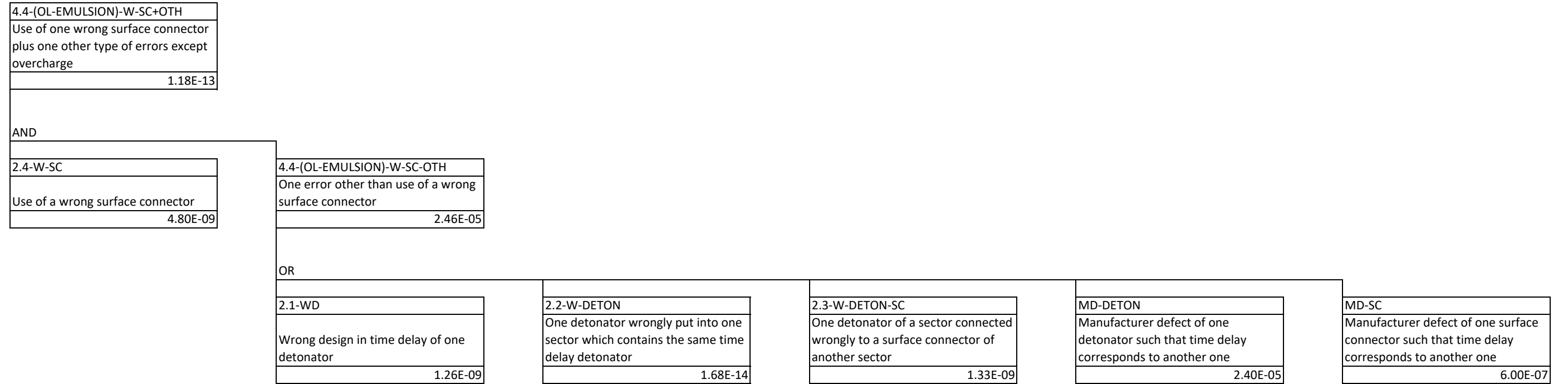


**4.3-(OL-EMULSION)-W-DETON-SC+OTH One detonator connected wrongly to a surface connector of another sector plus one other error except overcharge**

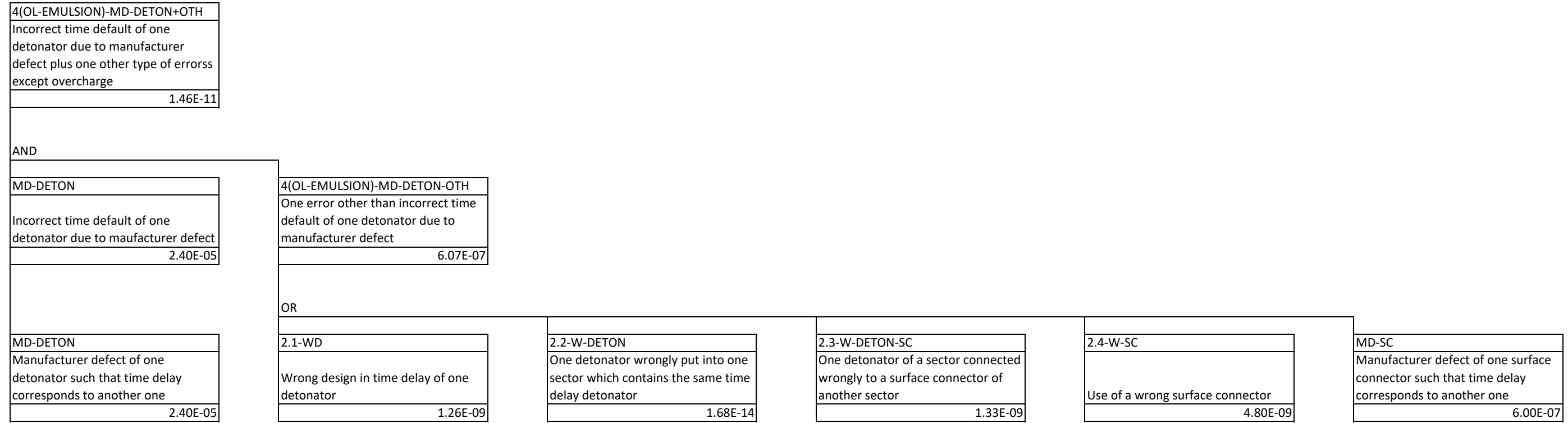




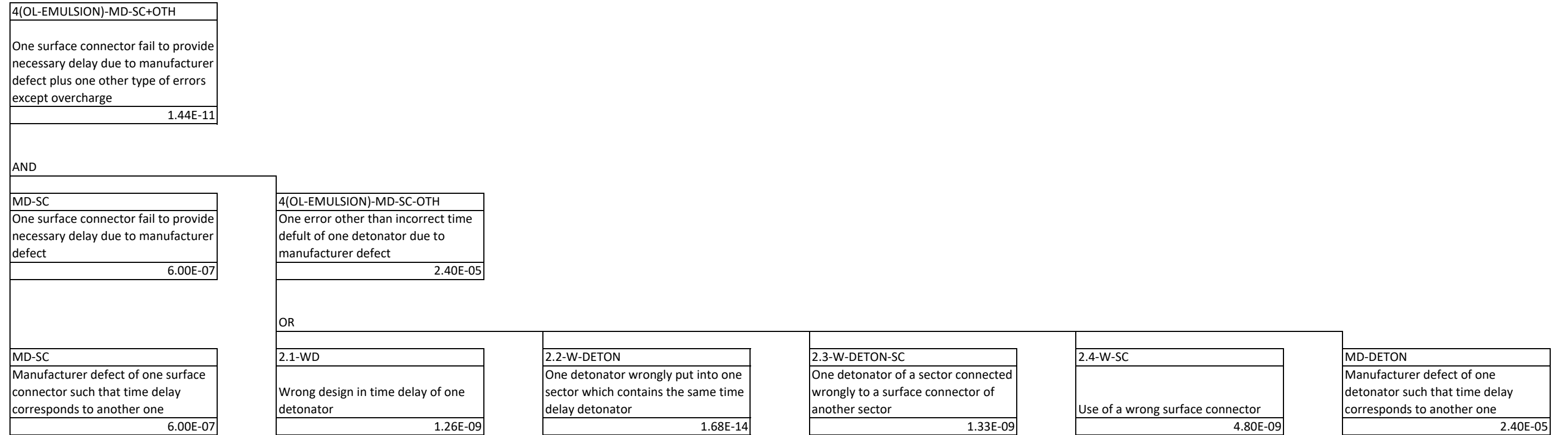
**4.4-(OL-EMULSION)-W-SC+OTH Use of one wrong surface connector plus one other type of errors except overcharge**



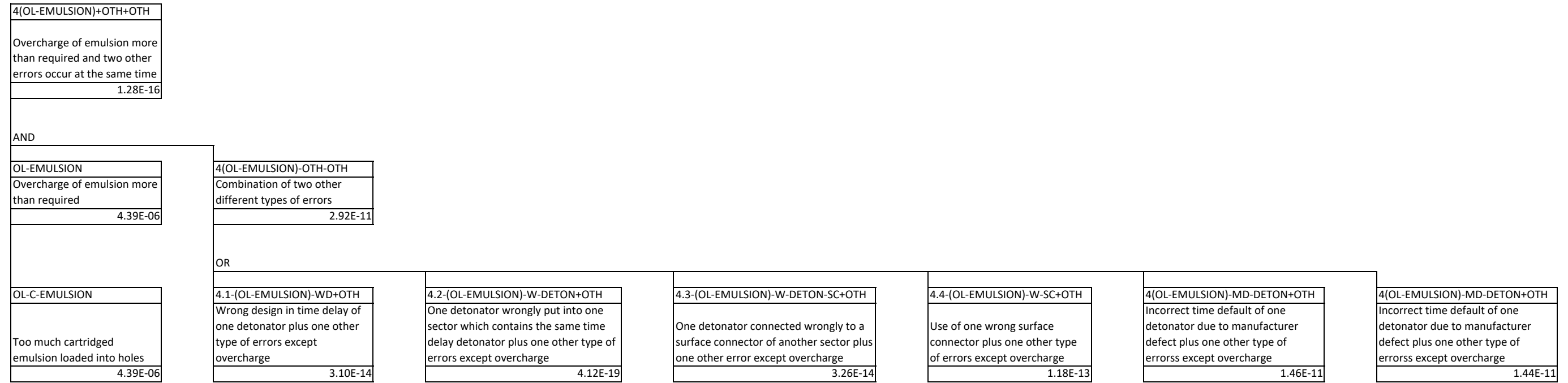
**4(OL-EMULSION)-MD-DETON+OTH Incorrect time default of one detonator due to manufacturer defect plus one other type of errors except overcharge**



**4(OL-EMULSION)-MD-SC+OTH One surface connector fail to provide necessary delay due to manufacturer defect plus one other type of errors except overcharge**



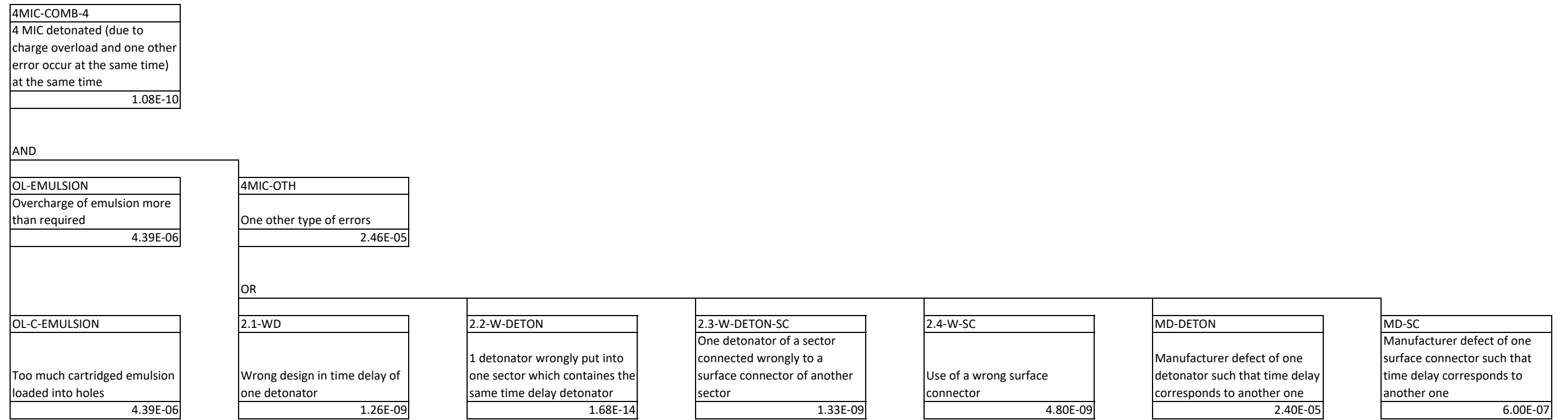
**4(OL-EMULSION)+OTH+OTH Overcharge of emulsion more than required and two other errors occur at the same time**



**4MIC-COMB-3                      4 MIC detonated (due to three different errors occur at the same time) at the same time**

<table border="1"> <tr> <td colspan="7">4MIC-COMB-3</td> </tr> <tr> <td colspan="7">4 MIC detonated (due to three different errors occur at the same time) at the same time</td> </tr> <tr> <td colspan="7" style="text-align: right;">3.84E-16</td> </tr> </table>							4MIC-COMB-3							4 MIC detonated (due to three different errors occur at the same time) at the same time							3.84E-16						
4MIC-COMB-3																											
4 MIC detonated (due to three different errors occur at the same time) at the same time																											
3.84E-16																											
OR																											
<table border="1"> <tr> <td>4(WD)+OTH+OTH</td> </tr> <tr> <td>Wrong design in time delay of one detonator plus two other type of errors</td> </tr> <tr> <td style="text-align: right;">3.08E-19</td> </tr> </table>	4(WD)+OTH+OTH	Wrong design in time delay of one detonator plus two other type of errors	3.08E-19	<table border="1"> <tr> <td>4(W-DETON)+OTH+OTH</td> </tr> <tr> <td>One detonator wrongly put into one sector which contains the same time delay detonator plus two other type of errors</td> </tr> <tr> <td style="text-align: right;">4.11E-24</td> </tr> </table>	4(W-DETON)+OTH+OTH	One detonator wrongly put into one sector which contains the same time delay detonator plus two other type of errors	4.11E-24	<table border="1"> <tr> <td>4(W-DETON-SC)+OTH+OTH</td> </tr> <tr> <td>One detonator connected wrongly to a surface connector of another sector plus two other type of errors</td> </tr> <tr> <td style="text-align: right;">3.24E-19</td> </tr> </table>	4(W-DETON-SC)+OTH+OTH	One detonator connected wrongly to a surface connector of another sector plus two other type of errors	3.24E-19	<table border="1"> <tr> <td>4(W-SC)+OTH+OTH</td> </tr> <tr> <td>Use of a wrong surface connector plus two other type of errors</td> </tr> <tr> <td style="text-align: right;">1.17E-18</td> </tr> </table>	4(W-SC)+OTH+OTH	Use of a wrong surface connector plus two other type of errors	1.17E-18	<table border="1"> <tr> <td>4(MD-DETON)+OTH+OTH</td> </tr> <tr> <td>Manufacturer defect of one detonator such that time delay corresponds to another one plus two other type of errors</td> </tr> <tr> <td style="text-align: right;">1.28E-16</td> </tr> </table>	4(MD-DETON)+OTH+OTH	Manufacturer defect of one detonator such that time delay corresponds to another one plus two other type of errors	1.28E-16	<table border="1"> <tr> <td>4(MD-SC)+OTH+OTH</td> </tr> <tr> <td>Manufacturer defect of one surface connector such that time delay corresponds to another one plus two other type of error</td> </tr> <tr> <td style="text-align: right;">1.27E-16</td> </tr> </table>	4(MD-SC)+OTH+OTH	Manufacturer defect of one surface connector such that time delay corresponds to another one plus two other type of error	1.27E-16	<table border="1"> <tr> <td>4(OL-EMULSION)+OTH+OTH</td> </tr> <tr> <td>Overcharge of emulsion more than required and two other errors occur at the same time</td> </tr> <tr> <td style="text-align: right;">1.28E-16</td> </tr> </table>	4(OL-EMULSION)+OTH+OTH	Overcharge of emulsion more than required and two other errors occur at the same time	1.28E-16
4(WD)+OTH+OTH																											
Wrong design in time delay of one detonator plus two other type of errors																											
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1.27E-16																											
4(OL-EMULSION)+OTH+OTH																											
Overcharge of emulsion more than required and two other errors occur at the same time																											
1.28E-16																											

**4MIC-COMB-4                      4 MIC detonated (due to charge overload and one other error occur at the same time) at the same time**



**3.1-WD**

**Wrong design in time delay of two detonators**

3.1-WD
Wrong design in time delay of two detonators
1.26E-11

AND

2.1-WD
Wrong design in time delay of one detonator
1.26E-09

P-AD-DETON
Wrong design in time delay of additional detonator
1.00E-02

**3.2-W-DETON**

**Two detonator wrongly put into one sector which contains the same time delay detonator**

3.2-W-DETON
Two detonator wrongly put into one sector which contains the same time delay detonator
1.68E-16

AND

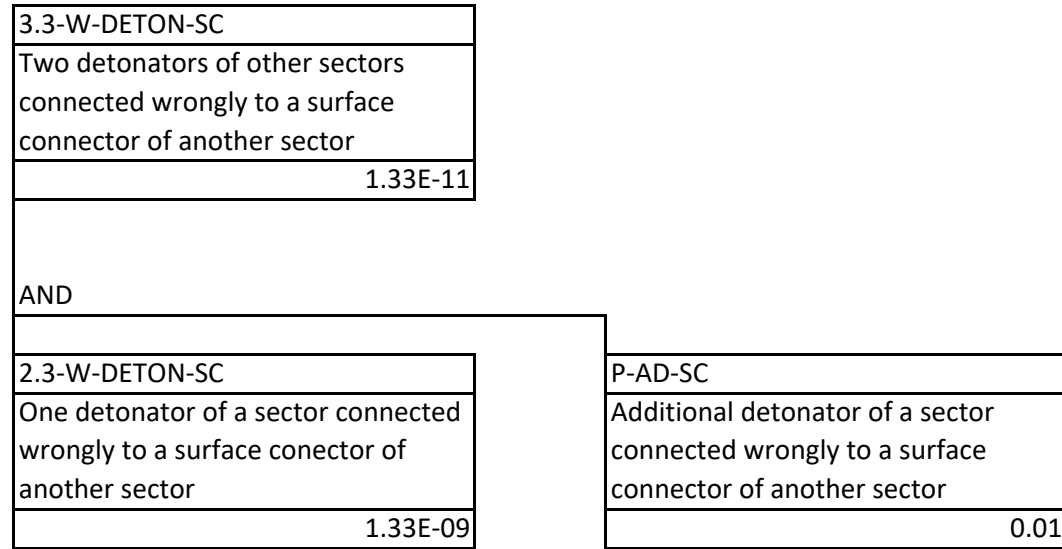
2.2-W-DETON
One detonator wrongly put into one sector which contains the same time delay detonator
1.68E-14

P-AD-DETON
Additional detonator wrongly put into one sector which contains the same time delay detonator
0.01



**3.3-W-DETON-SC**

**Two detonators of othe sectors connected wrongly to a surface connector of another sector**



**3.4-W-SC**

**Use of two wrong surface connector**

3.4-W-SC
Use of two wrong surface connector
4.80E-11

AND

2.4-W-SC
Use of wrong surface connector
4.80E-09

P-AD-SC
Additional use of wrong surface connector
0.01

**3MD-DETON**

**Incorrect time default of 2 detonators due to manufacturer defect**

3MD-DETON
Incorrect time default of 2 detonators due to manufacturer defect
2.40E-07

AND

MD-DETON
Manufacturer defect of one detonator such that time delay corresponds to another one
2.40E-05

P-AD-DETON
Manufacturer defect of another detonator such that time delay corresponds to another one
0.01

**3MD-SC**

**Surface connector fails to provide necessary delay due to manufacturer defect**

3MD-SC
Surface connector fails to provide necessary delay due to manufacturer defect
6.00E-09

AND

MD-SC
Manufacturer defect of one surface connector such that time delay corresponds to another one
6.00E-07

P-AD-SC
Manufacturer defect of another surface connector such that time delay corresponds to another one
0.01

**3MIC-ER-COMB                      3 MIC detonated at the same time (Due to combination of two types of errors)**

3MIC-ER-COMB
3 MIC detonated at the same time (Due to combination of two types of errors)
2.45E-10

OR

2.1-WD+OTH
Wrong design in time delay of one detonator plus one other type of errors
3.65E-14

2.2-W-DETON+OTH
One detonator wrongly put into one sector which contains the same time delay detonator plus one other type of errors
4.86E-19

2.3-W-DETON+OTH
One detonator of a sector connected wrongly to a surface connector of another sector plus one other type of errors
3.84E-14

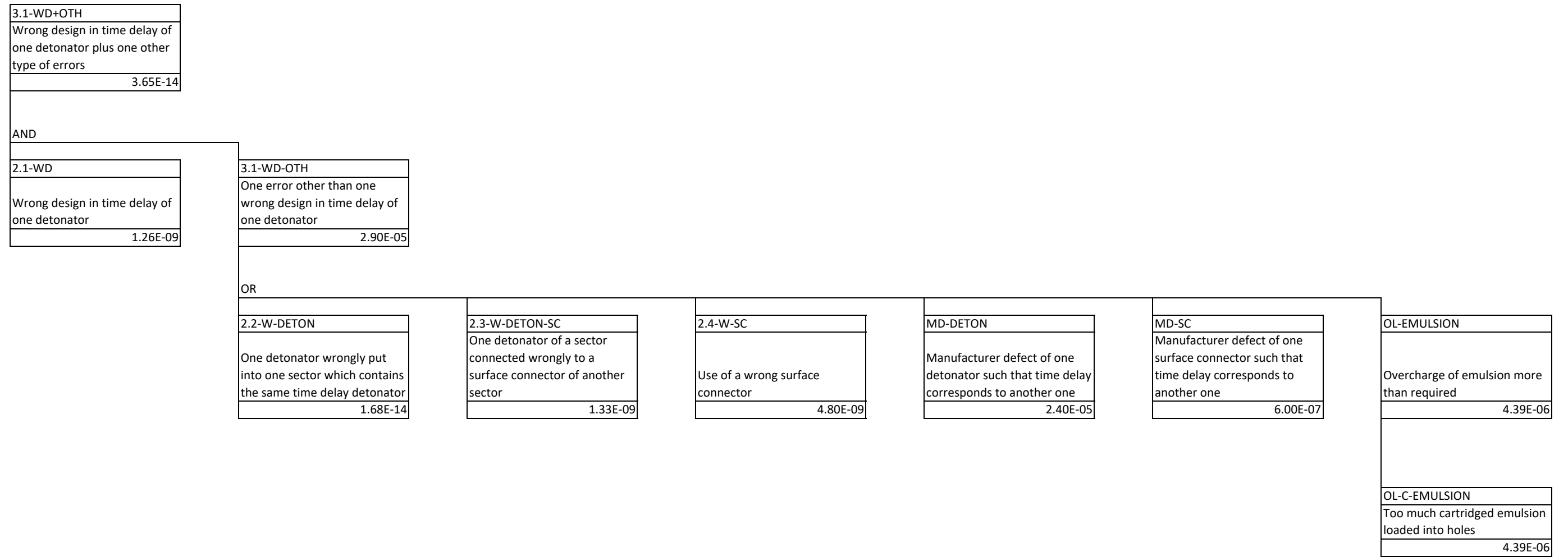
2.4-W-SC+OTH
Use of a wrong surface connector plus one other type of errors
1.39E-13

MD-DETON+OTH
Incorrect time default of one detonator due to manufacturer defect plus one other type of errors
1.20E-10

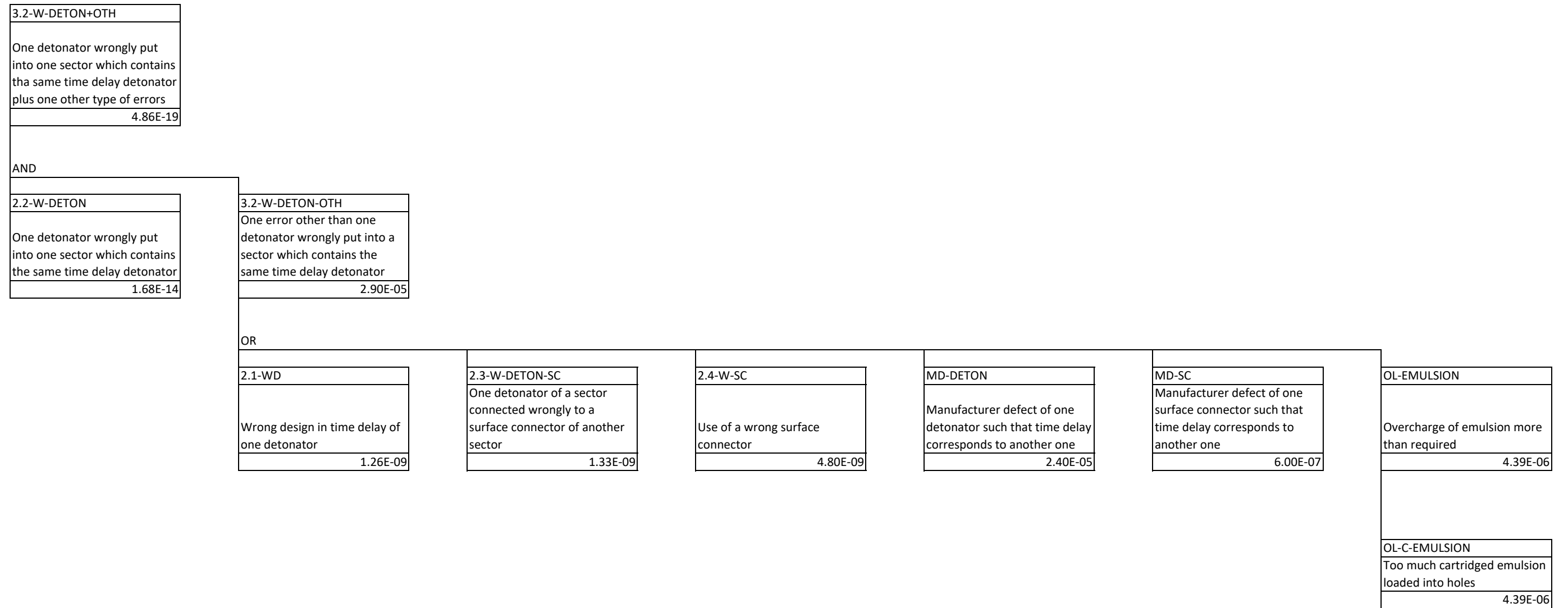
MD-SC+OTH
Surface connector fails to provide necessary delay due to manufacturer defect plus one other type of errors
1.70E-11

OL-EMULSION+OTH
Overcharge of emulsion more than required plus one other type of errors
1.08E-10

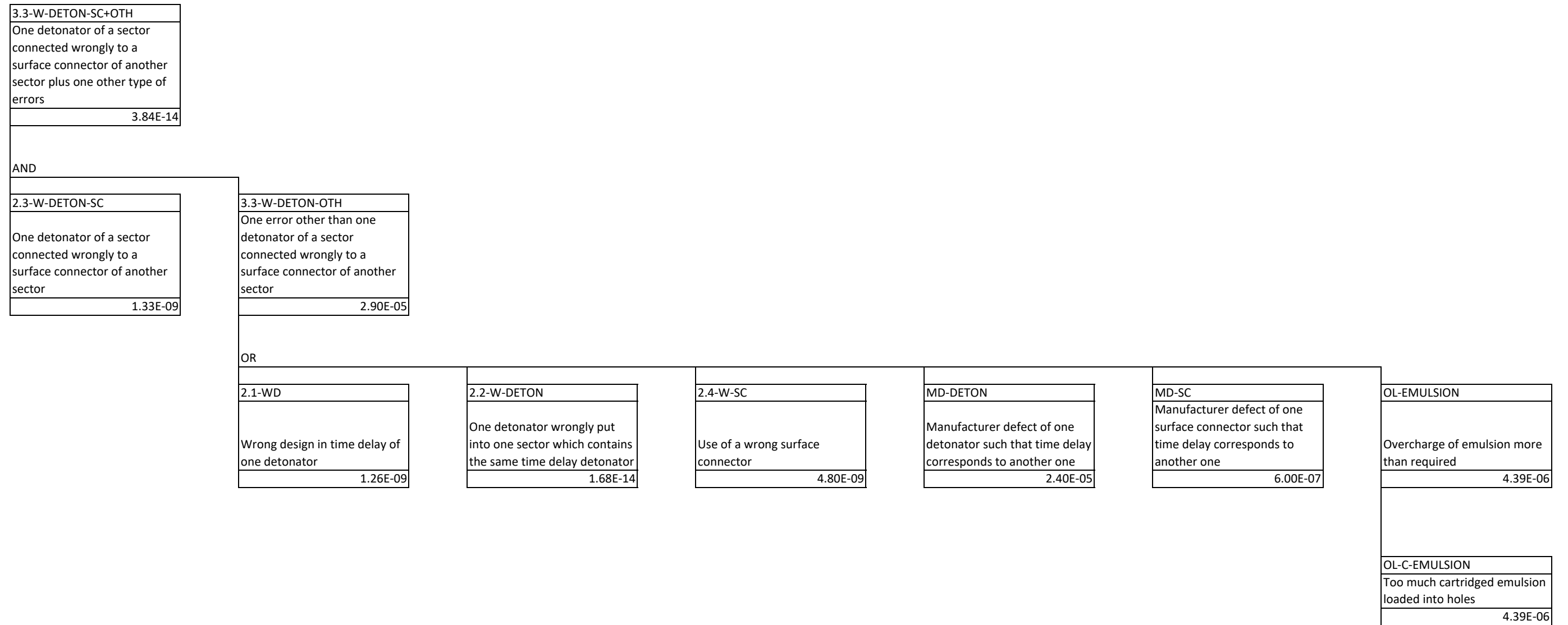
**3.1-WD+OTH Wrong design in time delay of one detonator plus one other type of errors**



**3.2-W-DETON+OTH**      **One detonator wrongly put into one sector which contains the same time delay detonator plus one other type of errors**

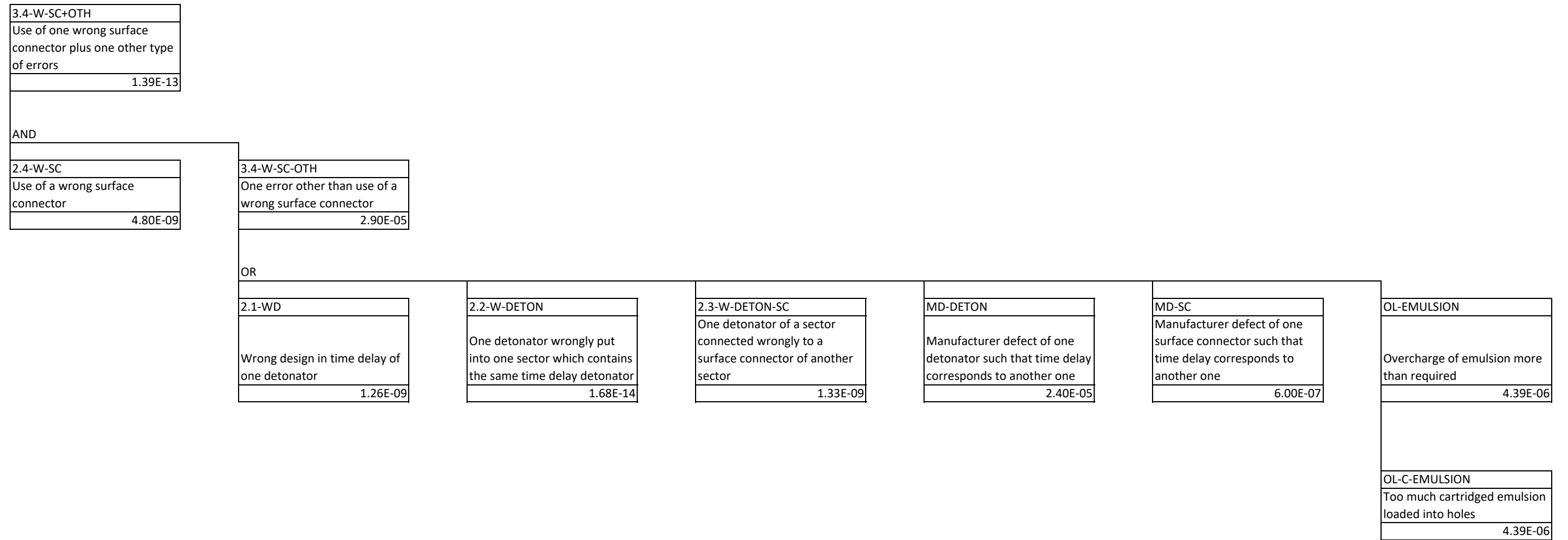


**3.3-W-DETON-SC+OTH**      **One detonator of a sector connected wrongly to a surface connector of another sector plus one other type of errors**



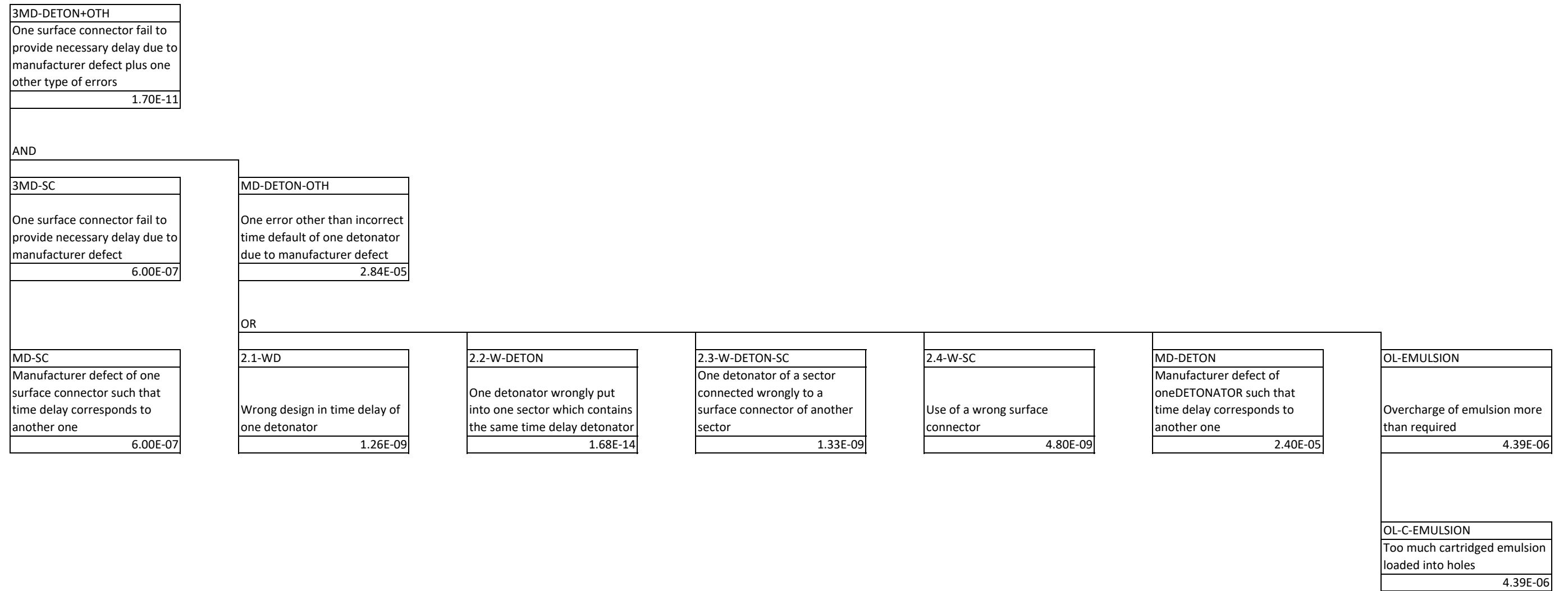


**3.4-W-SC+OTH Use of a wrong surface connector plus one other types of errors**

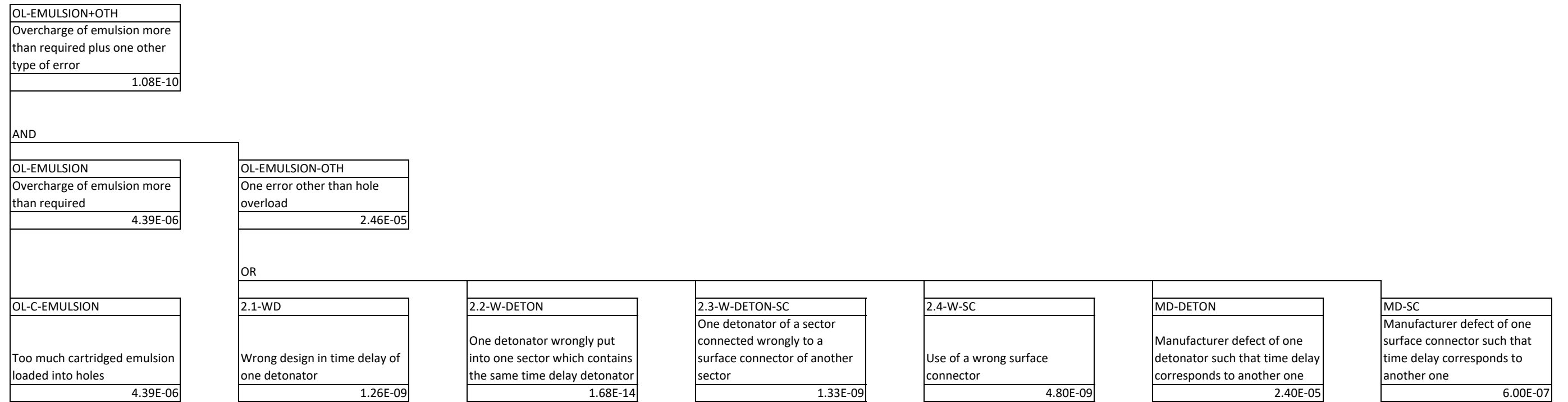




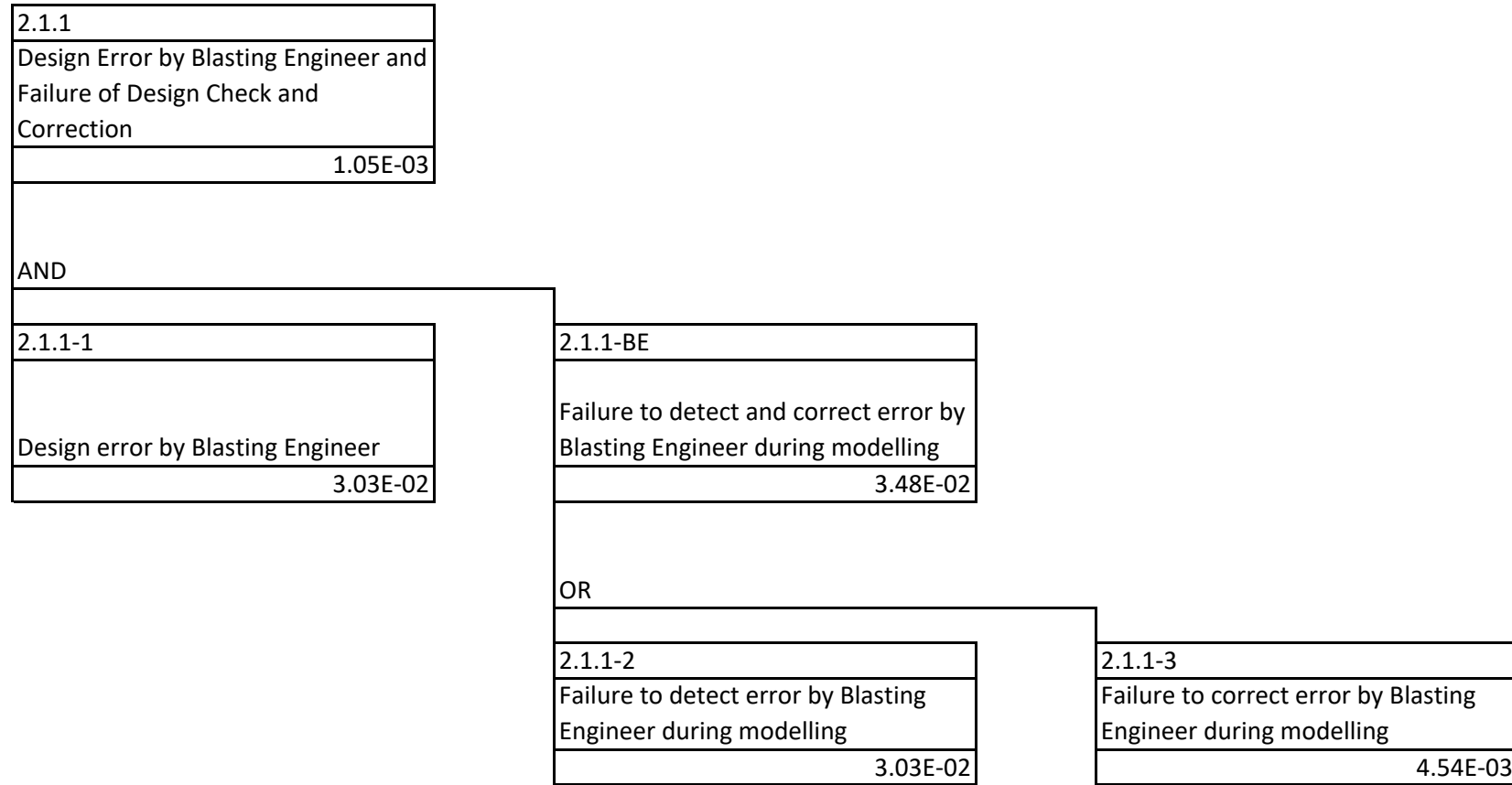
**3MD-SC+OTH One surface connector fail to provide necessary delay due to manufacturer defect plus one other type of errors**



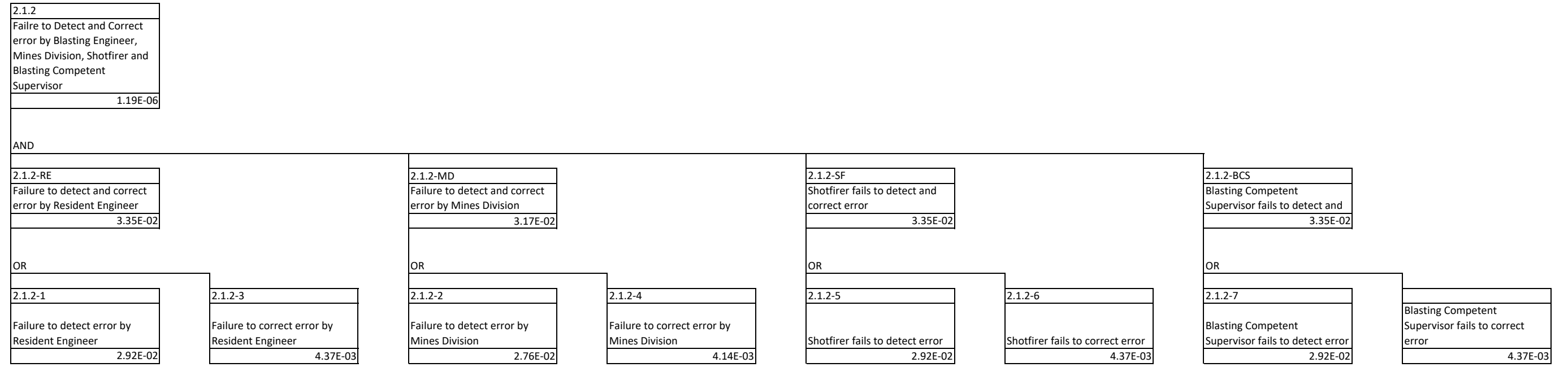
**OL-EMULSION+OTH Overcharge of emulsion more than required plus one other type of error**



**2.1.1 Design Error by Blasting Engineer and Failure of Design Check and Correction**

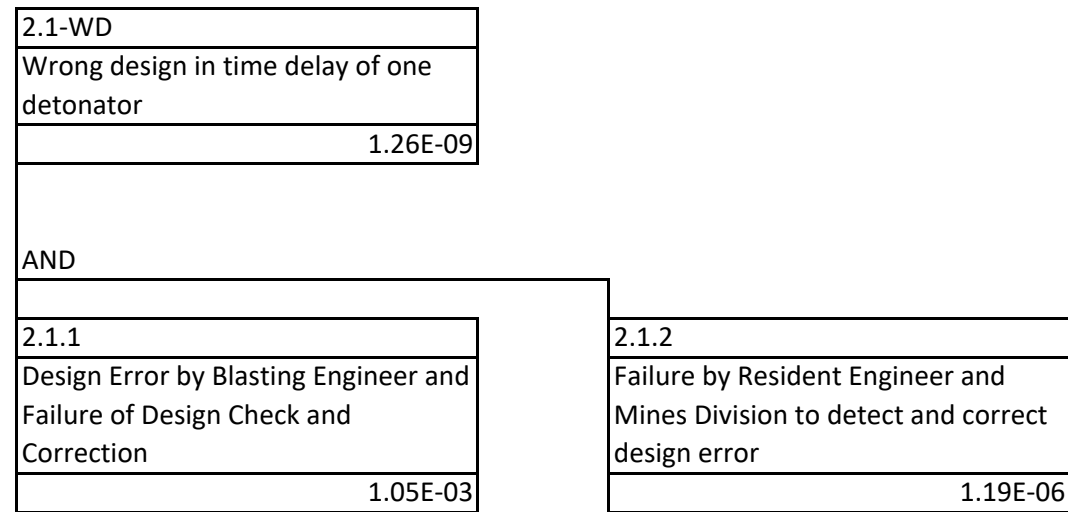


**2.1.2 Failure to detect and correct error by Blasting Engineer, Mines Division, Shotfirer and Blasting Competent Supervisor**

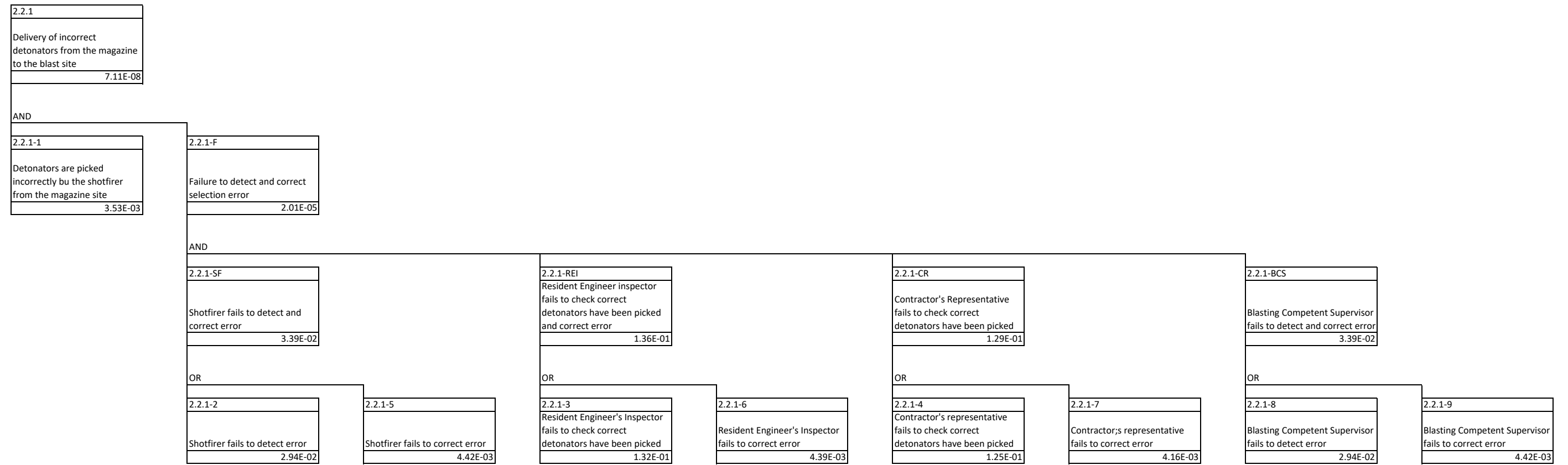


**2.1-WD**

**Wrong design in time delay of one detonator**

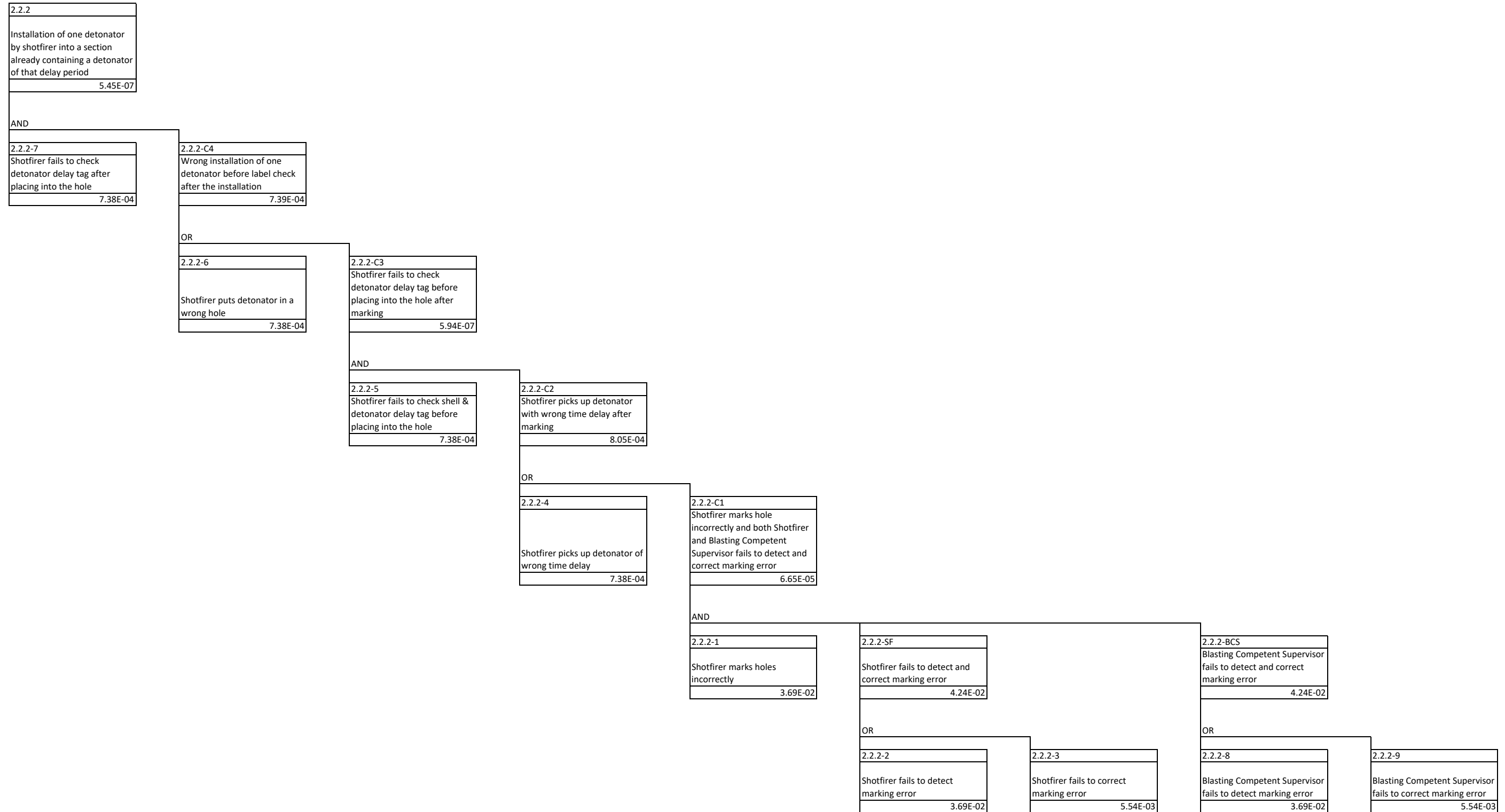


**2.2.1 Delivery of incorrect detonators from the magazine to the blast site**

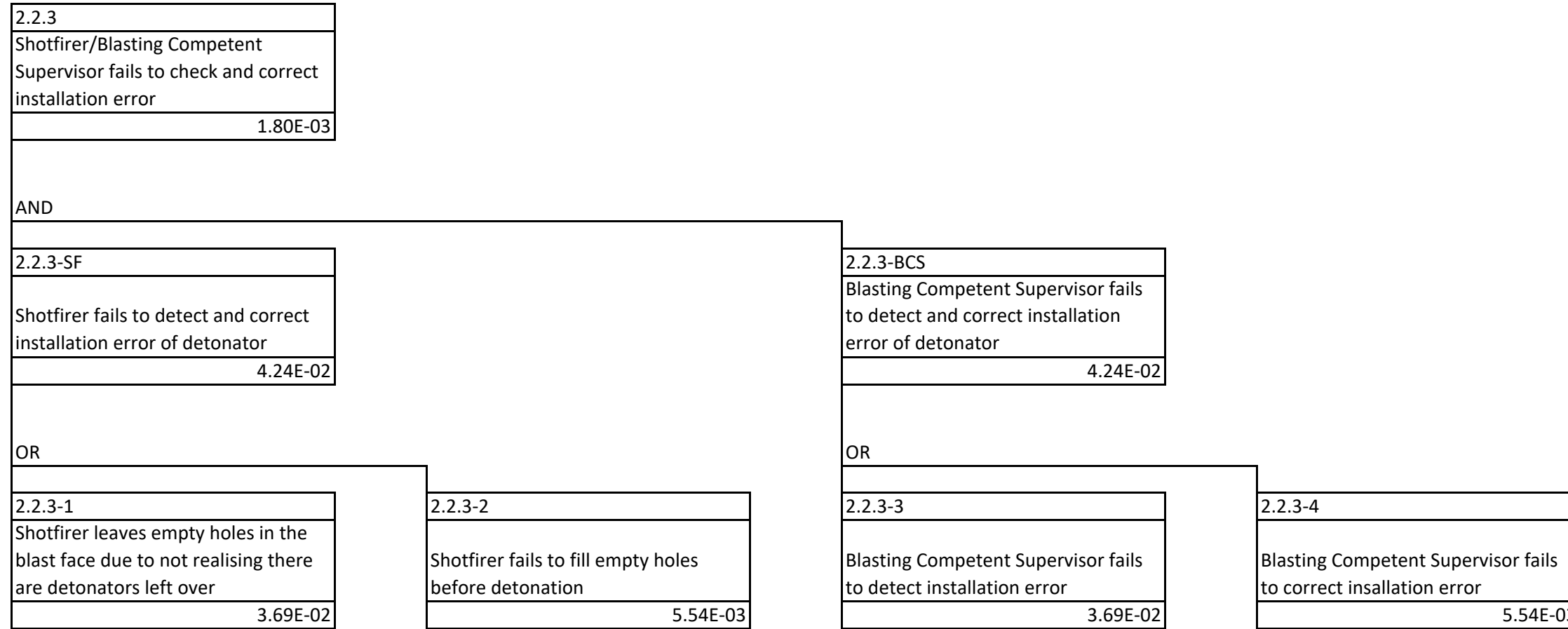




**2.2.2 Installation of one detonator by shotfirer into a section already containing a detonator of that delay period**



**2.2.3 Shotfirer/Blasting Competent Supervisor fails to check and correct installation error**



**2.2-W-DETON**

**One detonator wrongly put into one sector which contains the same time delay detonator**

2.2-W-DETON
One detonator wrongly put into one sector which contains the same time delay detonator
1.68E-14

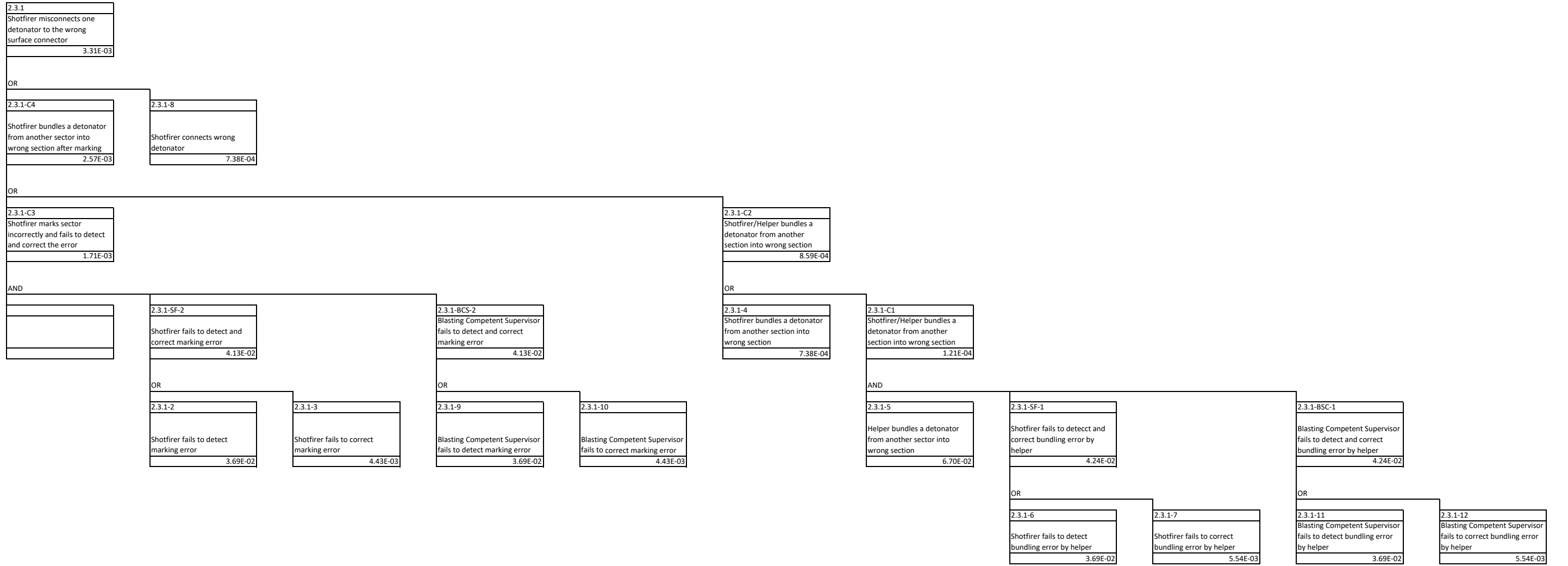
AND

2.2.1
Delivery of incorrect detonators from the magazine to the blast site
7.11E-08

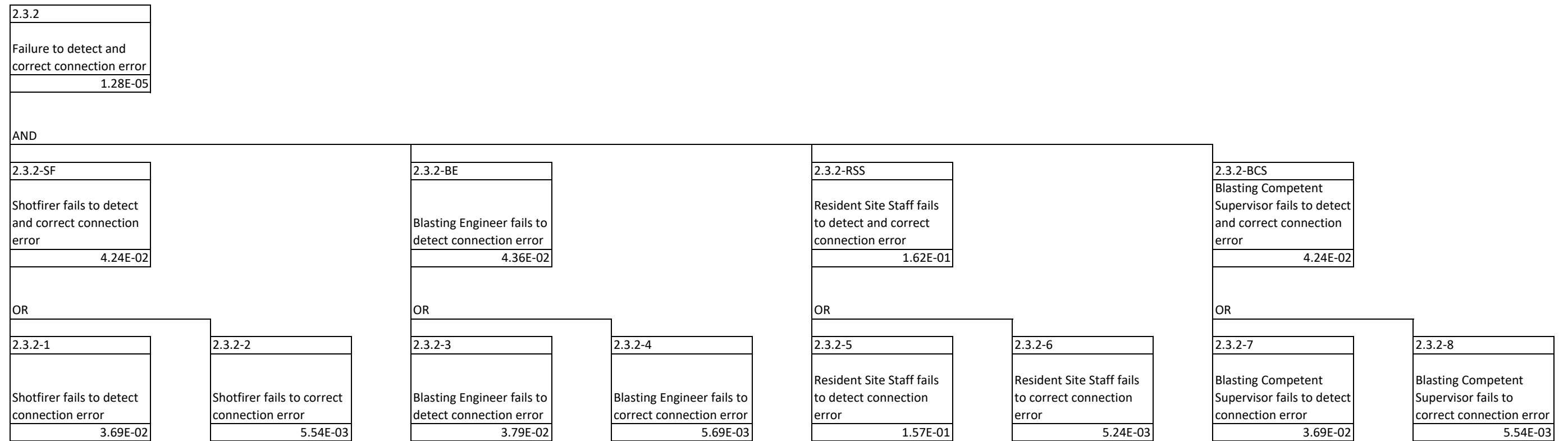
2.2.2
Installation of One Detonator by Shotfirer into a section already containing a detonator of that delay period
1.31E-04

2.2.3
Shotfirer /Blasting Competent Supervisor Fails to Check and Correct Installation Error
1.80E-03

2.3.1 Shotfirer misconnects one detonator to the wrong surface connector



**2.3.2 Failure to detect and correct connection error**



**2.3-W-DETON-SC**

**One detonator of a sector connected wrongly to a surface connector of another sector**

2.3-W-DETON-SC
One detonator of a sector connected wrongly to a surface connector of another sector
1.33E-09

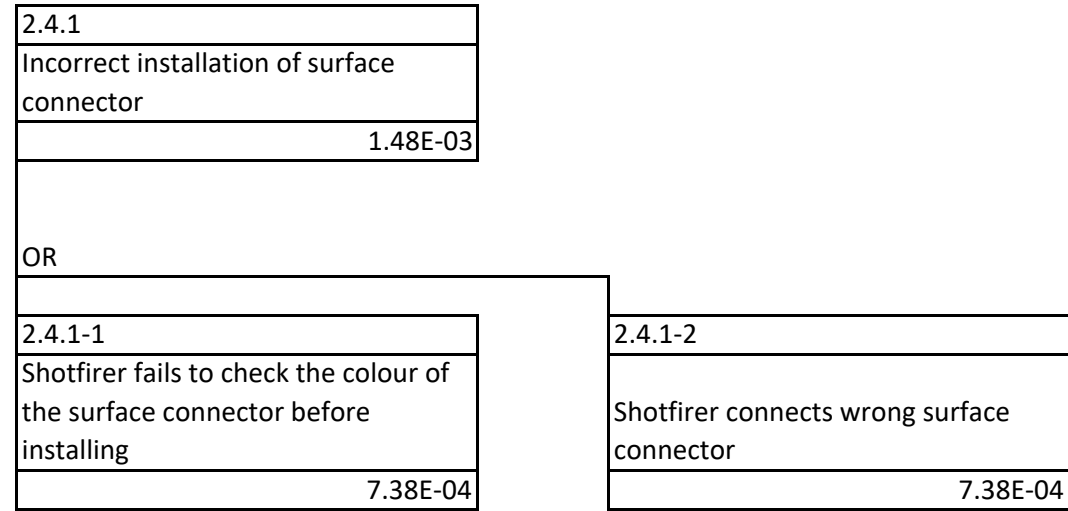
AND

2.3.1
Shotfirer misconencts one detonator to the wrong surface connector
7.93E-01

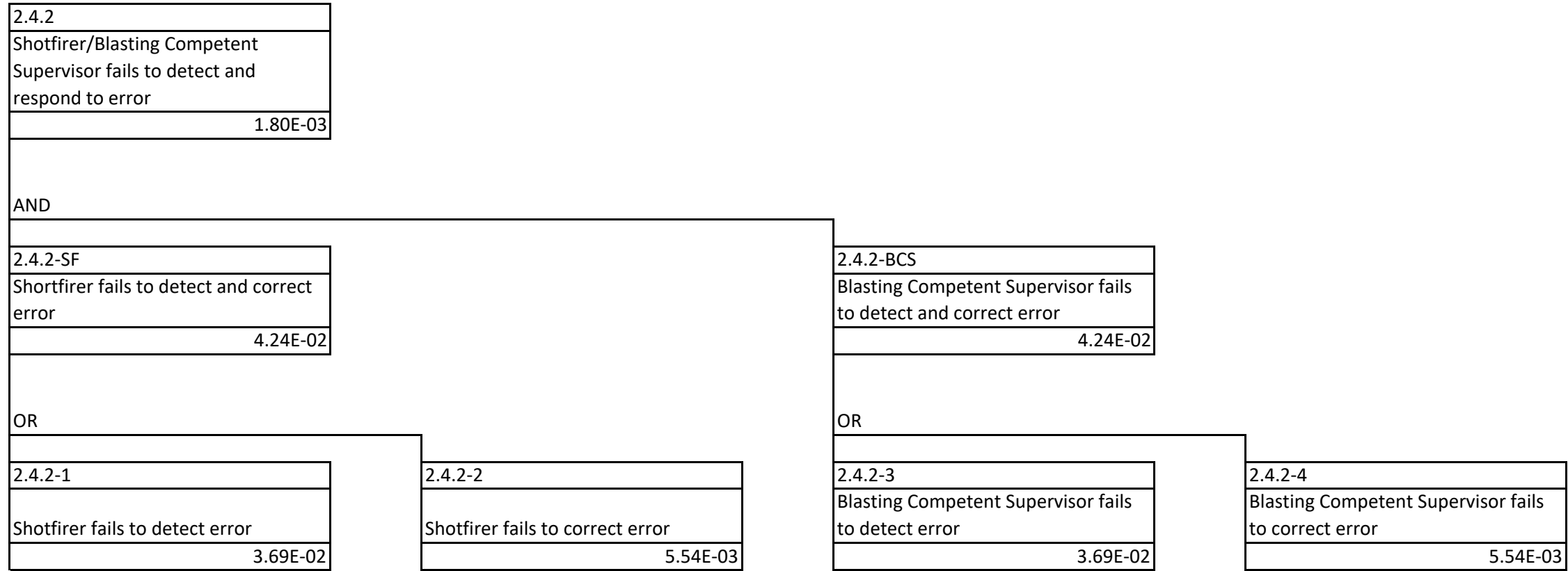
2.3.2
Failure to detect and correct connection error
1.28E-05

2.2.2
Installation of one detonator by Shotfirer into a section already containing a detonator of that delay period
1.31E-04

**2.4.1 Incorrect Installation of Surface Connector**

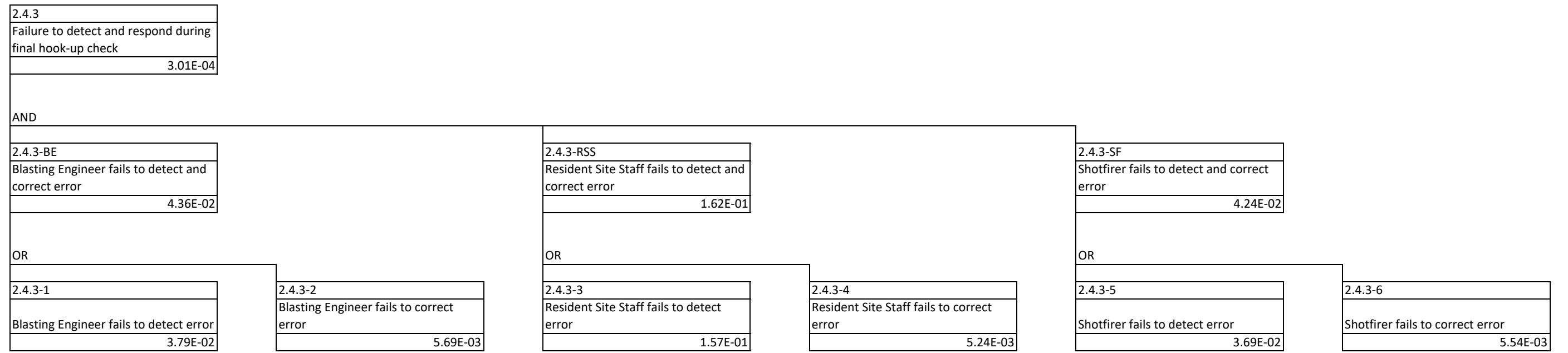


**2.4.2 Shotfirer/Blasting Competent Supervisor fails to detect and respond to error**





**2.4.3 Failure to detect and respond during final hook-up check**



**2.4-W-SC**

**Use of a wrong surface connector**

2.4-W-SC
Use of a wrong surface connector
4.80E-09

AND

2.4.1
Incorrect installation of surface connector
8.86E-03

2.4.2
Shotfirer/Blasting Competent Supervisor Fails to Detect and Respond to Error
1.80E-03

2.4.3
Failure to Detect and Respond during Final Hook-up Check
3.01E-04

**4.1.1**

**Excess cartridges are loaded into holes**

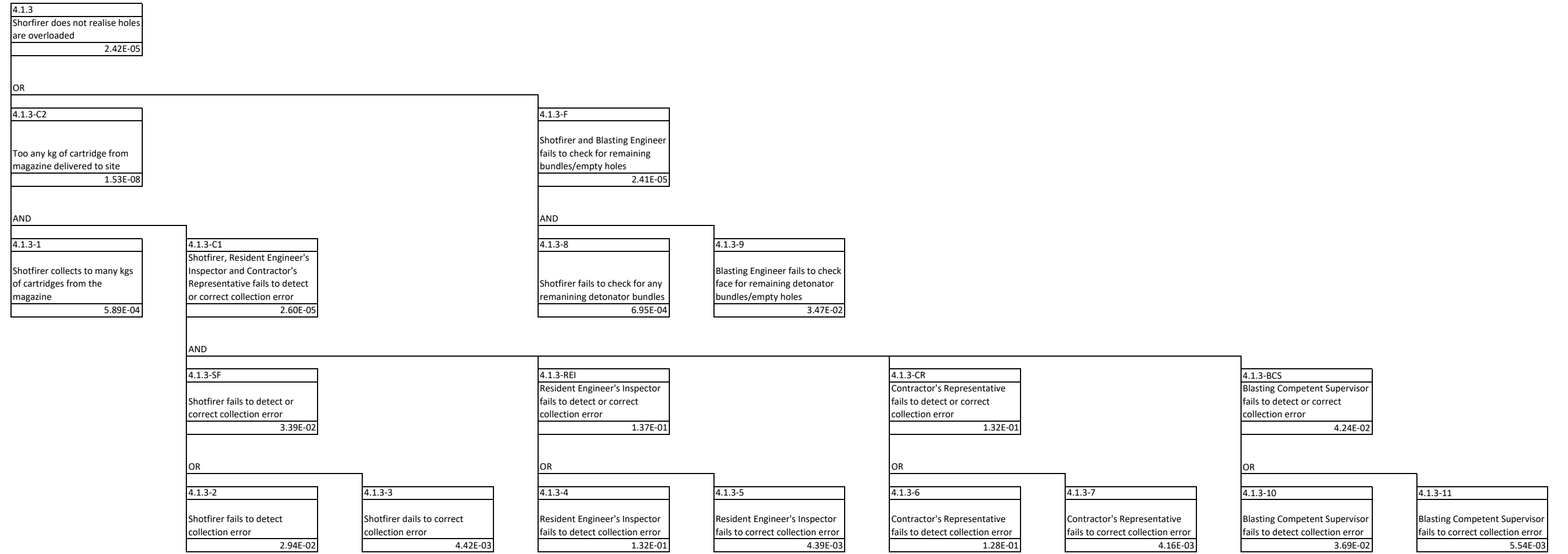
4.1.1
Excess cartridges are loaded into holes
7.38E-04
4.1.1-1
Shotfirer does not count number of cartridges picked up and loads too many
7.38E-04

**4.1.2**

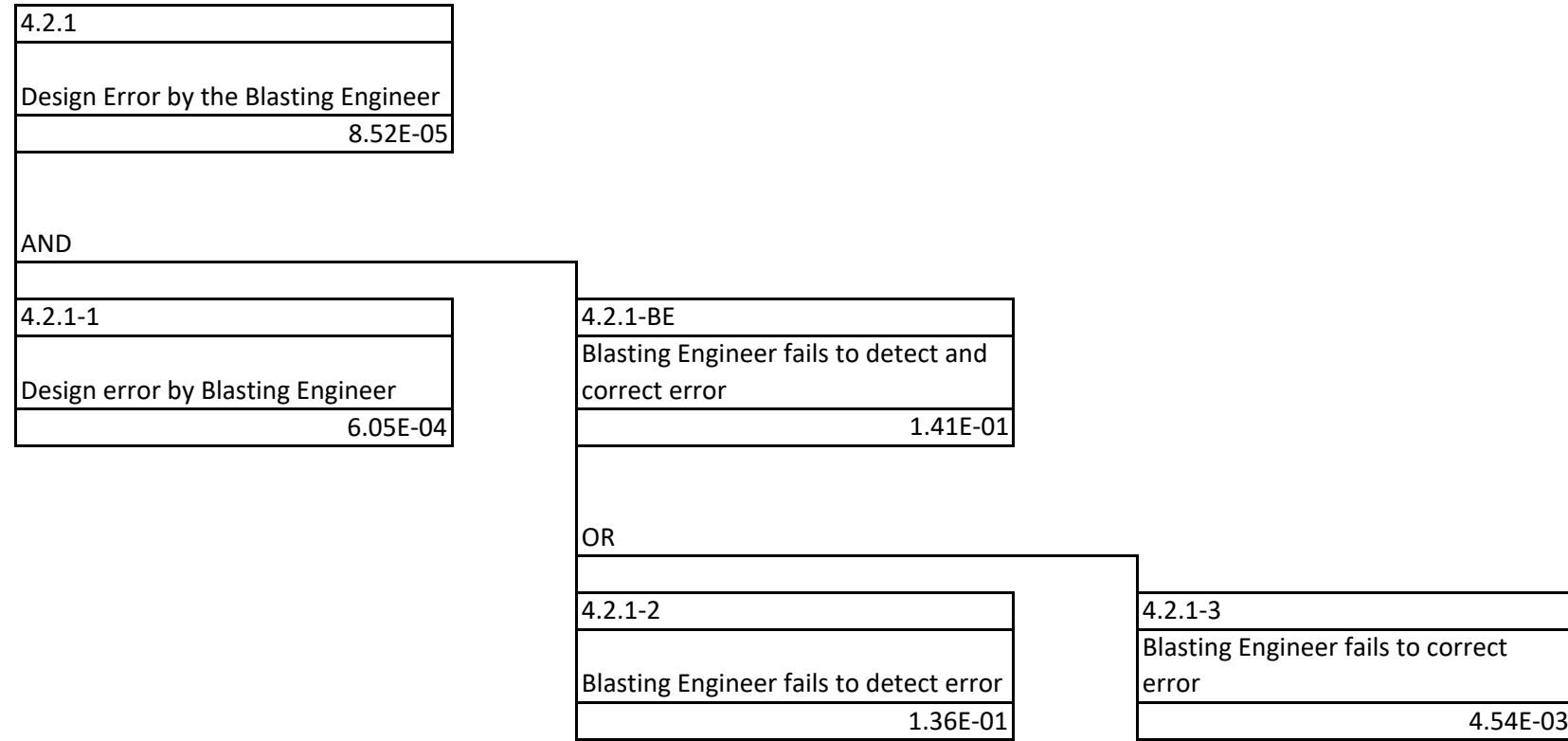
**Cartridges from blocked holes are not disposed of correctly**

4.1.2
Cartridges from blocked holes are not disposed of correctly
8.13E-03
4.1.2-1
Shotfirer intentionally overloads lifter holes
8.13E-03

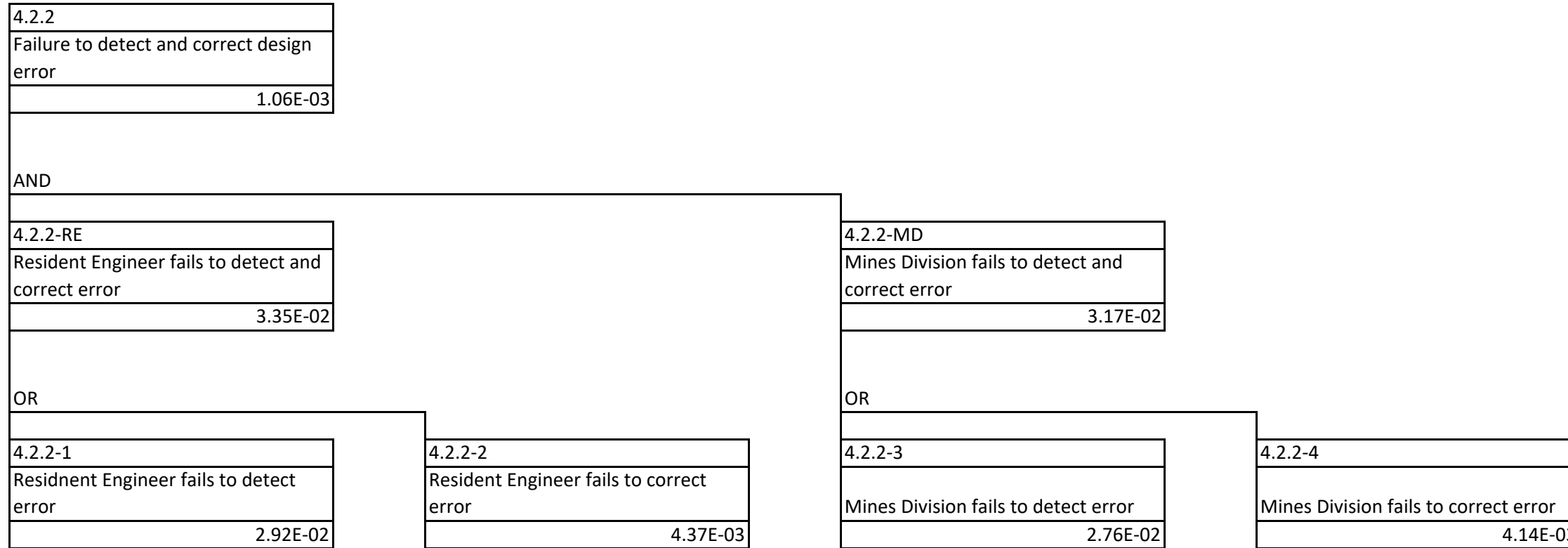
**4.1.3 Shotfirer does not realise holes are overloaded**



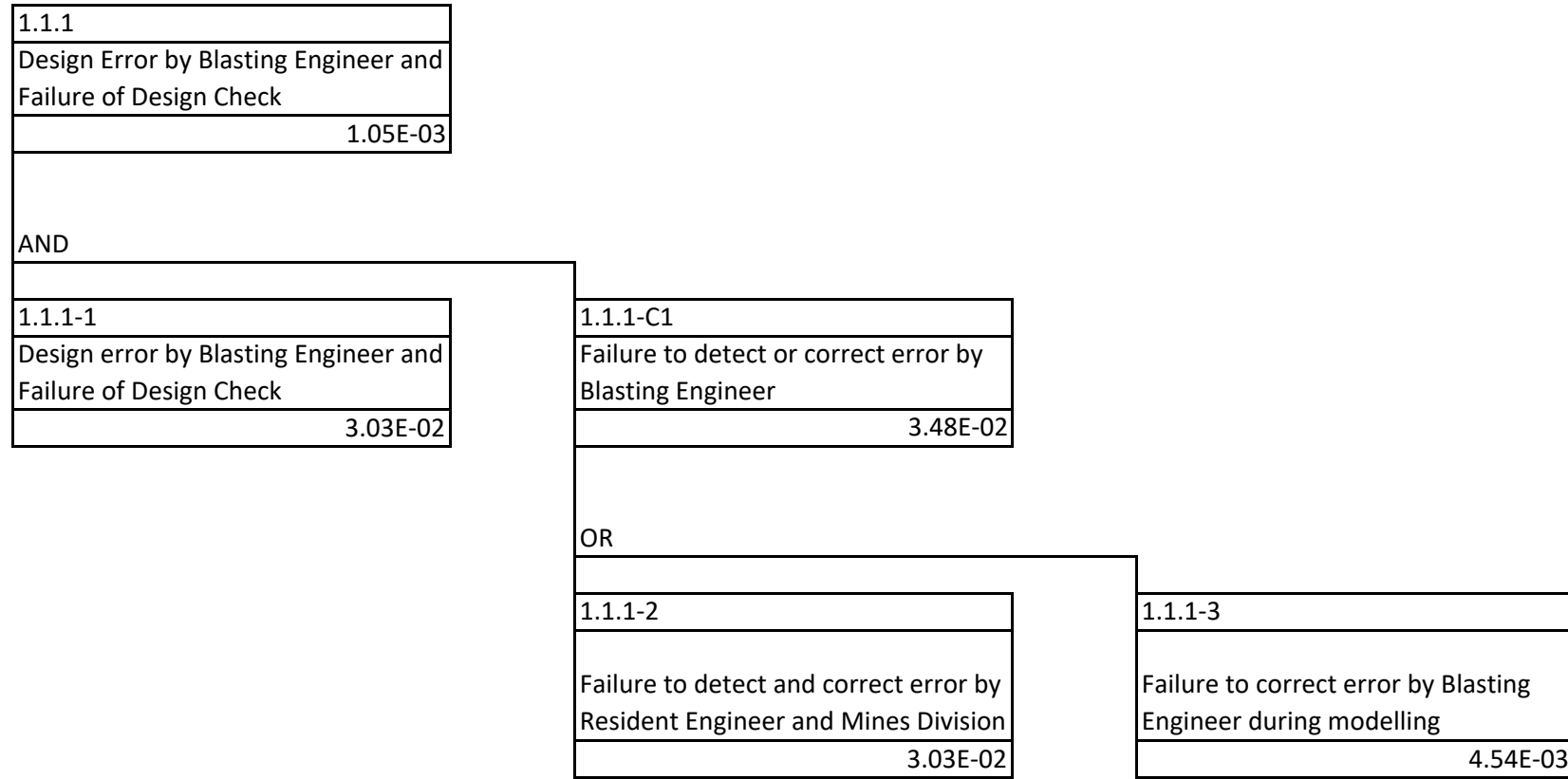
**4.2.1 Design Error by the Blasting Engineer**



**4.2.2 Failure to detect and correct design error**

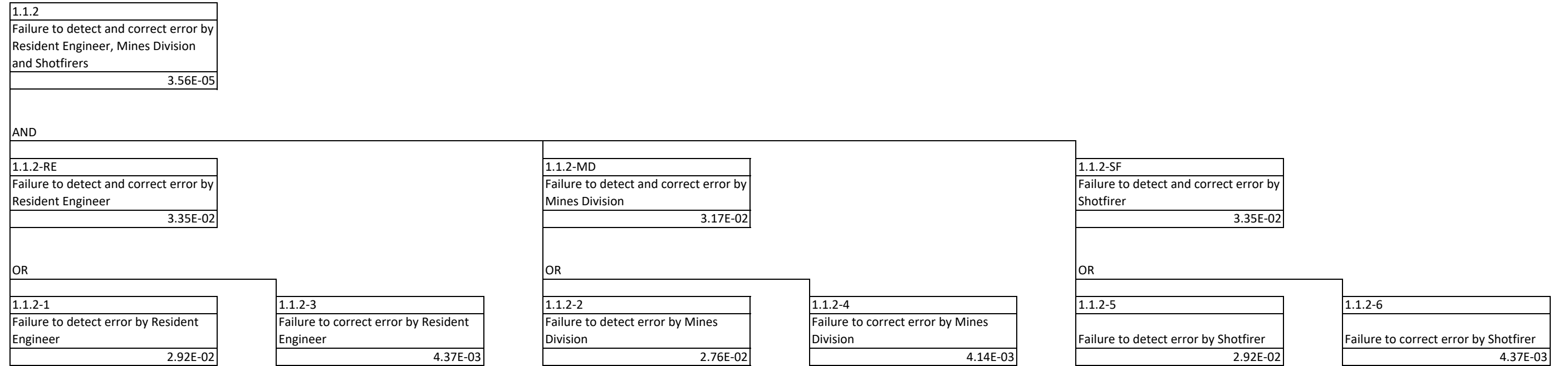


**1.1.1 Design Error by Blasting Engineer and Failure of Design Check**

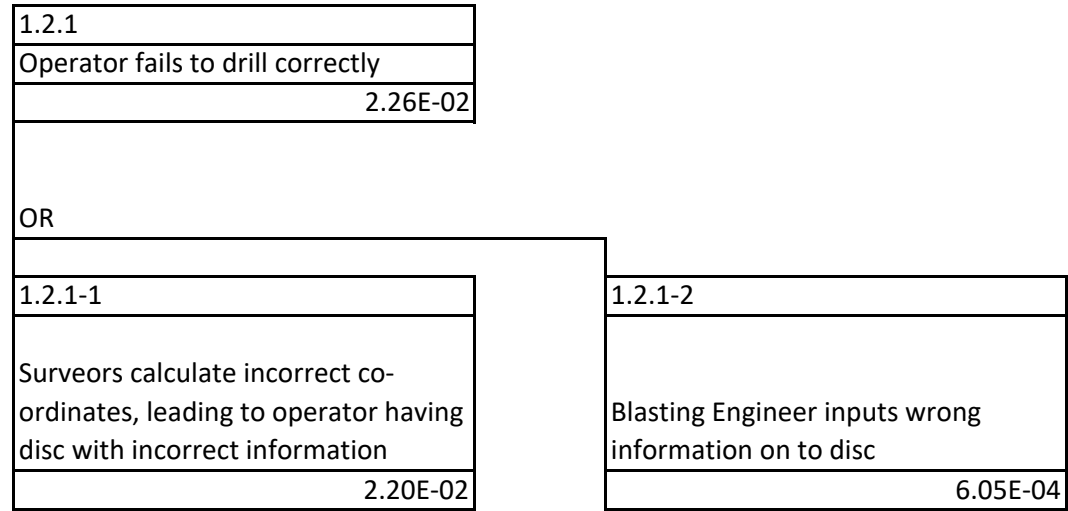




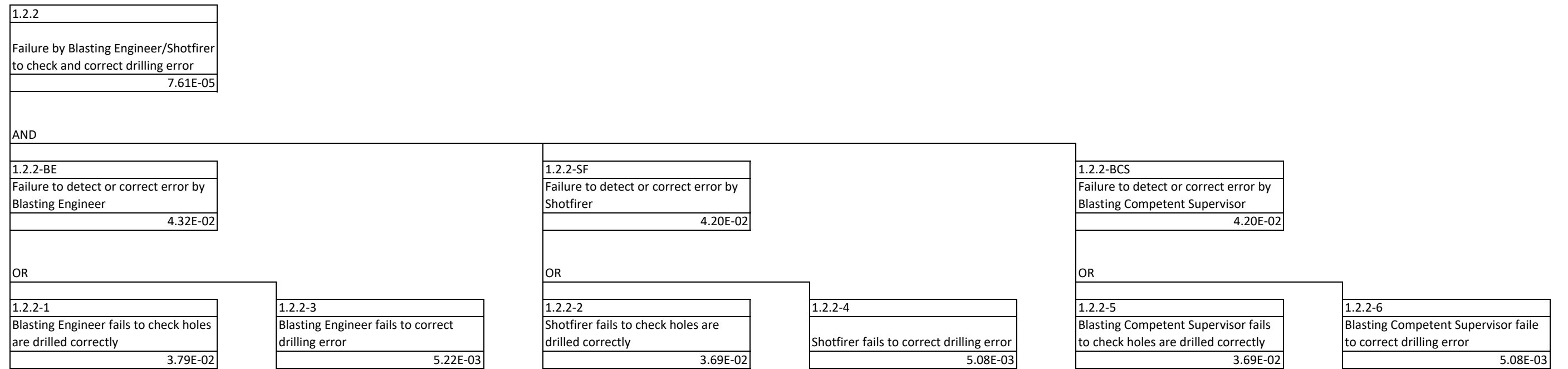
**1.1.2 Failure to detect and correct error by Resident Engineer and Mines Division**



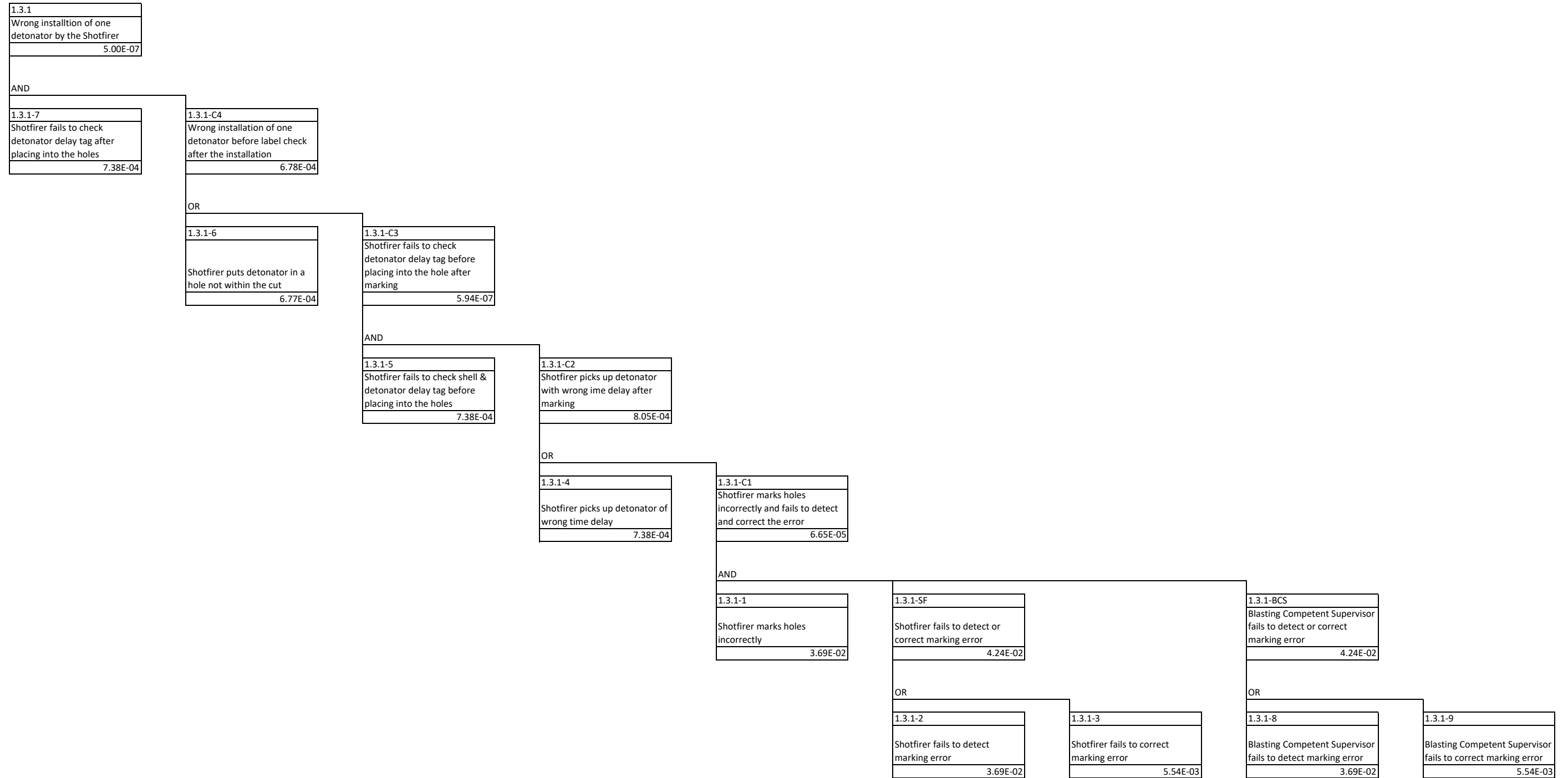
**1.2.1 Failure by Blasting Engineer/Shotfirer to check and correct drilling error**



**1.2.2 Failure by Blasting Engineer/Shotfirer to check and correct drilling error**



**1.3.1 Wrong installation of one detonator by the Shotfirer**



**1.3.2 Shotfirer fails to detect and correct that there are holes without detonators left in the face**

1.3.2
Shotfirer fails to detect and correct that there are holes without detonators left in the face
4.24E-02

OR

1.3.2-1
Shotfirer leaves empty holes in the blast face due to not realising that are detonators left over
3.69E-02

1.3.2-2
Shotfirer fails to fill empty holes before detonation
5.54E-03

**CH-WHD**

**Wrong hole diameter or location for relief holes at cut**

CH-WHD
Wrong hole diameter or location for relief holes at cut
8.79E-07

OR

CH-WHD-C1
Wrong design in relief holes
1.88E-08

CH-WHD-C2
Wrong location of drilling or incorrect frill size being used due to human error
8.60E-07

AND

1.1.1
Design error by Blasting Engineer and Failure of design check
1.05E-03

1.1.2
Failure to detect and correct error by Resident Engineer and Mines Division
3.56E-05

P-FF
Design error significant enough to cause higher vibration
0.5

AND

1.2.1
Operator fails to drill correctly
2.26E-02

1.2.2
Failure by Blasting Engineer/Shotfirer to check and correct drilling error
7.61E-05

P-FF
Design error significant enough to cause higher vibration
0.5

**CH-WD-TD**

**Wrong design of time delay of more than 2 production holes in cut**

CH-WD-TD
Wrong design of time delay of more than 2 production holes in cut
1.26E-13

AND

CH-WD-TD-C1
Wrong design of time delay of one production hole in cut
1.26E-09

P-AD-DETON
Wrong design of time delay of one additional production hole in cut
0.01

P-AD-DETON
Wrong design of time delay of one additional production hole in cut
0.01

AND

1.1.1
Design error by Blasting Engineer and Failure of design check
1.05E-03

1.1.2
Failure to detect and correct error by Resident Engineer, Mines Division and Shotfirers
1.19E-06

**CH-WI-TD**

**Wrong installation of more than two detonators in cut (longer time delay from other sector put into the cut)**

CH-WI-TD
Wrong installation of more than two detonators in cut (longer time delay from other sector put into the cut)
1.27E-11

AND

CH-WI-TD-C1
Wrong installation of one detonator in cut (longer time delay from other sector put into the cut)
1.27E-07

P-AD-DETON
Wrong installation of additional one detonator in cut (longer time delay from other sector put into the cut)
0.01

P-AD-DETON
Wrong installation of additional one detonator in cut (longer time delay from other sector put into the cut)
0.01

AND

1.3.1
Wrong installtion of one detonator by the Shotfirer
3.00E-06

1.3.2
Shotfirer fails to detect and correct that there are holes without detonators left in the face
4.24E-02



**CH-TD-MD**

**Incorrect time default of more than two detonators due to manufacturer defect**

CH-TD-MD
Incorrect time default of more than two detonators due to manufacturer defect
2.40E-09

AND

MD-DETON
Incorrect time default of one detonator due to manufacturer defect
2.40E-05

P-AD-DETON
Incorrect time default of one additional detonator due to manufacturer defect
0.01

P-AD-DETON
Incorrect time default of one additional detonator due to manufacturer defect
0.01

**CH Higher than expected vibration due to cut hole error**

CH
Higher than expected vibration due to cut hole error
8.81E-07

OR

CH-WHD
Wrong hole diameter or location for relief holes at cut
8.79E-07

CH-C1
Wrong time delay at cut
2.41E-09

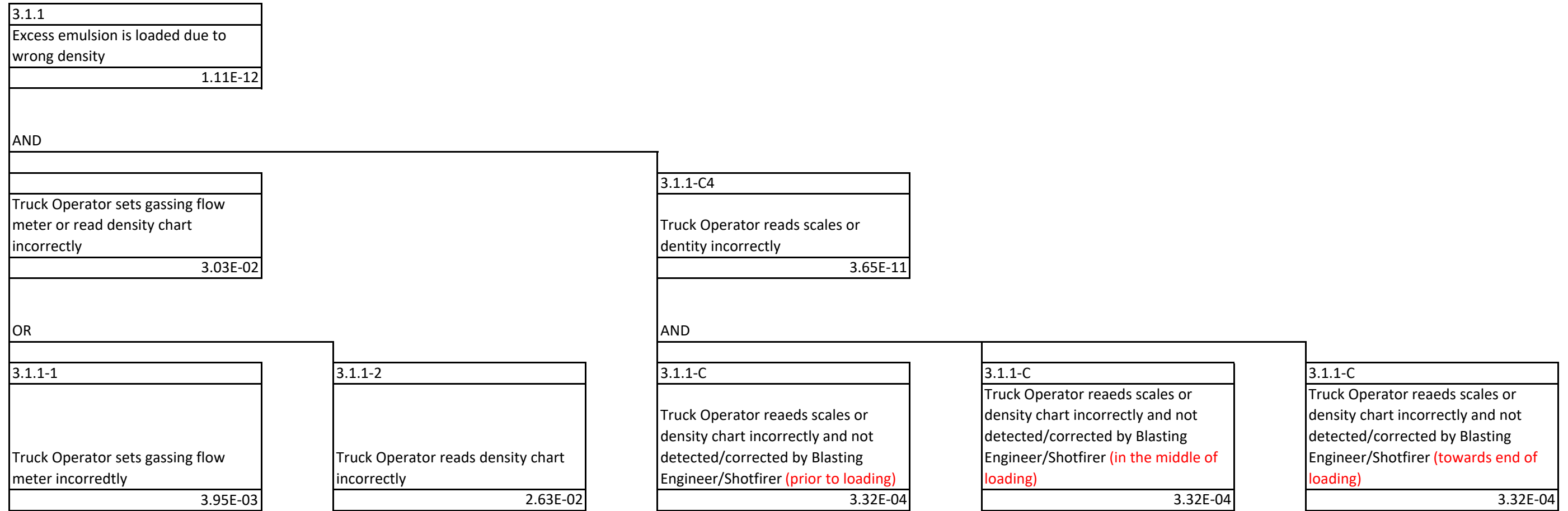
OR

CH-WD-TD
Wrong design of time delay of more than 2 production holes in cut
1.26E-13

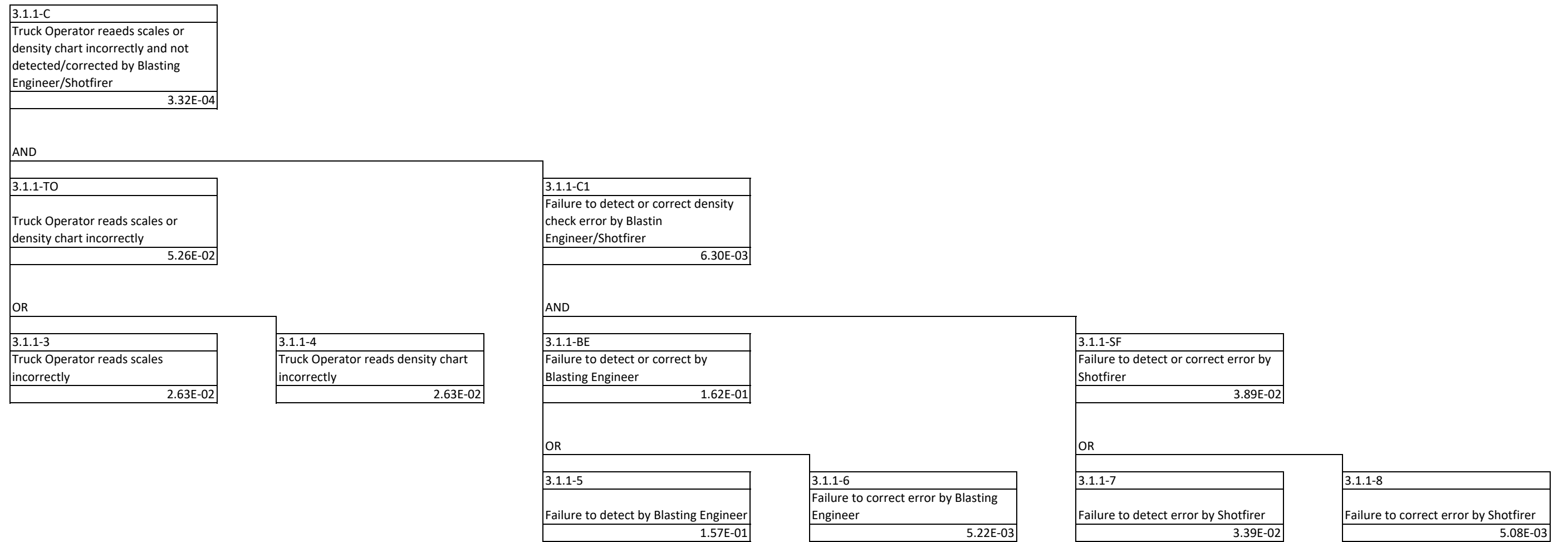
CH-WI-TD
Wrong installation of more than two detonators in cut (longer time delay from other sector put into the cut)
1.27E-11

CH-TD-MD
Incorrect time default of more than two detonators due to manufacturer defect
2.40E-09

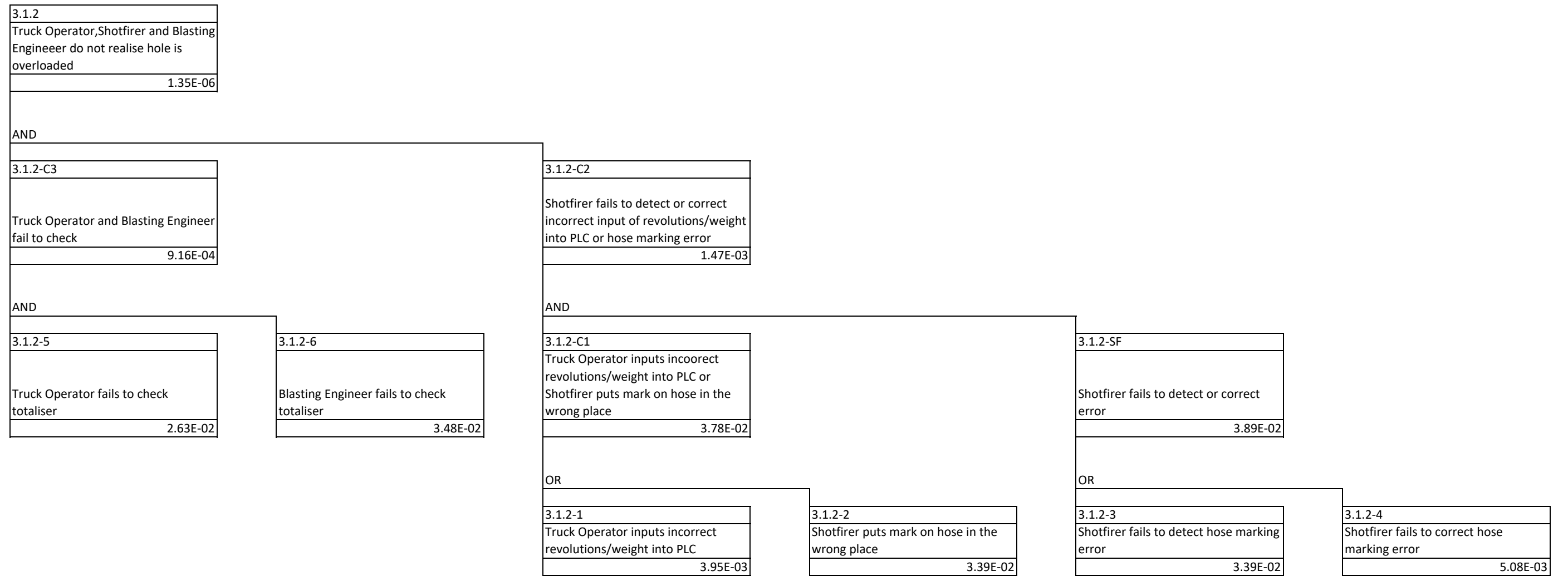
**3.1.1 Excess emulsion is loaded due to wrong density**



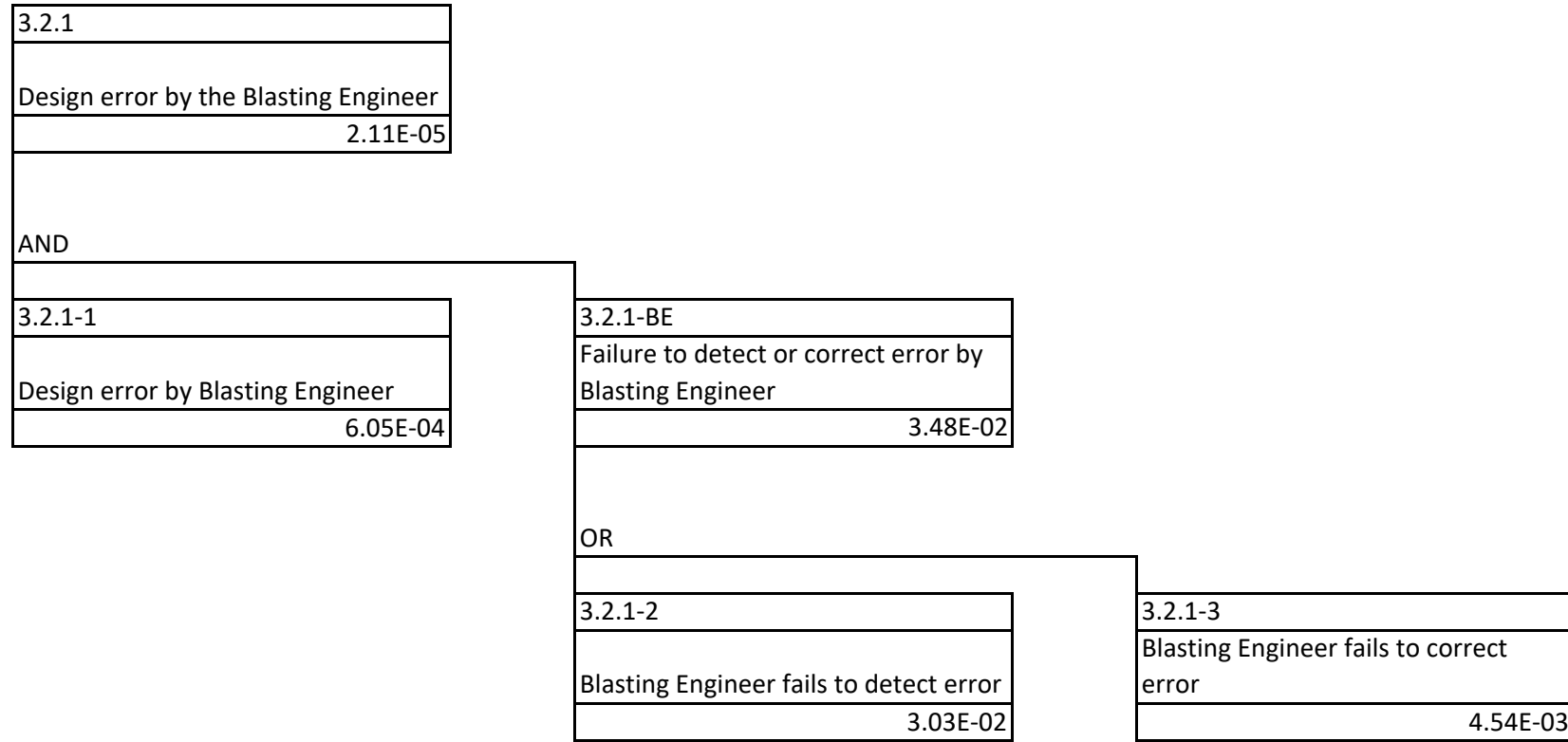
**3.1.1-C Truck Operator reads scales or density chart incorrectly and not detected/corrected by Blasting Engineer/Shotfirer**



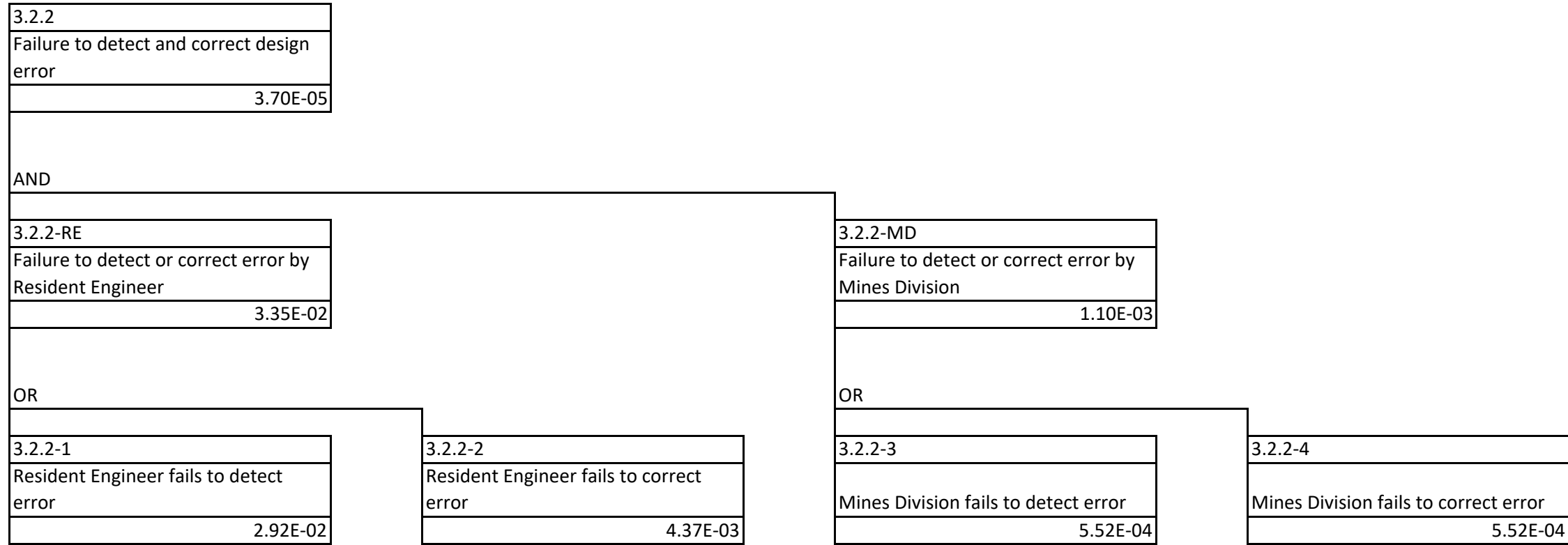
**3.1.2 Truck Operator, Shotfirer and Blasting Engineer do not realise hole is overloaded**



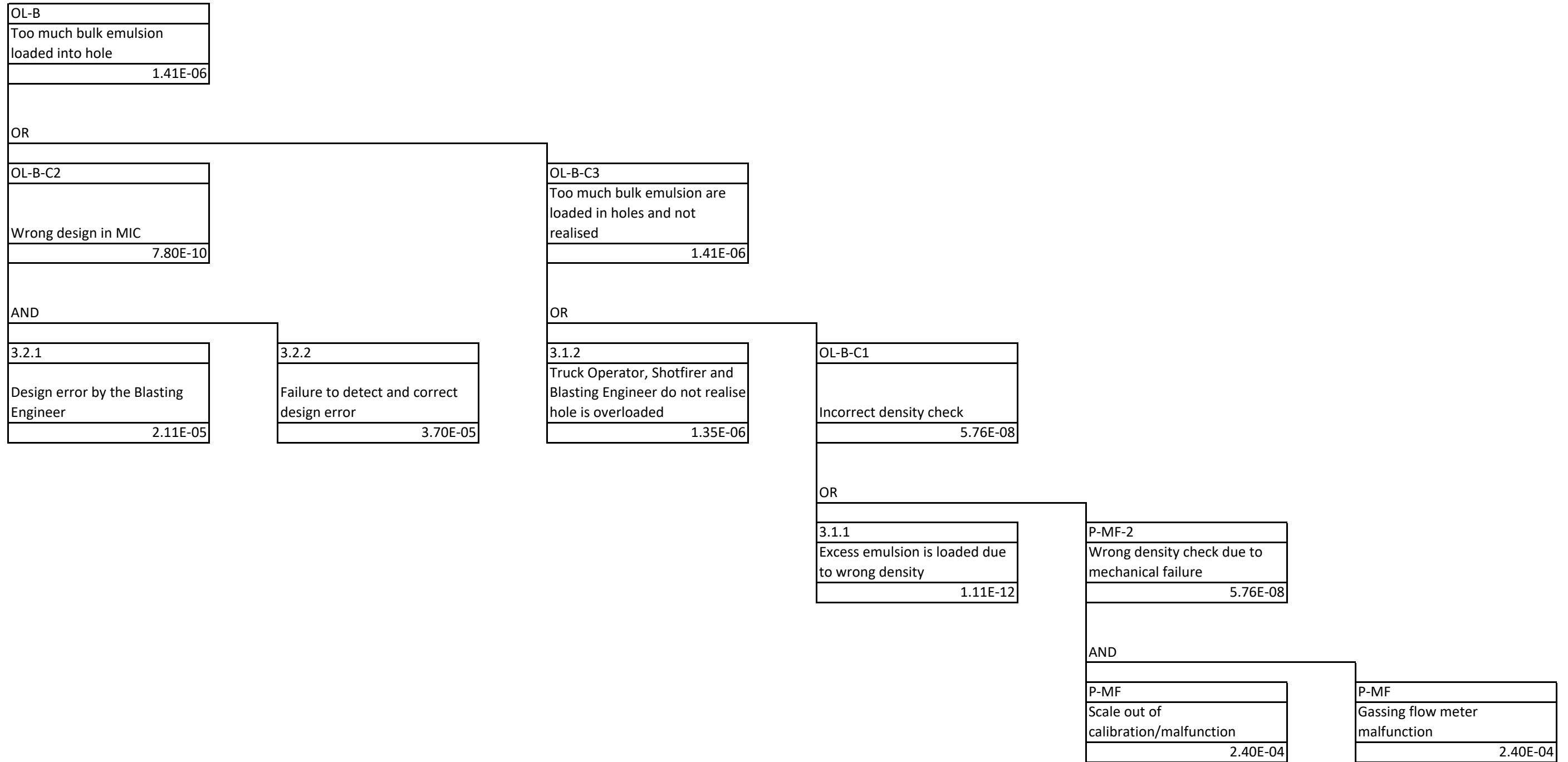
**3.2.1 Design error by the Blasting Engineer**



**3.2.2 Failure to detect and correct design error**



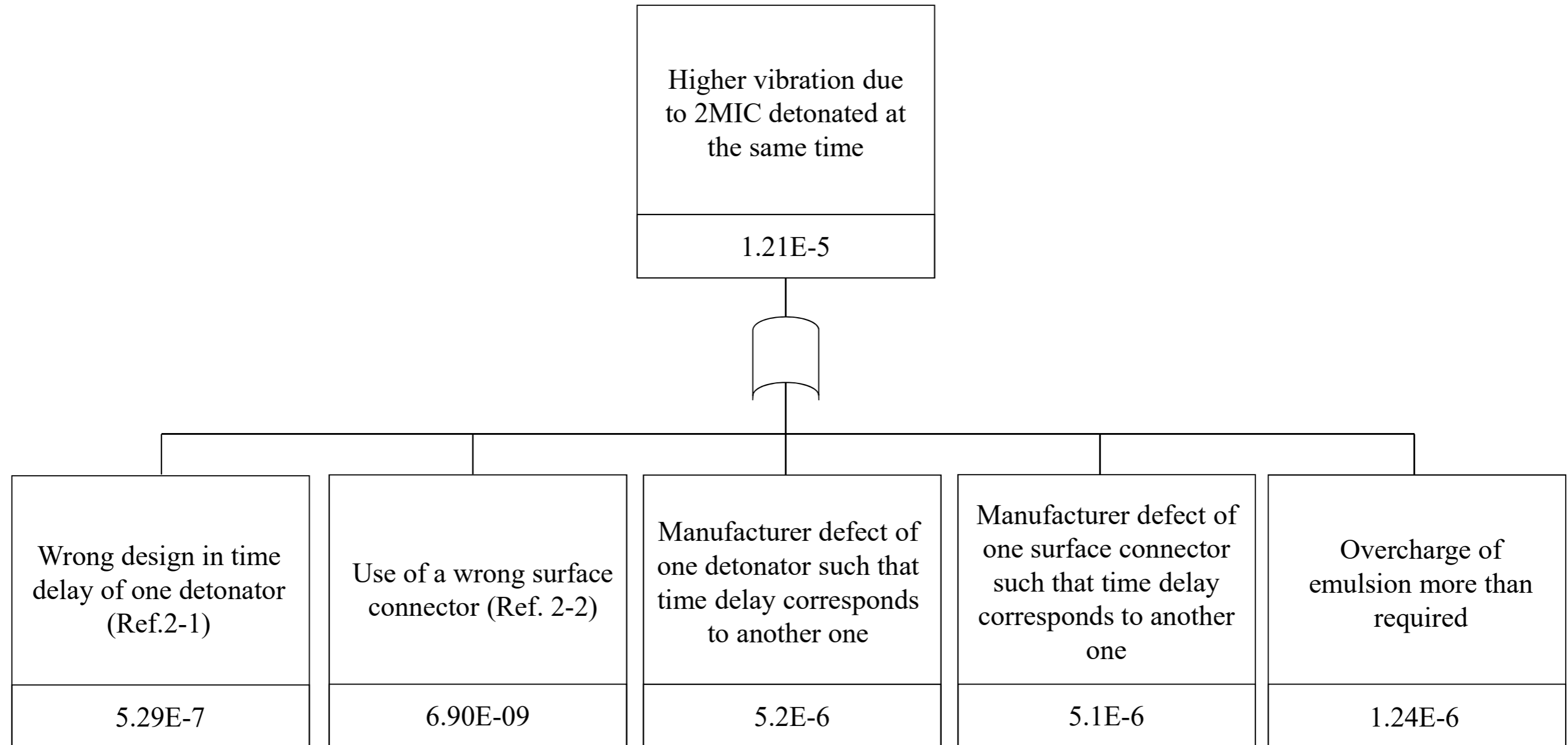
**OL-B Too much bulk emulsion loaded into hole**



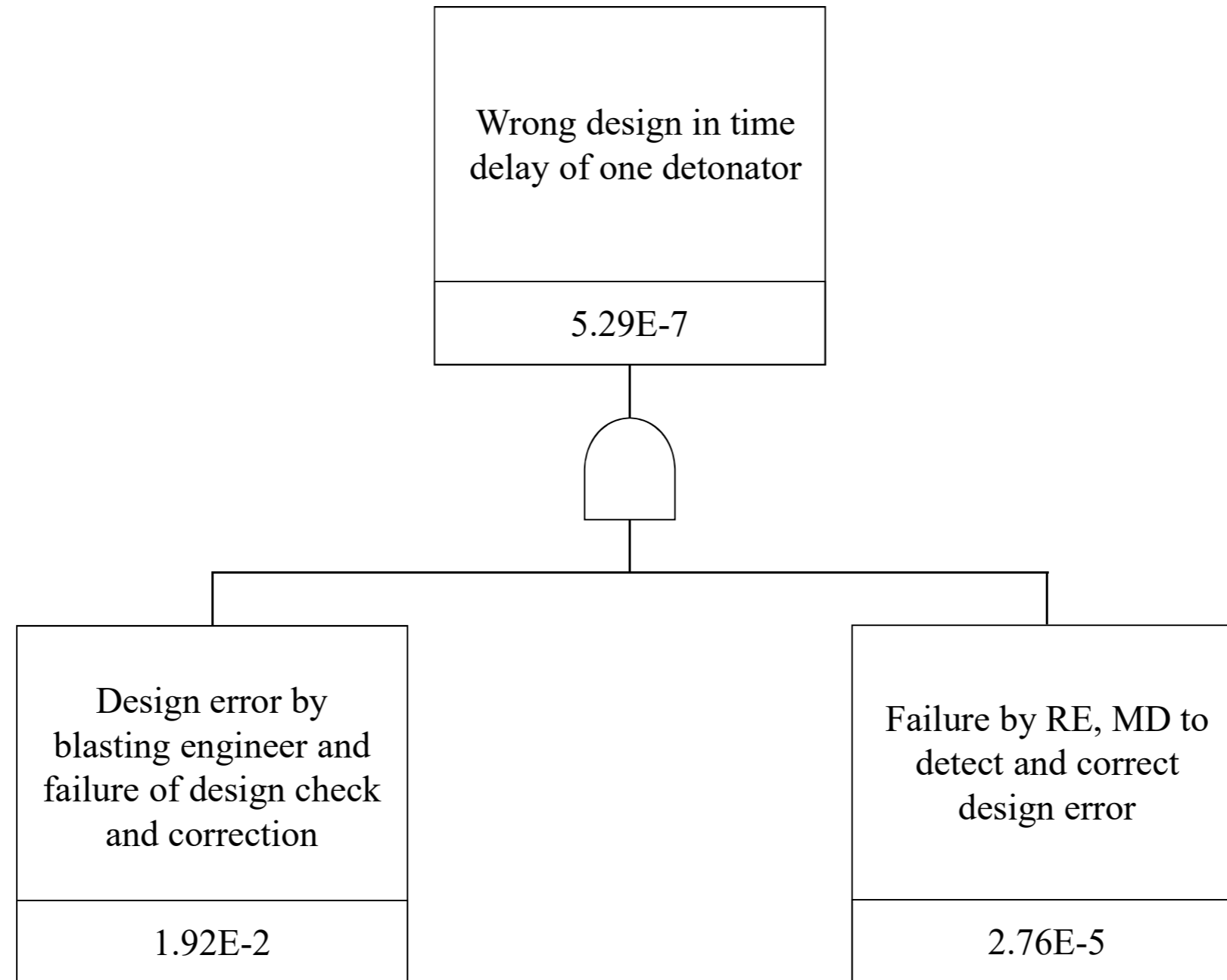


## **Annex 2**

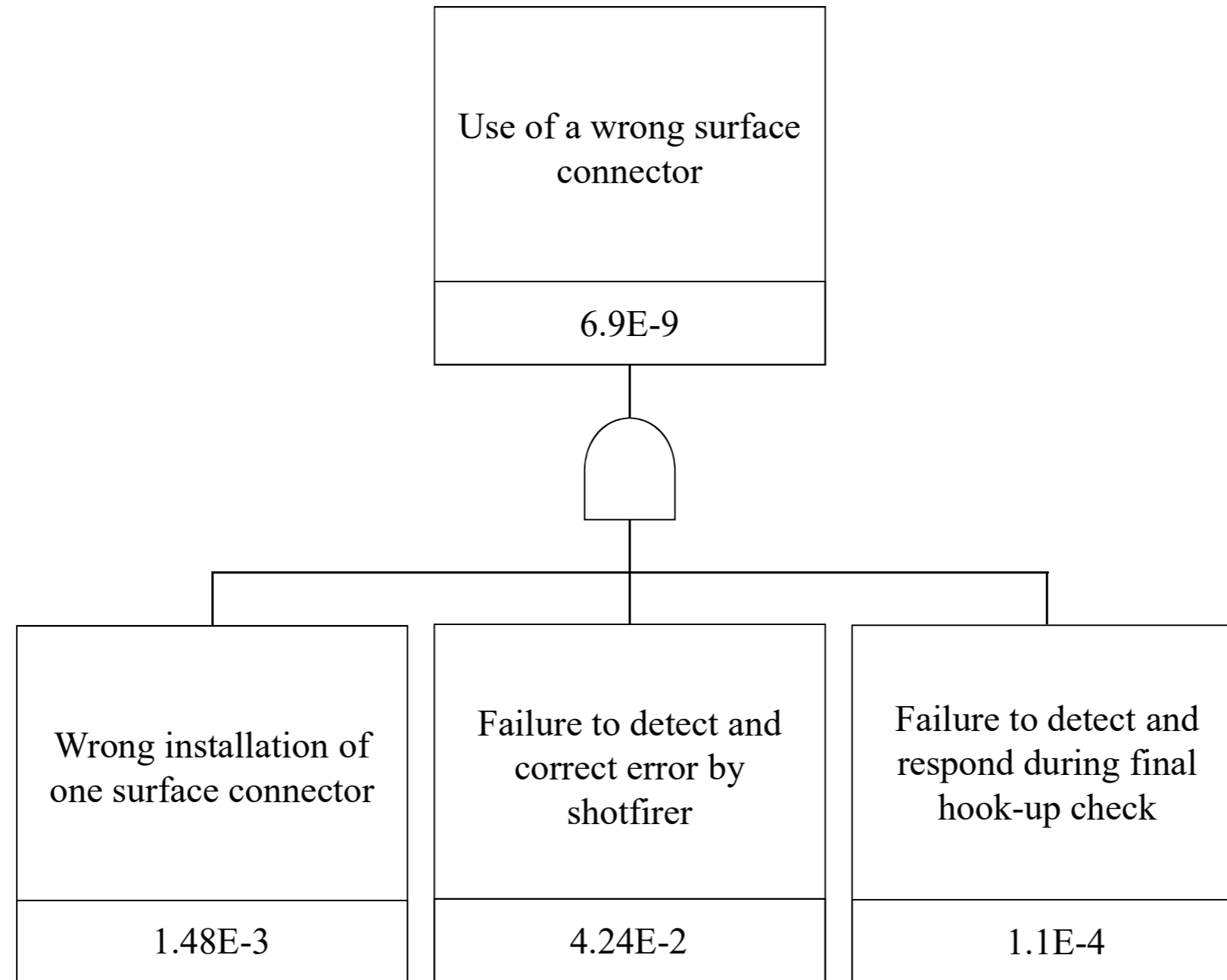
### Fault Trees for Surface Blasting

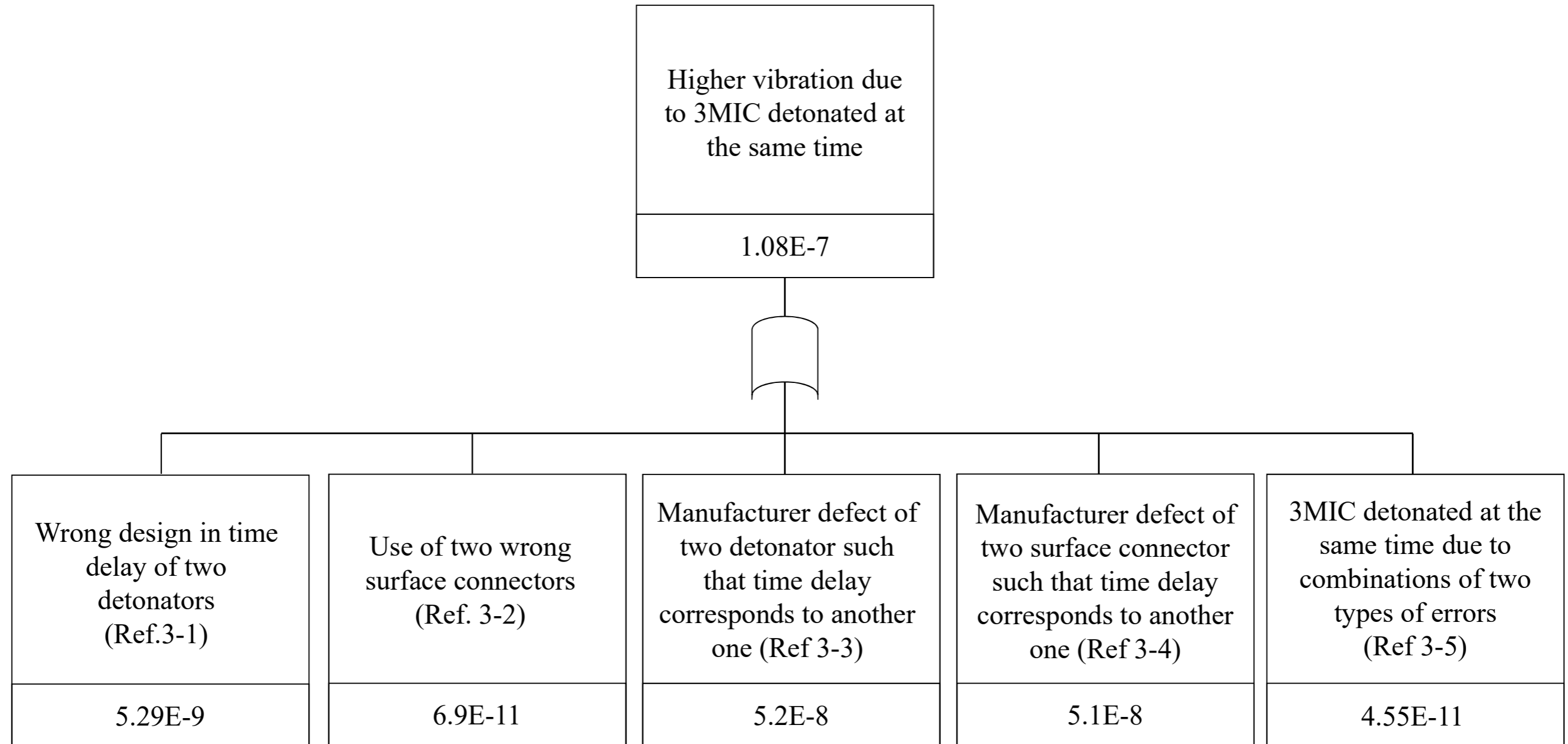


# Ref. 2-1

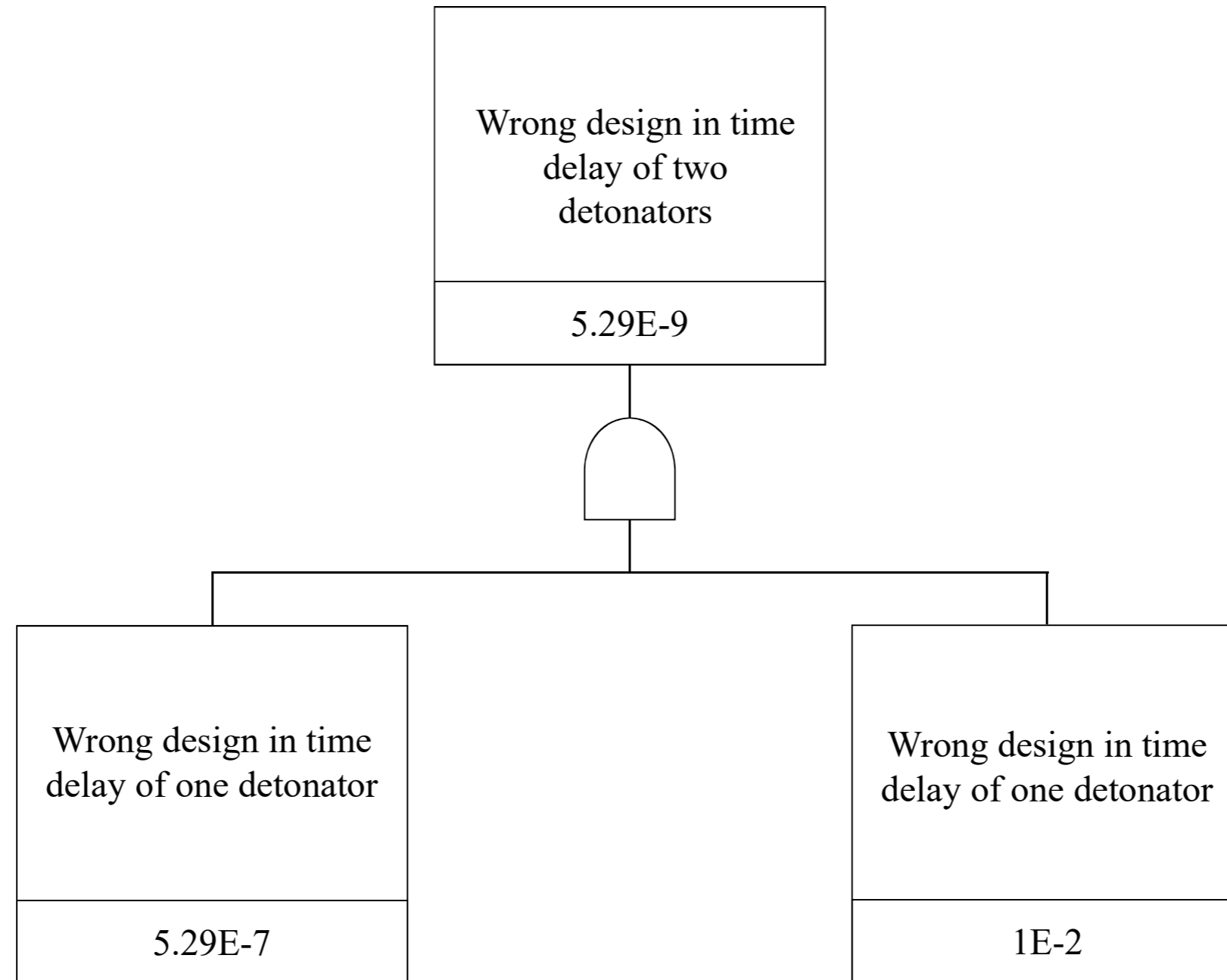


# Ref. 2-2

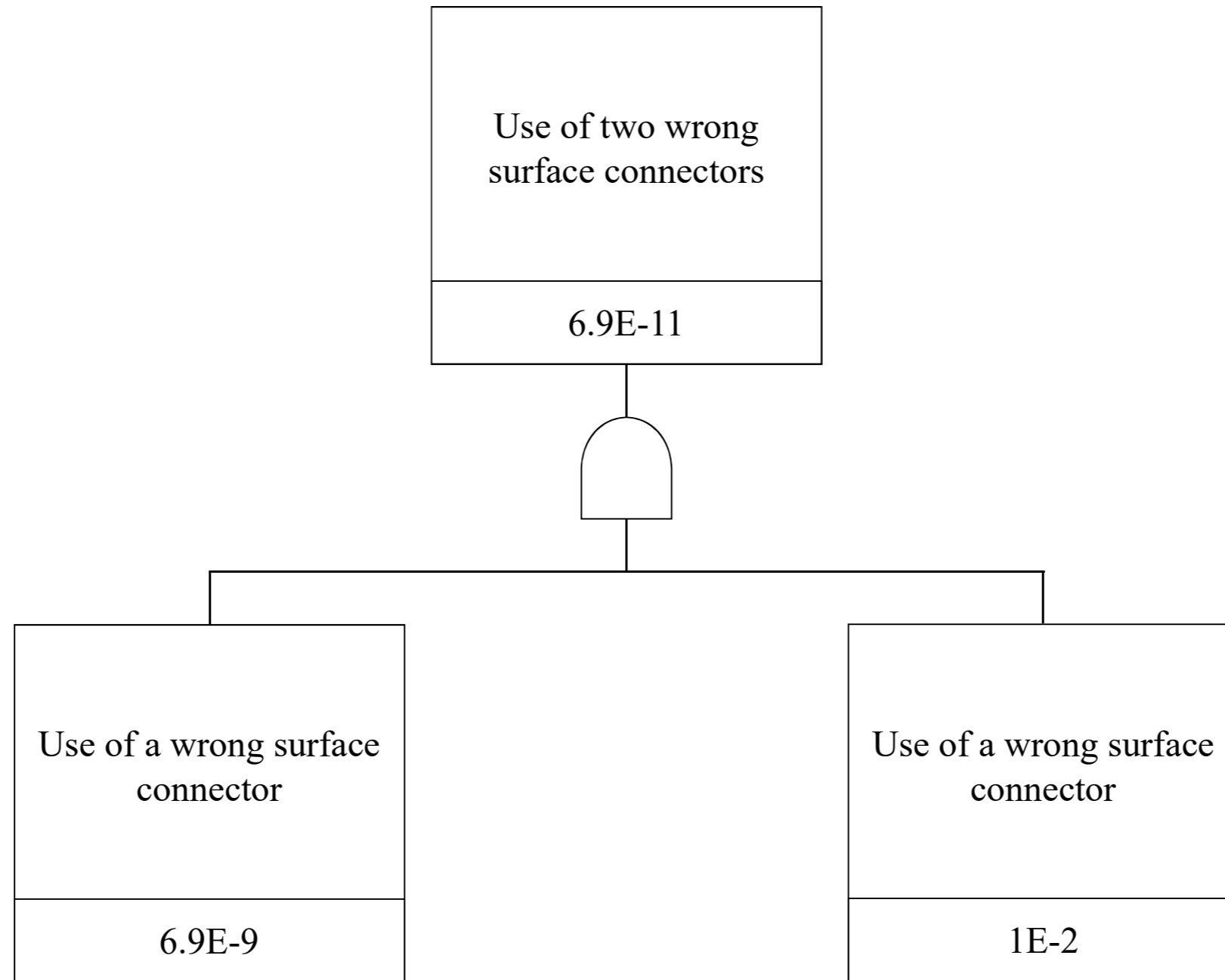




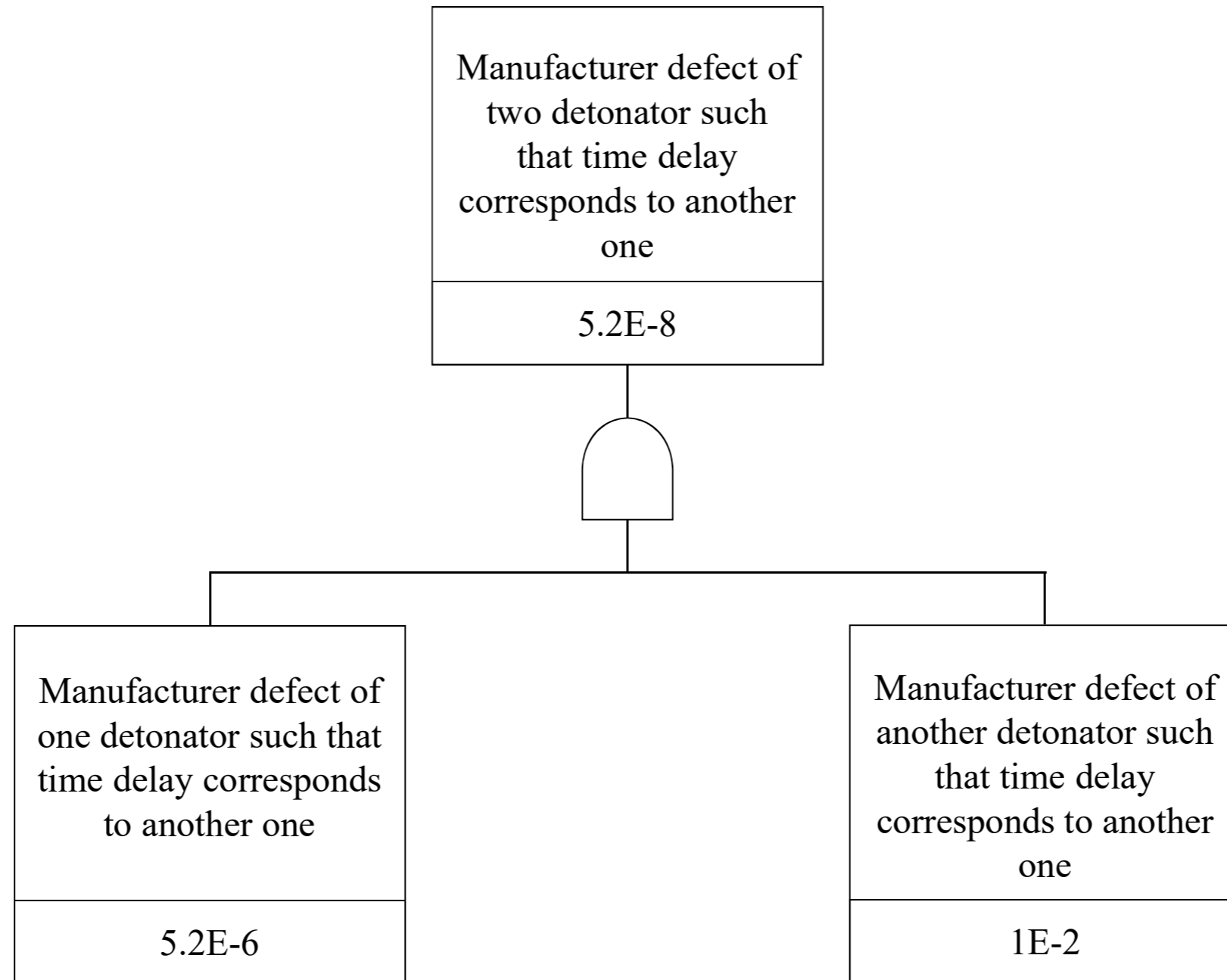
# Ref. 3-1



# Ref. 3-2

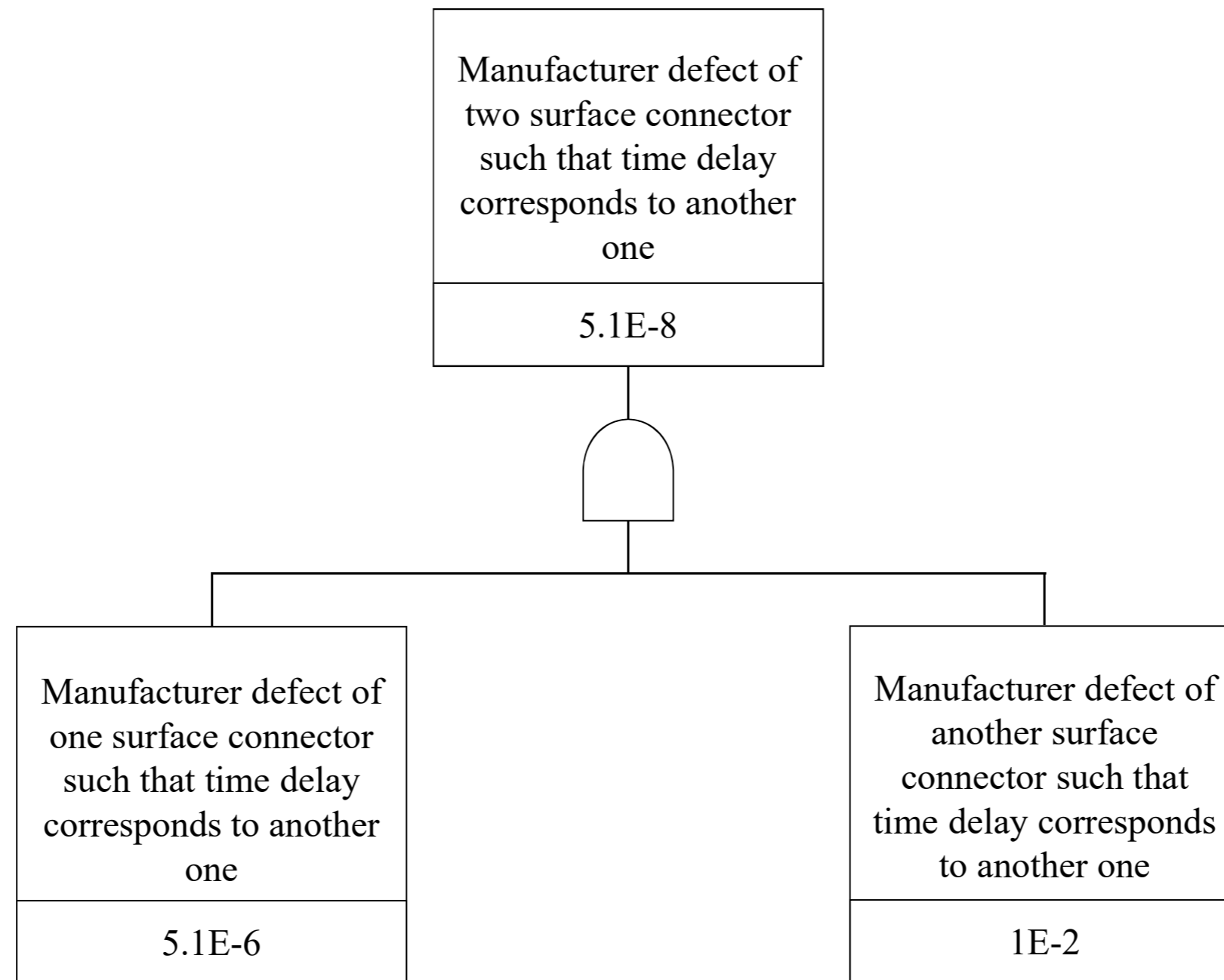


# Ref. 3-3

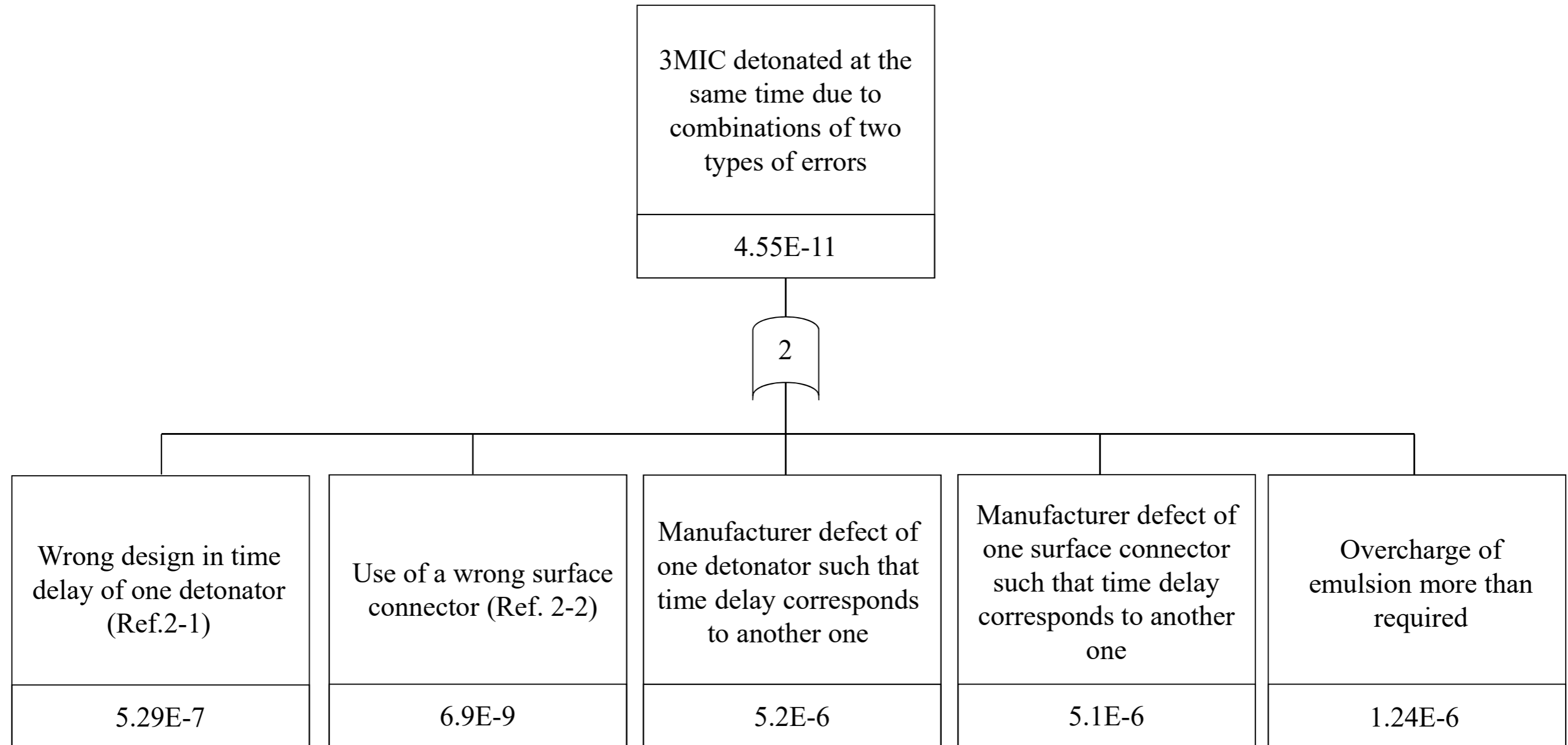


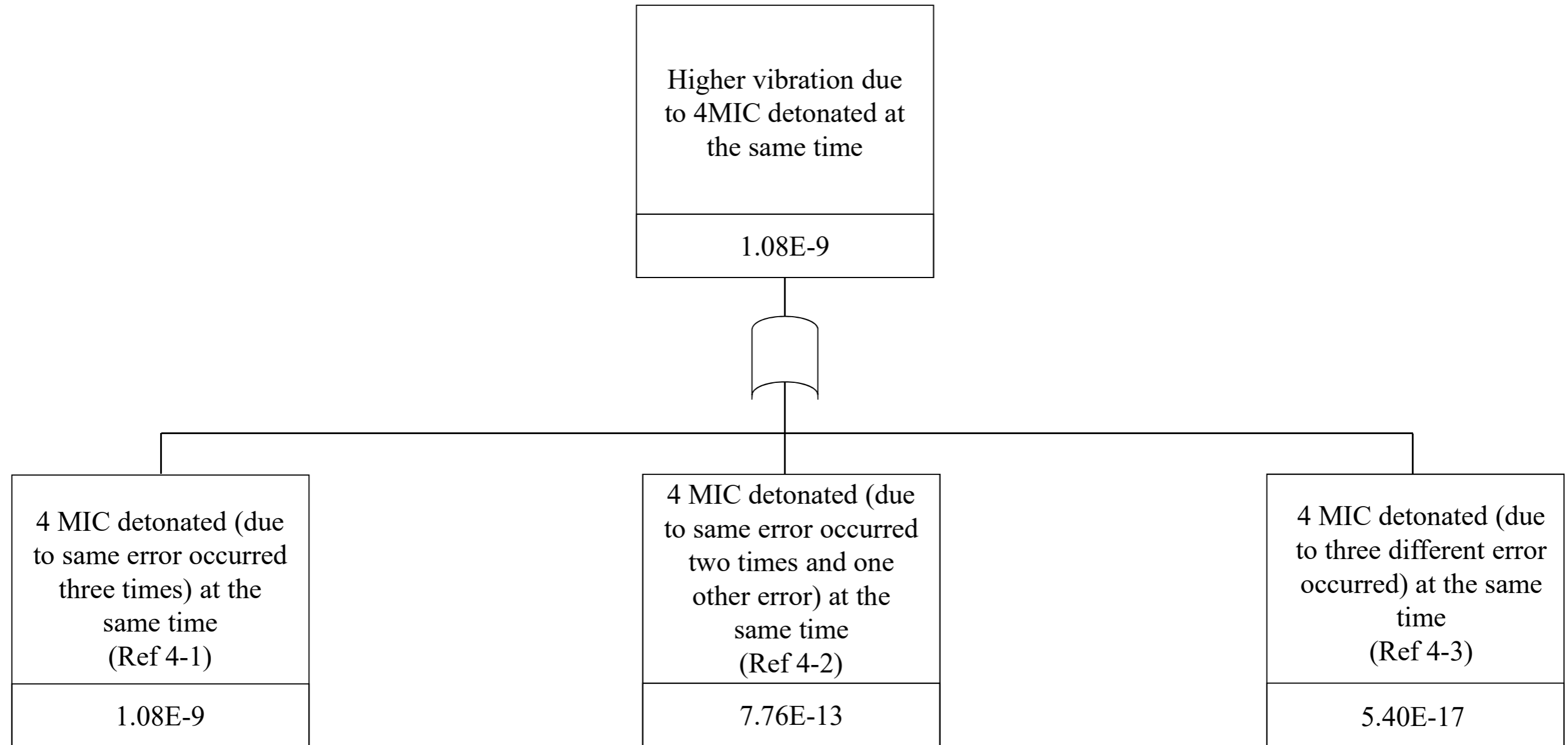


# Ref. 3-4

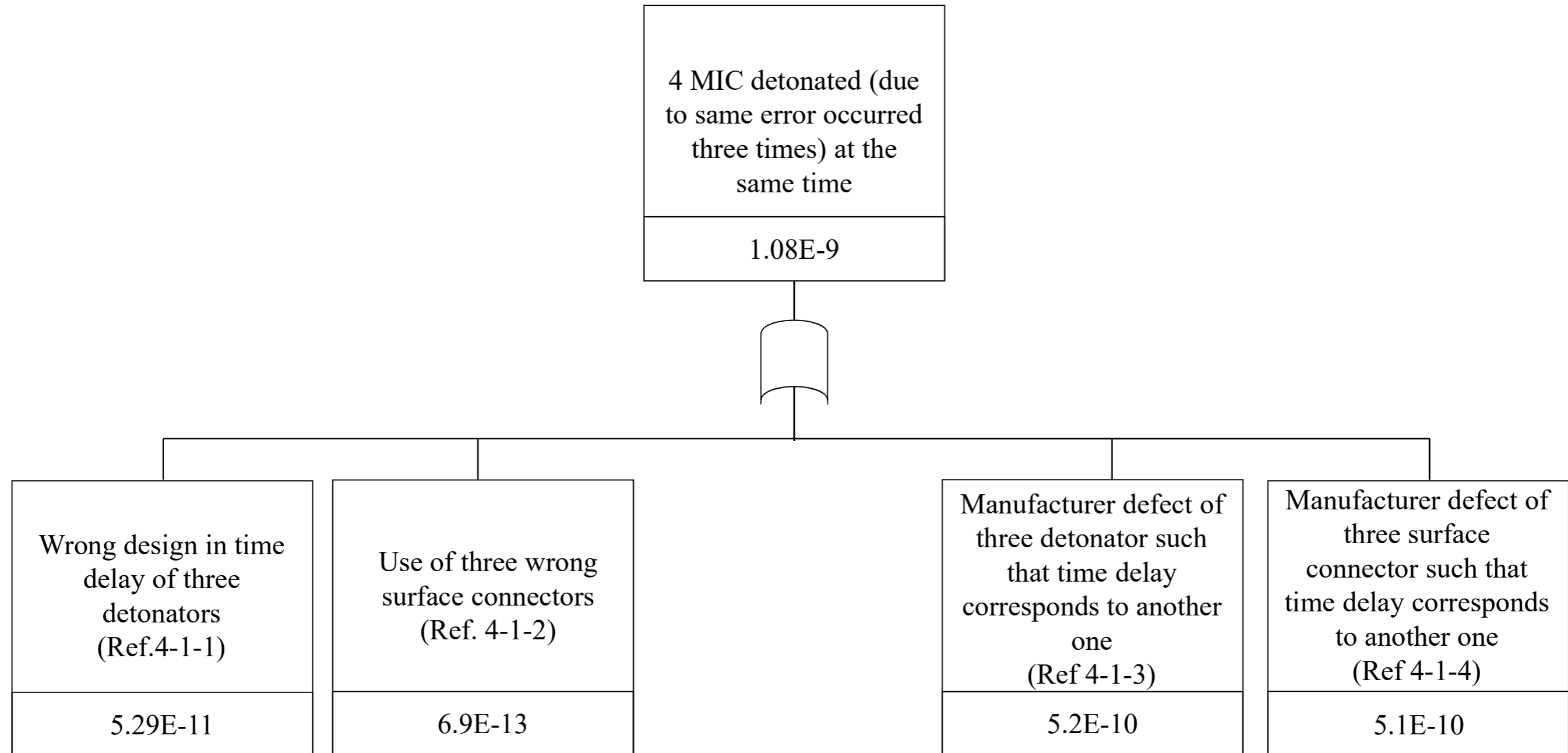


# Ref. 3-5

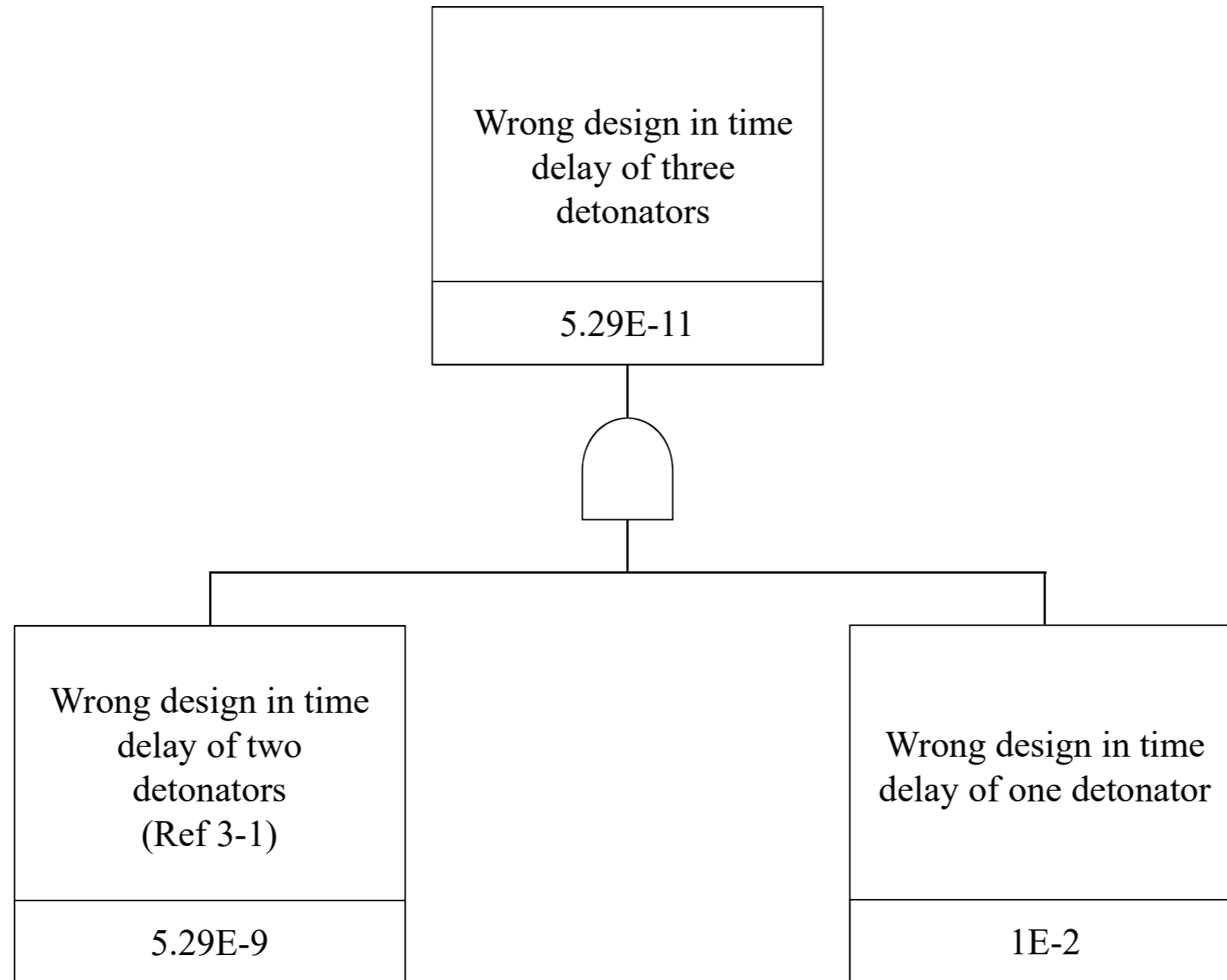




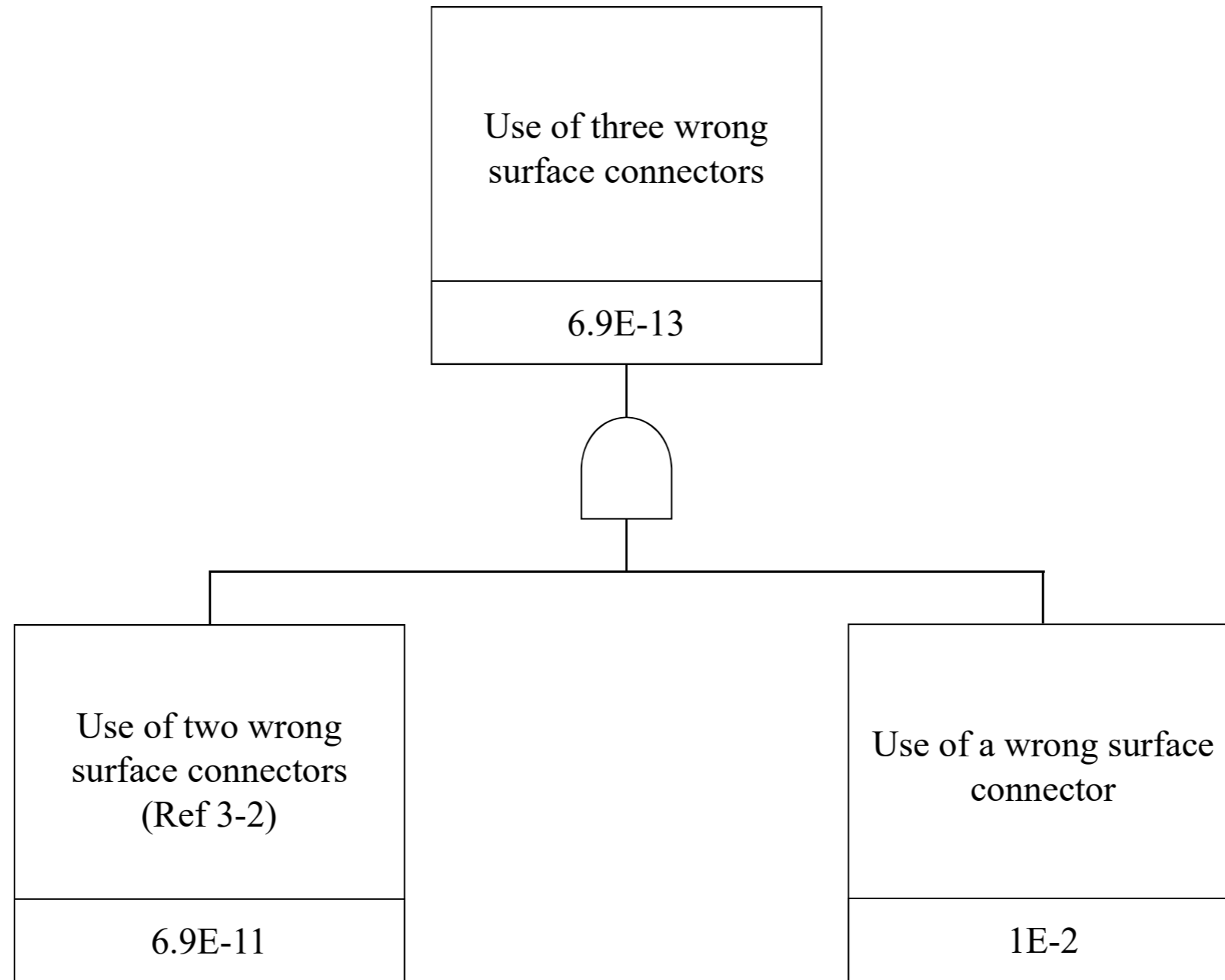
# Ref. 4-1



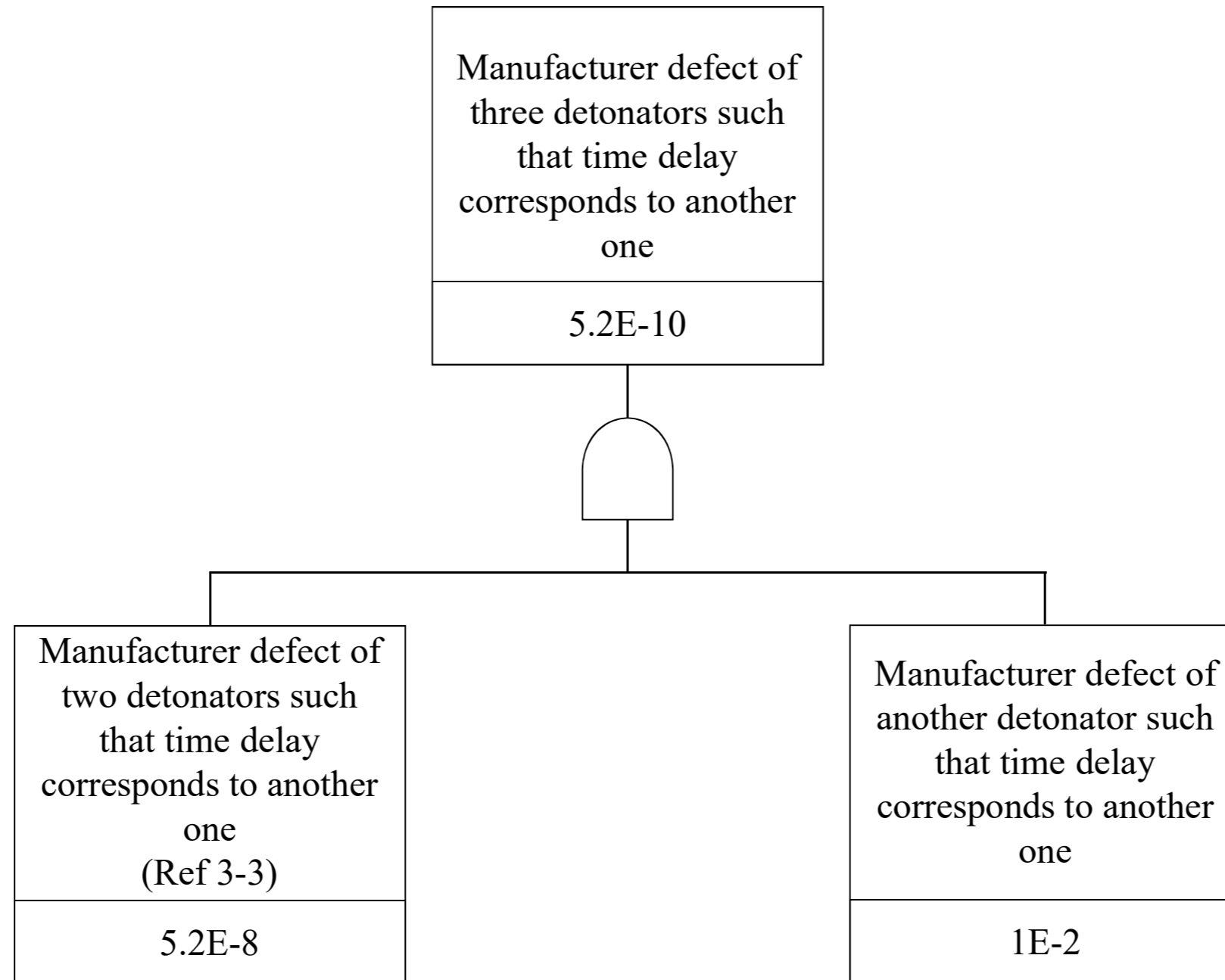
# Ref. 4-1-1



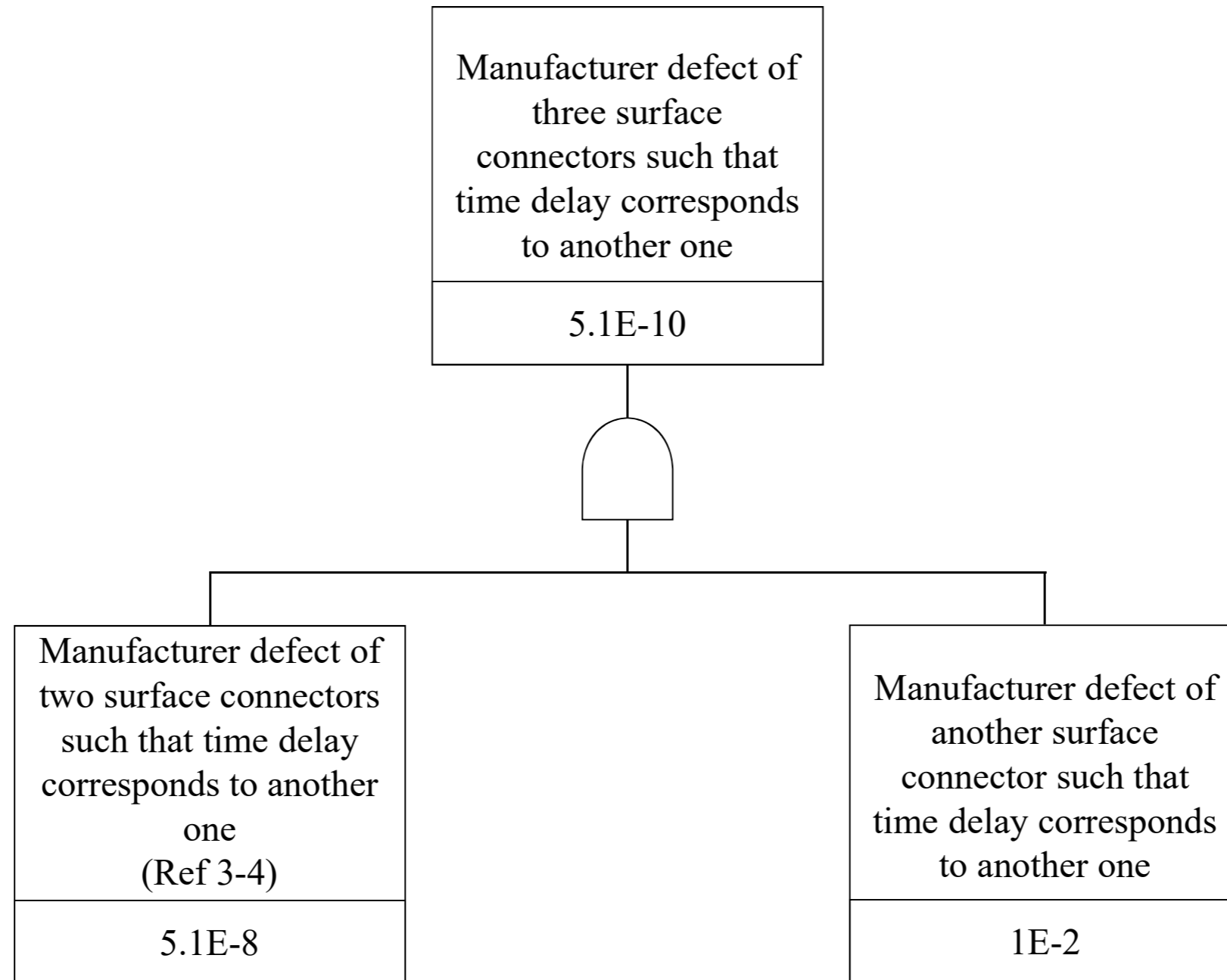
# Ref. 4-1-2



# Ref. 4-1-3

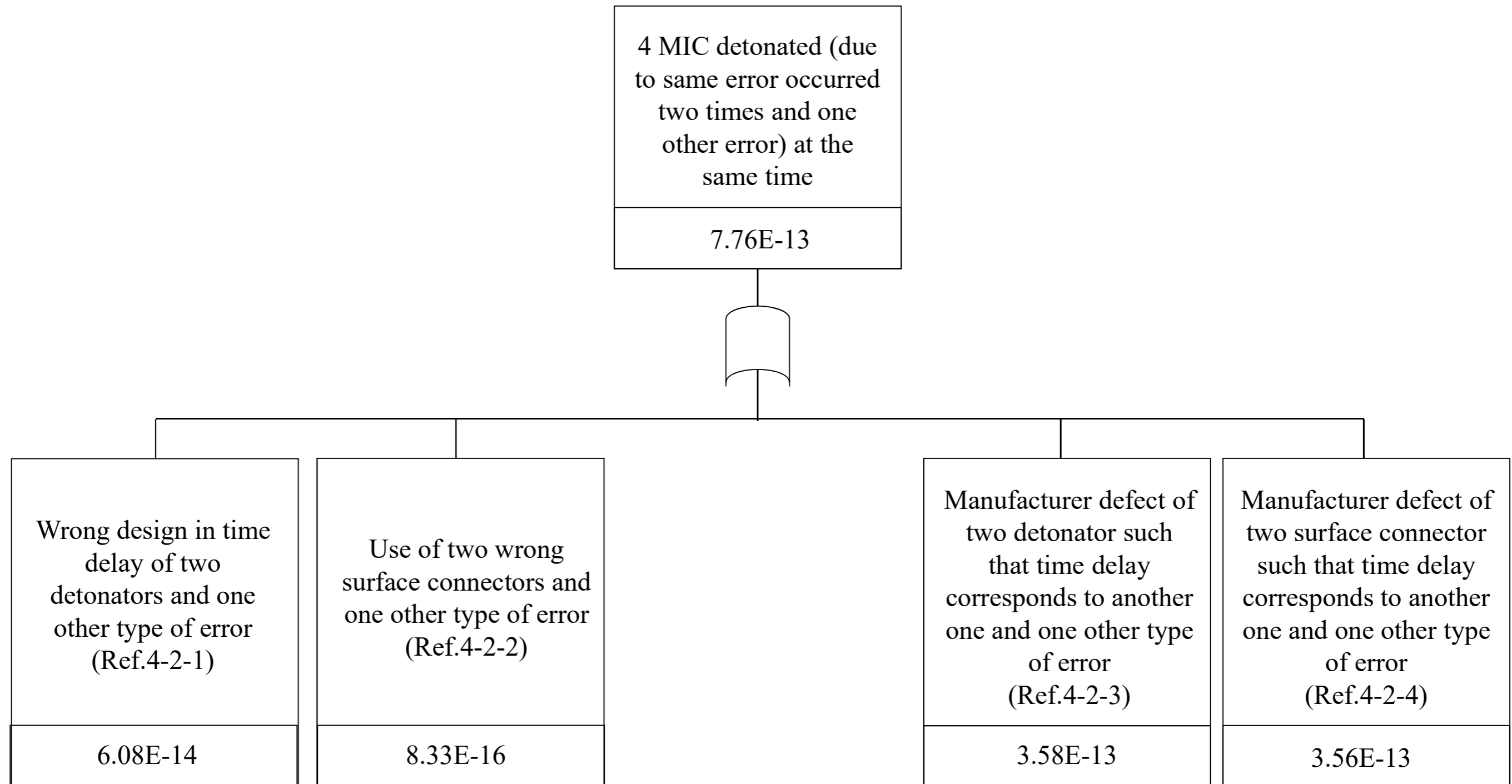


# Ref. 4-1-4

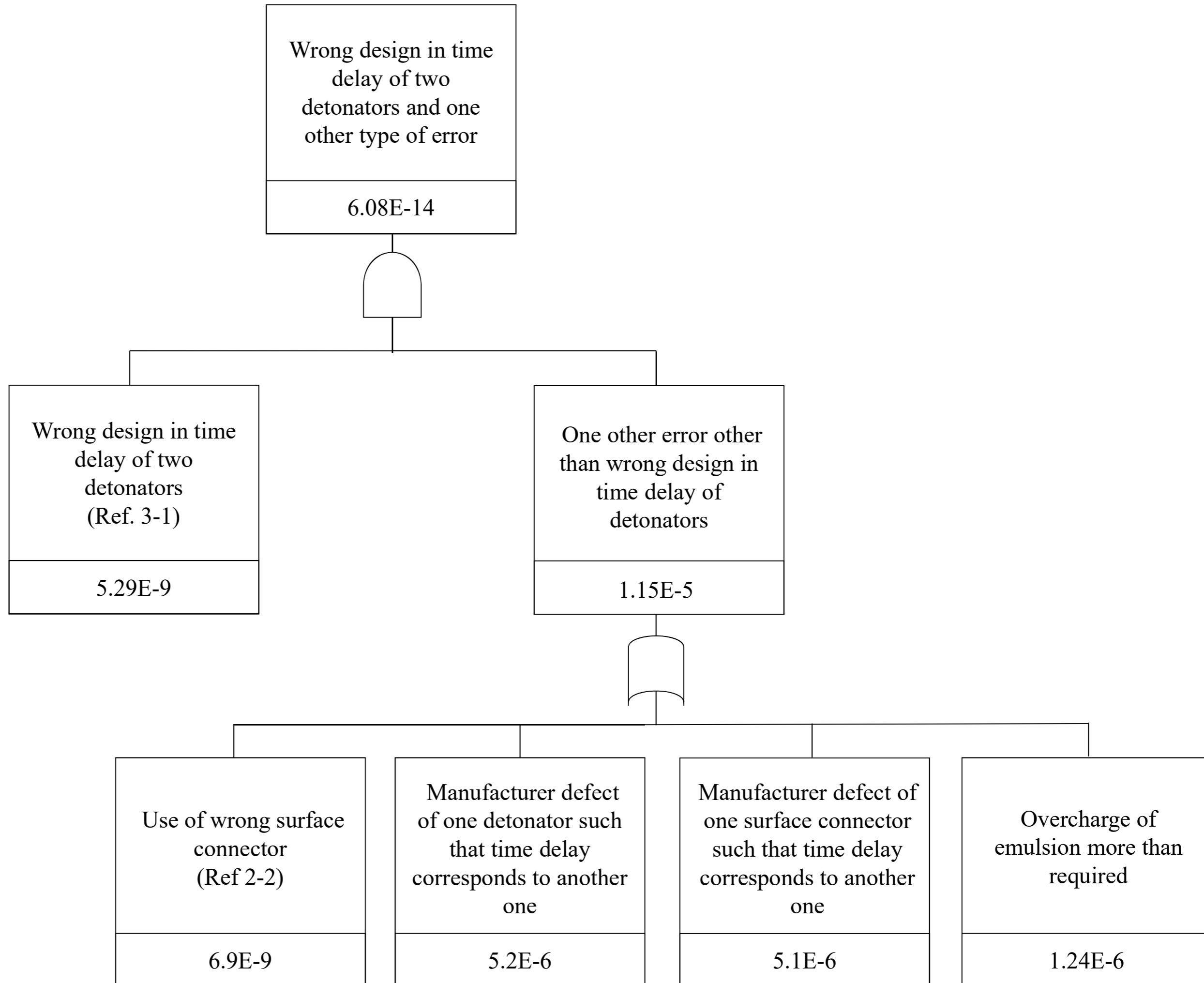




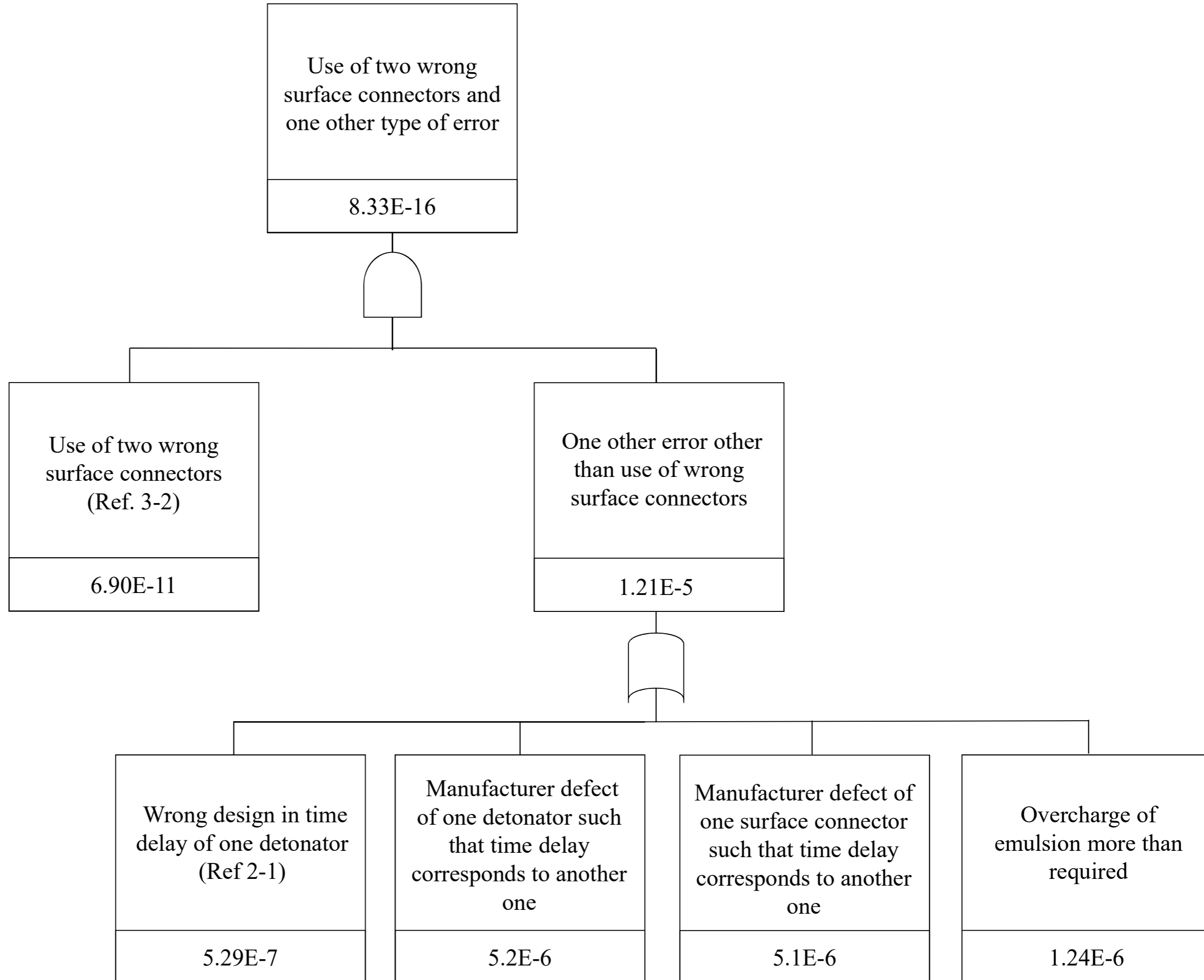
# Ref. 4-2



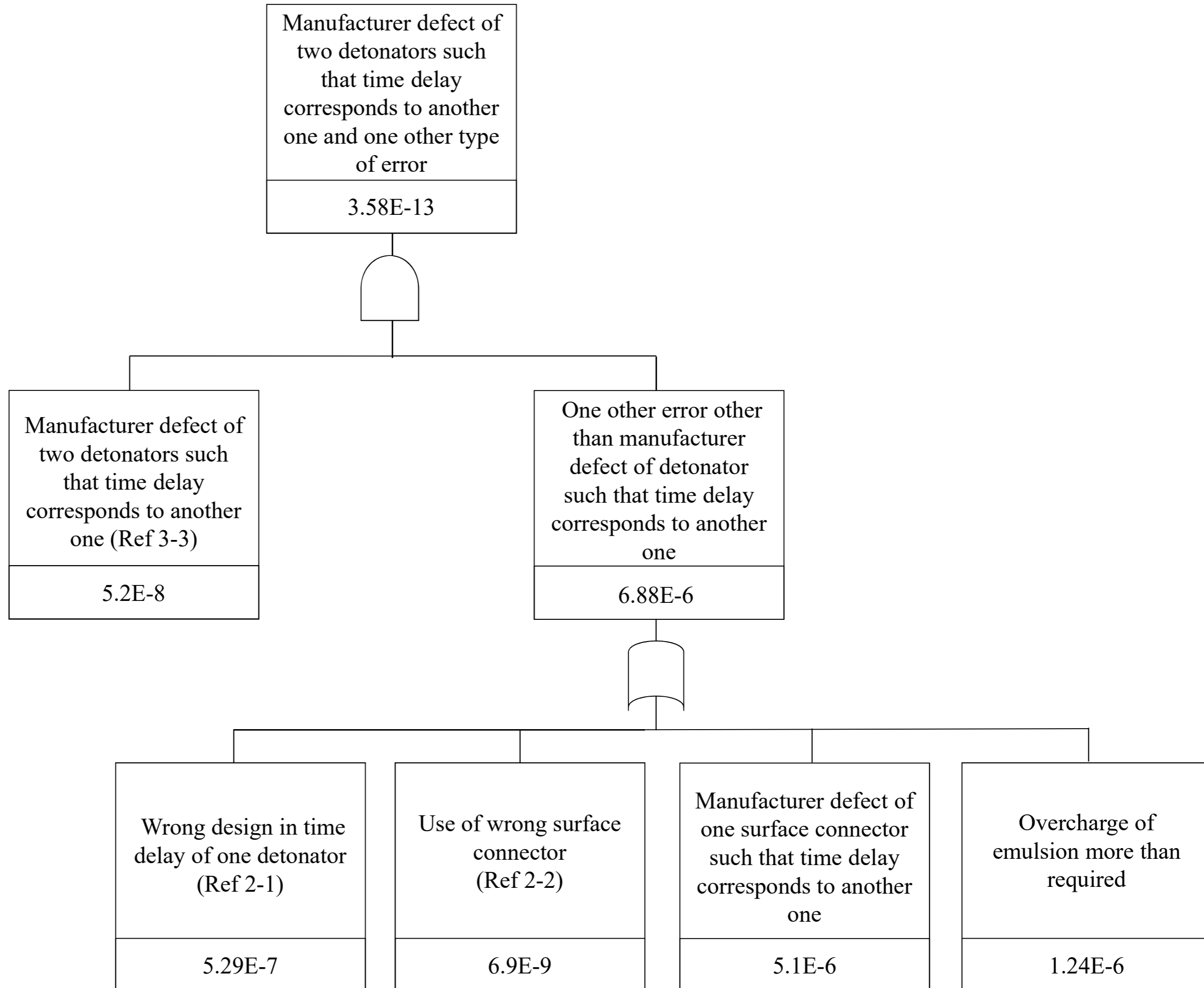
Ref. 4-2-1



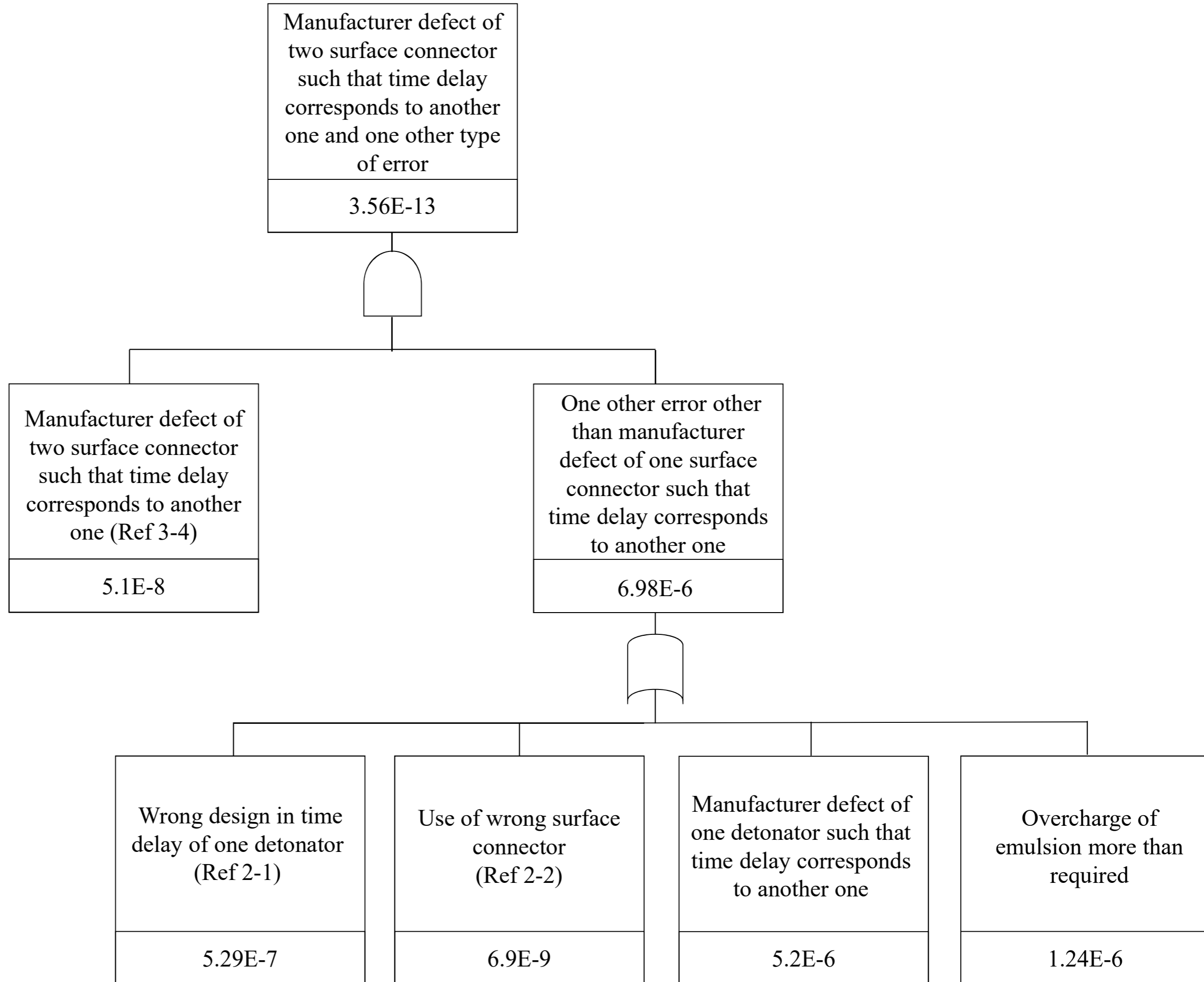
Ref. 4-2-2



Ref. 4-2-3



Ref. 4-2-4



# Ref. 4-3

