Process hazard and risk analysis
Risk graph matrix
Version: 1.1

Process Industry
IEC 61511

Last Edited: 2005-03-03

The risk graph matrix is used for SIL assignment of Safety Instrumented Functions. Integrity levels are established by combining the risk graph consequence parameter C and the likelihood summarized as the risk graph parameters F, P and W. Individual integrity levels for Health, Environmental and Financial hazards could be determined. The overall target SIL of the considered Safety Instrumented Function (SIF) is the maximum determined integrity level.

1 Consequence parameter selection

Number of fatalities and/or serious injuries likely to result from the occurrence of the hazardous event. Determined by calculating the numbers in the exposed area when the area is occupied taking into account the vulnerability to the hazardous event.

Severity level (C) is the estimated consequence of the hazardous event. Select proper level for Health, Environmental and Financial hazards. Fill in the chosen severity letter (A-F) for each individual hazard in the C column.

Determining proper severity levels presupposes consequence categories calibrated to meet the tolerable risk levels established by company risk management and authorities!

2 Occupancy parameter selection

Probability that the exposed area is occupied at the time of the hazardous event. Determined by calculating the fraction of time the area is occupied at the time of the hazardous event. This should take into account the possibility of an increased likelihood of persons being in the exposed area in order to investigate abnormal situations which may exist during the build-up to the hazardous event (consider also if this changes the C parameter).

Exposure rate (F) is the probability that the exposed area is occupied at the time of the hazardous event. The exposure rate is only valid for health risks (H) . If occupancy is permanent or if credit already has been given for a reduced occupancy likelihood when the health severity level was chosen, the "Permanent" alternative (F_D) shall be chosen . Exposure rate F_C shall be chosen if occupancy is frequent or if the occupancy is dependent on the hazardous situation! Exposure rate F_B should be chosen if the area is occupied just occasionally and human presence is obviously independent of the hazardous situation! Exposure rate F_A should only be chosen if the hazardous area is confined and human presence rare and independent of the hazardous situation. Fill in the selected correlating number (0-2) in the P column. A value of 1 for the occupancy parameter is predefined for the environmental and financial hazards

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3 Avoidance parameter selection

The probability that exposed persons are able to avoid the hazardous situation which exists if the safety instrumented function fails on demand. The value of this parameter depends on if there exists independent methods of alerting the exposed persons to the hazard prior to the hazard occurring and if there exists methods of escape.

Avoidance probability (P) is the probability of avoiding the hazardous event even if the considered safety function fails to prevent the event. Normal choice is PB "Avoidance conditions not fulfilled". PA could be chosen individually for the health hazard (H) if all persons in the hazardous area likely are evacuated to a safe area in time if the SIF fails on demand. Besides time are independent facilities for alerting and evacuating all people in the hazardous area required. PA could also be claimed if the hazardous event likely is avoided in time by manual operator actions. In this case is also PA relevant for the environmental and financial hazards. Independent facilities for alerting the operator of the functional failure and for manually bringing the process to a safe state are an absolute demand. The access of time is also a very important requirement for claming PA, and 1 hour is a minimum requirement between operator alert and the hazardous event for taking credit for "Possibility of avoidance" (PA). Fill in the correlating number (0 or 1) of the selected avoidance parameter in the F column.

4 Demand rate parameter selection

The number of times per year that the hazardous event would occur in the absence of the safety instrumented function under consideration. This can be determined by considering all failures which can lead to the hazardous event and estimating the overall rate of occurrence. Other protection layers should be included in the consideration.

The demand rate parameter (W) is selected by estimating or calculating the residual demand rate or frequency of the hazardous event if the considered SIF is not implemented. This frequency can be determined by combining frequencies of failures and other initialising events leading to the hazardous event. Credit should be given for non SIS implemented safety barriers. Layer Of Protection Analysis (LOPA) is a recommended frequency analyse method. The total risk reduction credit for barriers implemented in the normal control system (BPCS), including alarms and operator response, is maximized to 10 times by definition in IEC 61511 (risk reduction factor >0.1). Fill in the chosen number correlating to the estimated or calculated residual demand rate in column W.

5 Risk graph matrix SIL-assignment

Finally add the F, P and W numbers for each of the Health, Environmental and Financial hazards. Fill in the resulting parameter sum in the "Likelihood" column of the form. Use the risk graph matrix to read out the integrity level (IL) for each of the hazards by combining its severity letter (A-F) with its likelihood sum (1-12). The overall target SIL equals the maximum determined integrity level of these (health, environmental and financial).

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Description of process industry risk graph parameters (IEC 61511-3 Table D.1)

Parameter		Description
Consequence	C	Number of fatalaties and/or serious injuries likely to result from the occurence of the hazardous event. Determined by calculating the numbers in the exposed area when the area is occupied taking into account the vulnerability to the hazardous event.
Occupancy	F	Probability that the exposed area is occupied at the time of the hazardous event. Determined by calculating the fraction of time the area is occupiedat the time of the hazardous event. This should take into account the possibility of an increased likelihood of persons being in the exposed area in order to investigate abnormal situations which may exist during the build-up to the hazardous event (consider also if this changes the C parameter).
Probability of avoiding the hazard	P	The probability that exposed persons are able to avoid the hazardous situation which exists if the safety instrumented function fails on demand. This depends on there being independent metods of alerting the exposed persons to the hazard prior to the hazard occuring and there being methods of escape.
Demand rate	W	The number of times per year that the hazardous event would occur in the absence of the safety instrumented function under consideration. This can be determined by considering all failures which can lead to the hazardous event and estimating the overall rate of occurence. Other protection layers should be included in the consideration.

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C	Human harm (H)	Probability Loss of Life		Max. health consequences due to the hazardous event	Additional comments to the health consequence categories
C_F	Catastrophic	PLL = 1		Several (3 or more) dead. Many (10 or more) critical injured.	Several fatalities likely.
C_E	Extensive	PLL = 0.1 – 1.0		Some (1 to 2) dead. Several (3 or more) critical injured.	Individual fatality/fatilities likely.
C_D	Serious	PLL = 0.01 – 0.1		Some (1 to 2) critical injuries. Several (3 or more) injured.	Several lost time injury/injuries. One or some lasting disablement. Fatality/fatalities not likely but possible
C_C	Considerable	PLL < 0.01		Some (1 to 2) injuries. Serious discomfort.	One or some lost time injury/injuries. Minor probability of lasting disablement. Fatalaty improbable.
C_B	Marginal	PLL = 0		Minor injury/injuries. Lasting discomfort.	No lost time injury/injuries. Medical treatment required.
C_A	Negligible	PLL = 0		Negligible injury/injuries. Temporary discomfort.	No lost time injury/injuries. No medical treatment required.

C	Environmental harm (E)	Effluent Influence	Effluent Extension	Max. environmental consequences due to the hazardous event	Additional comments to the environmental consequence categories
C_F	Catastrophic	Lasting	Wide	Wide permanent or long time harm. Decontamination impossible or hard.	A liquid spill into river or sea. A wide vapour or aerosol release. The effluent causes lasting or permanent damage to plants and wildlife.
C_E	Extensive	Lasting	Confined	Confined permanent or long time harm. Decontamination impossible or hard.	A liquid spill to ground water. A confined vapour or aerosol release. The effluent causes lasting or permanent damage to plants and wildlife.
C_D	Serious	Lasting	Limited	Limited permanent or long time harm. Decontamination impossible or hard.	Onsite liquid spill. A limited vapour or aerosol release (within fence). The effluent causes lasting or permanent damage to plants and wildlife.
C_C	Considerable	Temporary	Wide/Confined	Wide to confined temporary harm. Decontamination easy or not needed	A liquid spill into river or sea. A limited vapour or aerosol release. The effluent causes temporary damage to plants and wildlife.
C_B	Marginal	Temporary	Limited	Limited (on site) temporary harm. Decontamination easy or not needed	Onsite liquid spill. A limited vapour or aerosol release (within fence). The effluent causes temporary damage to plants and wildlife.
C_A	Negligible	Negligible		Negligible environmental harm. Decontamination not needed	Moderate leak from flange or valve. Small liquid spill or small soil pollution not effecting ground water. Negligible environmental effects

C	Financial harm (F)	Damaged property (k€)	Production loss (k€)	Max. financial consequences due to the hazardous event	Additional comments to the financial consequence categories
C_F	Catastrophic	>10 000	>50 000	Devastating loss off production, market share and image.	Devastating damage to production unit and/or plant. Event causing or requiring a production stop for more than a year
C_E	Extensive	1 000 - 10 000	5 000 - 50 000	Extensive loss of production. Large loss of market share and/or image	Extensive damage to equipment and/or property. Event causing or requiring a lasting production stop of several months
C_D	Serious	100 - 1 000	500 - 5 000	Large loss of production. Considerable loss of market share and/or image	Serious damage to equipment and/or property. Event causing or requiring a lasting production stop up to a month
C_C	Considerable	10 - 100	50 - 500	Considerable loss of production. Marginal loss of market share.	Considerable damage to equipment and/or property. Event causing or requiring a lasting production stop up to a week
C_B	Marginal	1-10	5-50	Minor loss of production. No loss of market share and/or image.	Minor damage to equipment Event causing or requiring a day of production stop.
C_A	Negligible	<1	<5	Negligible loss of production. No loss of market share and/or image.	Negligible damage to equipment Event causing or requiring a temporary (hours) production stop

This is only an example on how consequences could be divided into different categories. It is important to point out that it is the responsibility of each individual company to, by themselves, divide consequences into different categories!

Risk graph matrix
SIL-assignment form for Safety Instrumeted Functions

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Projekt:
Issued by:
Date:
Revision:

Process:
Plant:
System:
Chartnr:

Consequence parameter			Risk graph matrix						Occupancy parameter				Avoidence parameter				Demand rate parameter			
			Likelihood sum (**F+P+W**)						*Frequency of human presence in the hazardous zone. Credit for limited occupancy must not have been taken choosing the consequence categories!*				*Probability of avoiding the hazardous event **if the SIF fails on demand**. Implies **independent** facilities provided to "shut-down" so hazard can be avoided or enable all persons to escape to a safe area.*				Demand rate			**W**
Severity Level		**C**	1-2	3-4	5-6	7-8	9-10	11-12					*Conditions to be fullfilled for P_A:*				W_9	Often	> 1/ y	9
C_F	Catastrophic	F	NR	IL 1	IL 2	IL 3	IL 4	NO					*•Facilities to alert operator that the SIS has failed*		*•Independent*		W_8	Frequent	1 / 1-3 y	8
C_E	Extencive	E	NR	NR	IL 1	IL 2	IL 3	IL 4	Exposure rate			**F**	*facilities to bring process to safe state*		*•Time betwen*		W_7	Likely	1 / 3-10 y	7
C_D	Serious	D	OK	NR	NR	IL 1	IL 2	IL 3	F_D	Permanent	=1	2	*operator alert and hazardous event >1h*				W_6	Probable	1 / 10-30 y	6
C_C	Considerable	C	OK	OK	NR	NR	IL 1	IL 2	F_C	Frequent	0.1-1	2	Avoidance probability			**P**	W_5	Occational	1 / 30-100 y	5
C_B	Marginal	B	OK	OK	OK	NR	NR	IL 1	F_B	Occasionally	0.01-0.1	1	P_B	Avoidance conditions not fulfilled		1	W_4	Remote	1 / 100-300 y	4
C_A	Negligible	A	OK	OK	OK	OK	NR	NR	F_A	Rare	<0.01	0	P_A	All avoidance conditions are fulfilled		0	W_3	Improbable	1 / 300-1000 y	3
																	W_2	Incredible	1 / 1000-10000 y	2
																	W_1	Inconceivable	1 / 10000-100000 y	1

SIF-No:	Hazardous Event Description	Safety Instrumented Function (SIF) Description	Consequence Type	Consequence C	Influence F	Influence P	Demand W	Likelih. Sum	Integrity IL	Integrity SIL	Comments
01	Flash separator rupture due to overpressure. Hydrocarbon explosion.	Pressure protection function blocking high pressure liquid feed to vessel in case of "high pressure".	*H*	**F**	2	1	3	**6**	2	**2**	This example is described more in detail in the separate document: **Process hazard and risk analysis** ***Risk graph matrix*** ***SIL-assignment example***
			E	**D**	*1*	1		**5**	0		
			F	**E**					1		
02			*H*								
			E		*1*						
			F								
03			*H*								
			E		*1*						
			F								
04			*H*								
			E		*1*						
			F								
05			*H*								
			E		*1*						
			F								