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משרד האוצר - מחוז דרום
הוועדה המחוזית החליטה ביום :
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תאריך יו"ר הוועדה המחוזית

מועצה אזורית תמר

נספח סיכוני גז טבעי לתסקיר השפעה על הסביבה

מס' תכנית 656-0301937

(מפעל אמוניה ומוצרים נלווים)

הזמט בע"מ – ינואר 2019

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התיק הוכן עבור: המועצה האזורית תמר

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מהדורה: R4

תאריך: ינואר 2019

המועצה האזורית תמר
ים המלח

תקציר סקר סיכונים וסיווג אווירה נפיצה

1. תקציר זה כולל את הנחות העבודה ותוצאות סקר הסיכונים וסיווג אווירה נפיצה של תחנת ה PRMS. **כאשר יהיה תכנון מפורט של התחנה וסביבתה, ייתכן כי יהיה צורך לבצע סקר סיכונים וסיווג אווירה נפיצה בהתאם לנתונים המדויקים אז (באחריות יזם המפעל).**
2. החומר הנבחן הינו מתאן CH_4, החומר העיקרי בגז טבעי. הגז הטבעי מגיע בלחץ של 50-80 ברג (כאשר באופן מחמיר הסקרים התייחסו ללחץ של 80 ברג) ומופחת ללחץ של 50 ברג.
3. <u>סיווג אזורי אווירה נפיצה:</u>

3.1. סיווג אווירה נפיצה בוצע לפי תקן Hazardous Area Classification of Natural Gas Installations, Institution of Gas Engineering and Managers (IGEM) /SR/25 edition 2 2010.

3.2. הנחות העבודה עבור סיווג האווירה הנפיצה מסביב לצנרת בתוך התחנה:

3.2.1. הסקיד יהיה מתחת לסככה ועל כן לפי התקן אזור התחנה מוגדר בתוך מבנה.

3.2.2. בתחנה יהיה אוורור טבעי המוגדר – more than adequate, כלומר אוורור טבעי יותר מהנדרש. אוורור זה מאפשר לקבל את הסיווג אזורים המינימלי. אוורור טבעי פחות מאוורור זה יגרום לאזורי אווירה נפיצה רחבים יותר.

3.2.3. בחישוב לבדיקת שטח האוורור הטבעי הנדרש יש לקחת בחשבון את מספר אביזרי הציוד על הצנרת. התקן מגדיר חישוב לפי אביזרי הצנרת הקיימים למציאת מספר אביזרי צנרת היכולים לדלוף בו זמנית. מכיוון שאין תכנון מפורט נכון לזמן כתיבת הסקר, הונח ערך ביניים של 4 פריטים דולפים בו זמנית. מספר זה עלול להשתנות עם התכנון המפורט ובכך להקטין את טווחי האווירה הנפיצה בתחנה או להגדילה ואף להגיע לכל הסככה או לאזור סיווג מחמיר יותר (למשל zone 1 במקום zone 2).

3.3. תוצאות הסיווג עבור הצנרת בתחנה והמלצות לתכנון:

3.3.1. מתקני ומערכות גז טבעי יהיו ממוקמים באזור בעל אוורור טבעי. יש לוודא שלא תתאפשר הצטברות גז מתחת לגג הסככה. יש לשקול גג משופע עם שחרור גז בנקודה הגבוהה.

3.3.2. עבור אוורור יותר מהנדרש בתחנה ועבור ההנחות העבודה המפורטות לעיל, טווח האווירה נפיצה בתנאים סטנדרטיים הינו 2 מטרים מסביב לצנרת העילית בתחנה, הן מסביב לצנרת של 80 ברג ומסביב לצנרת של 50 ברג zone 2.

3.4. הנחות העבודה עבור סיווג אווירה נפיצה מסביב לוונטים בתחנה:

3.4.1. יתוכננו ארובות נישוב (וונטים) בקוטר עד "2 בתחנת הפחתת לחץ ומניה.

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3.4.2. הוונט יהיה וונט אידאלי – וונט המופנה כלפי מעלה, ללא זוויות, וללא הפרעות בזרימה. על וונט אידאלי להיות מאושר על ידי הספק בוונט אידאלי וכן להיות מאושר על ידי רשות הגז (עם הגשת המסמכים לבדיקתה).

3.4.3. הוונט יהיה ממוקם בגובה של 1.5 מטרים מעל גובה הסככה. זהו גובה סטנדרטי ושינוי של גובה זה עלול לשנות את הסיווג מהוונט.

3.5. תוצאות הסיווג עבור הוונט בתחנה והמלצות לתכנון:

3.5.1. יש למקם את הוונט בגובה של 1.5 מטרים מעל גובה הסככה.

3.5.2. יש לוודא כי הוונט הינו וונט אידאלי.

3.5.3. שינוי קוטר קצה הוונט ידרוש עדכון ובחינה של טווחי האווירה הנפיצה (רדיוס נטול מקורות הצתה).

3.5.4. יש לשמור מרחק של 1 מטר מהוונט zone 1.

3.5.5. מסביב לוונט יש לשמור את הטווחים הבאים ללא מקורות הצתה (מוגדר כ zone 2):

- רדיוס של 19 מטרים מסביב לפתח קצה הוונט ועד גובה של 100 מטרים. רדיוס זה ישמר עם הארכה למטה של 0.1 מטרים מתחת לקצה הוונט.
- רדיוס של 10 מטרים מתחת לקצה הוונט עם הארכה למטה עד 2.9 מטרים מתחת לקצה הוונט.
- רדיוס של 5.5 מטרים מסביב לנקודות הניקוז של הוונט.

4. <u>סקר סיכונים:</u>

4.1. סקר הסיכונים בודק מספר נושאים – מרחקי הפרדה הנדרשים לפי מדיניות המשרד להגנת הסביבה; הערכת סיכונים הסתברותית עבור ה PRMS בהתאם לנדרש בת"י 5664-1 (בחינה של סיכון אישי (IR) וסיכון ציבורי (SR)) וכן השפעה הדדית של תחנת ה PRMS. בנוסף הוגדרו מרחקים לקו בניין ולתחום סקירה עבור הצנרת התת קרקעית וכן סווג האזור בקרבת הצנרת, בהתאם לת"י 5664-2.

4.2. מרחק ההפרדה מה PRMS נבחן לפי חוזר מנכ"ל בנושא מדיניות מרחקי הפרדה ממקורות סיכון נייחים (מרץ 2014) ונמצא כי יש לעמוד במרחק הפרדה של 84 מטרים לרצפטורים ציבוריים (לפי הגדרתם בחוזר המנכ"ל).

4.3. הערכת סיכונים הסתברותית ל PRMS נעשתה בהתאם לדרישות רשות הגז הטבעי ולפי המתודלוגיה של הספר הסגול ("Guidelines for Quantitative Risk Assessment" 2005 edition ('Purple book')) ובעזרת תכנת TNO-Effects גרסה 8 של ה EPA. הקריטריונים בהערכת סיכונים זו: Individual risk & Societal risk

4.3.1. סיכון אישי של 10^{-6} ומעלה (קו בנין) – סיכון שמייצג תדירות שנתית היפותטית למוות של אנשים (לא ממוגנים) כתוצאה מתקרית חומ"ס. בקונטור של סיכון זה אסור שיימצאו רצפטורים מחוץ לגבולות המפעל. נמצא כי טווח זה הינו 80 מטרים מהצנרת העילית בתחנה. כיום כל האזור מיועד לתעשייה ואין ולא מתוכנן רצפטור ציבורי בטווח הנדון.

4.3.2. סיכון אישי של 10^{-8} ומעלה (מרחק סקירה) –טווח זה הינו 110 מטרים מהצנרת. המפעל היחיד שאינו מפעל האמוניה, הנמצא בטווח זה, הינו מפעל חיפה כימיקלים דרום.

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לפי המצב הקיים כיום במפעל חיפה כימיקלים דרום – הסיכון הציבורי שמטילה התחנה המתוכננת קביל.

4.3.3. תרחישים עבור סקר הסיכונים בוצעו תוך הבנה כי קיים ברז ניתוק אוטומטי בכניסה לכל סקיד. תחנת ה PRMS תכלול 3-5 סקידים שונים, כאשר אחד מהם מיועד למפעל האמוניה. הסקר לקח בחשבון 4 סקידים בעת חישוב הסיכון האישי.

4.3.4. עבור צנרת הגז טבעי התת קרקעית (צנרת פלדה בקוטר 18" ואורך של כ800 מטרים) מה PRMS הקיים ל PRMS המתוכנן, נבדק תחום סקירה, קו בניין וסיווג האזור הסמוך בהתאם לת"י 5664-2.

- תחום סקירה לצנרת התת קרקעית הינו 75 מטרים. בתחום זה על תכנון הצנרת להתאים לסיווג האזור לפי התקנים הרלוונטיים לצנרת הולכה בלחץ גבוה. כמו כן לא יוקמו בתחום זה רצפטורים ציבוריים.
- קו בניין לצנרת התת קרקעית הינו 25 מטרים. בטווח זה אין לבנות מבנים מאוישים, או מבנים המכילים תשתית בעלת ערך משמעותי (כגון מרכזיות טלפונים, מרכזי מחשוב או ציוד לבקרה אווירית).

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המועצה האזורית תמר
ים המלח

NG Supply Line – Ammonia plant

Risk Assessment

By: Hazmat, Risk Eng. Department

October 2018

Classification	Department	Reference	Project no.

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Section I - Introduction

1. General

Gadish group engineering is planning a Natural Gas pressure reduction and metering station (PRMS) at the future ammonia plant in Mishor Rotem. In light of this, risk assessments have been conducted to examine potential risks deriving from the planned gas line, required separation distances and to seek adequate solution to minimize the potential risk to the PRMS and its surroundings.

This report is written with the assumption that there will be no odorization of the gas in the station.

2. Goals

2.1. Identifying potential risks resulting from the planned PRMS.

2.2. Calculating required separation distances from the planned gas supply line.

2.3. Suggesting risk reduction means and providing recommendations.

3. Method

3.1. Data from correspondences with Gadish and Baran companies.

3.2. Analogy with similar PRMS stations in order to execute risk scenarios.

3.3. Separation distances

Analysis according to separation distances policy document from stationary risk sources of the Ministry of the Environmental Protection (March 2014), using ALOHA software version 5.4.7 (the software required by the Ministry of Environmental Protection) and TNO-Effects software version 8.

3.4. Individual risk assessment (10^{-6} risk contour) – building proximity line for the PRMS

Analysis of natural gas scenarios using ALOHA software version 5.4.6, and TNO-Effects software version 8, "Guidelines for Quantitative Risk Assessment" 2005 edition ('Purple book') and calculative models. Individual risk assessment was conducted according to Guidelines for quantitative risk assessment CPR18E, 2005 edition ('Purple book').

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3.5. Societal risk assessment (within 10^{-8} risk contour) – survey range for PRMS

Analysis with mathematical model based on the individual risk assessment and according to Guidelines for quantitative risk assessment CPR18E, 2005 edition ('Purple book').

3.6. Survey range, building proximity distance and area classification for the underground pipeline from existing PRMS to planned PRMS – were taken from SI 4665 part 2.

4. Description of the Natural Gas Supply Line

The gas supply will be distributed from the PRMS to the various NG consumers in the ammonia plant. The line from the existing PRMS to the new PRMS will be 800 meters long, with an automatic shutoff valve at the entrance of the PRMS station. The PRMS station will include about 3-6 skids to different plants, one of them will be the ammonia plant.

Following is a principal description of **one skid** at the planned PRMS station:

Line number	**SKID-section 1**	**SKID-section 2**
Diameter (inch)	18	6
Feed pressure (barg)	80	50
Volumetric flow (Sm^3/h)	300,000	18,000
Length (m)	12.3	3.5

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The scenarios and analysis in this report assume 4 skids in the PRMS station.

This report assumes that there will be an automatic shutoff valve at the entrance of **each skid,** which may close the NG supply if necessary.

The pipeline from PRMS station to consumers was not taken into consideration in this report, since the PRMS and the pipeline are still in preliminary design. The pipeline is likely to be underground, as much as possible.

5. Risks Deriving from Natural Gas

Natural gas is a mixture of gases; the main component is Methane CH_4.

Following is a detail of identifying data and characteristics from compressed natural gas:

UN Number: 1971

Risk Group: 2.1 (Flammable Gases)

Boil Temperature: -161.5 C°

Fusion Temperature: -182.6 C°

Relative Molar Mass: 16.05 (for Methane)

Flash Temperature: -222.2 C°

Auto-ignition Temperature: 650 C°

Upper Explosiveness Range: 15.00%

Lower Explosiveness Range: 5.00%

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6. Summary of conclusions and recommendations

Conclusions

6.1 There are no public receptors in the pipeline's immediate surrounding area. The station is located in the industrial zone Mishor Rotem.

6.2 The amount of NG in the supply line (about 436 kg) is below the threshold quantity requiring a scenario analysis according to The Ministry of Environmental Protection (5,000 kg). Nevertheless, such a scenario of gas leak and UVCE was analyzed. The scenario result shows that if there is a leak in the pipe, the threat zone is 84 meters from the pipeline. There are no public receptors located within the threat zone.

6.3 The individual risk along the pipeline was also calculated. The pipeline section has an individual risk contour of 10^{-6} at 80 meters from the pipeline, and 10^{-8} contour at a distance of 110 meters from the pipeline (after mathematical calculations including probabilities in each grid cell). The only plant outside the planned ammonia plant within 110 meters is HCS.

6.4 The survey range for the underground pipe line from the existing PRMS to the planned PRMS (800 meters long, with 18'' diameter and a pressure of 80 barg), was taken according to SI 5664 part 2 and is 75 meters.

6.5 The building proximity distance for the underground pipe line from the existing PRMS to the planned PRMS (800 meters long, with 18'' diameter and a pressure of 80 barg), was taken according to SI 5664 part 2 and is 25 meters.

6.6 The area surrounding the underground pipe line, according to SI 5664 part 2 is defined as area classification 4. The planner should take into account the wall thickness factor according to this classification.

6.7 Passive safeguards- The station will be located under a shed.

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6.8 The distance to a concentration of 25% of the lower explosive limit in air was calculated, for a scenario of full rupture of a 18" NG pipe line connected to infinite source, assuming the shut off valve has not been closed (see appendix 1). As can be seen from the results, at 5 meters distance, the cloud concentration is above 25%LEL at about 53.31 meters height. As long as there are no ignition sources within 5 meters and there are no ignition sources at height, ignition is not expected. Nevertheless, proximity distance was calculated with a strict assumption that ignition could occur.

Recommendations

6.9 Ignition sources near the NG supply line will be eliminated:

- Electrical equipment will be installed according to hazardous area classification.
- When determining the vents height verify that there are no ignition sources at least:

  2" vent: 0.4 meters beneath the vent tip, 5.5 meters beneath the vent drain hole and 19 meters horizontally from the vent tip (see Hazardous Area Classification).
- Hot work will require a permit.

6.10 In any case, firefighting and fire prevention equipment will be installed in accordance with the project's fire prevention report.

6.11 It should be emphasized that leakage and fire incidents are short-term incidents, as long as the gas supply is connected to the gas station. That is to say that the exposure time to thermal radiation flux is short. It should be verified that in case of a leakage, the gas supply is disconnected as fast as possible.

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Section II – Separation distances according to Ministry of Environmental Protection

1. Description

1.1 The **Natural Gas** amount in the pipeline (about 109 kg at a time for the PRMS station) does not exceed the threshold quantity listed in Appendix B of the Ministry of Environmental Protection CEO instruction regarding separation distances determination policy (March 2014), 5000 kg. Therefore, the station is not required to comply with the separation distances policy. However, it was decided to examine a reference scenario according to the policy requirements- gas ignition and explosion.

Due to the natural gas's characteristics and since it is lighter than air, in a scenario of leakage in an open space, the buoyant gas floats upwards in the shape of an overturned cone and dilutes quickly. In this case, and due to the expected small amount of gas in the flammable zone, it is presumable that the occurrence of a UVCE (Unconfined Vapor Cloud Explosion) scenario is of very low probability. Nevertheless, such a scenario was analyzed as per the Ministry of Environmental Protection specifications.

2. The scenario analyzed

Source	Scenario
NG Pipeline Section	Leakage from a hole 1" in diameter and gas cloud explosion UVCE

3. Data used for the analysis

3.1. Software

The Ministry of Environmental Protection requirements for natural gas scenario are: leak, from 1'' diameter hole, in a tank with the dimensions of the actual pipe on site. ALOHA software does not enable modeling a tank with such dimensions therefore, Effects version 8 (TNO Safety software), was used to determine the leak rate.

The result was then fed into the ALOHA software as a direct-instantaneous source (the Effects showed that the leak will last 55 sec, until the vessel (pipe) is empty).

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3.2. Substance

Scenario for the natural gas was made for the substance Methane, which is the primary component of natural gas.

3.3. Vessel volume

Vessel volume regarding NG is as the pipeline volume.

3.4. Meteorological conditions

The meteorological conditions are based on the Ministry of Environmental Protection specification to be:

Wind speed: 3 m/s at a height of 10 meters.

Terrain: Urban.

Cloud cover: 50%

Ambient temperature: 25° C

Substance temperature: process temperature.

Atmospheric stability condition: D.

Inversion: none.

Relative humidity: 50%.

Level of congestion (in the flammable part of the vapor cloud): Congested

3.5. End points

End point used to determine the threat zone is based on reference values for planning condition as stated in the Ministry of Environmental Protection specifications as follows:

- Explosion – overpressure of 0.1 bar.
- Heat radiation - 1.6 kW/m^2

3.6. NG analysis

Pipeline diameter

NG- Line diameter is 15.34'' (mean diameter)

Pipeline length

Line length is 16 m within each SKID

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4. Results of the scenarios

Source	Scenario	Environmental Reference Value	Results
NG Pipeline Section	Leakage from a hole 1" in diameter and gas cloud explosion UVCE (instantaneous leak)	0.1 bar	84 meters

5. Conclusions and Recommendations

5.1. There are no public receptors in the pipeline's immediate surrounding area or in the threat zones calculated. The station is located in Mishor Rotem.

5.2. The results show that if there is a leak in the NG pipeline, the threat zone is 84 meters from the pipeline. It should be noted that explosion scenario for NG is very unlikely, and if it does happen this threat zone is for window damage. It should be noted that such a leakage will be identified within few minutes and the shutoff valve will be closed. As mentioned in clause 5.1 above there are no public receptors within the threat zone.

5.3. Ignition sources near the NG supply line will be eliminated:

- Electrical equipment will be installed according to Hazardous Areas Classification report.
- Hot work will require a permit.

5.4. In any case, firefighting and fire prevention equipment will be installed in accordance with the project's Fire prevention report.

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Section III – Proximity distance assessment for the PRMS

1. Description

The proximity distance is the distance from the potential source of release in which the **IR – (Individual Risk)** is 10^{-6}. The IR represents the frequency of a hypothetical individual (assumed to be unprotected) death due to loss of containment events, as described in annex 3.

Societal Risk (SR) represents the frequency F of having an accident with N or more people being killed simultaneously. The distance from the potential source of release, in which the IR is 10^{-8}, needs to be considered.

The Societal Risk is presented as an F-N curve, where N is the number of deaths and F the cumulative frequency of accidents with N or more deaths (N Is a number ranging from 1 death to the maximum theoretical number of fatalities).

Natural gas leakage from any of the lines, except the underground pipeline, are to be considered.

2. Methodology

This report calculates the proximity distances and combines several factor/terms:

- Frequencies of LOC (loss of containment) for pipes (m^{-1} y^{-1}) (table 3.7 in the "purple book")
- Length of the pipe (m)
- Probability of a direct ignition (table 4.5 in the purple book)
- Probability of ignition for a time interval of one minute (table 4.A.1 in the "purple book")

The area of interest is divided into grid cells, at this case, 20 meters X 20 meters each. For each scenario the proximity distance is calculated. Then all the contributions are summed up.

According to Guidelines for quantitative risk assessment CPR18E, 2005 edition ('Purple book'), the probability of death and the fraction of people suffering death should be calculated up to the level of 1% lethality.

There are no public receptors in the vicinity of PRMS, therefore the societal risk has not been calculated.

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3. Scenarios analyzed

All scenarios were analyzed for above ground pipes only.

3.1 Leakage from a hole in the pipe, with immediate ignition and conflagration of the gas jet resulting in Jet-Fire.

3.2 Leakage from a hole in the pipe, with delayed ignition of vapor cloud and conflagration at the ignition point, without an explosion (Flash-Fire).

3.3 Based on the design and INGL remarks, full bore rupture scenarios were considered extremely rare and their risk distances were not mentioned in the total risk calculation.

4. Data used for the analysis

3.1 Software

- The JET FIRE scenarios were analyzed with Effects version 8 (TNO Safety software) since ALOHA does not model a leak from the pipeline when the valve is open. Therefore, all JET FIRE scenarios were analyzed in the same software in order to maintain compatibility.
- The FLASH FIRE scenarios were analyzed with Effects version 8 (TNO Safety software) and a corresponding mathematical model (since ALOHA does not have a model for flash fire). Effects has been used since ALOHA does not model a leak from the pipeline when the valve is open. Therefore, all FLASH FIRE scenarios were analyzed in the same software in order to maintain compatibility.

3.2 Substances

Scenarios for the natural gas were made for the substance Methane, which is the primary component of natural gas.

3.3 Frequencies and probabilities

- Frequency of a leak for diameters larger than 5.9'' (150 mm) is 5×10^{-7} m^{-1} y^{-1} (taken from the purple book)
- Probability of immediate ignition ($P_{im.ig}$) is:

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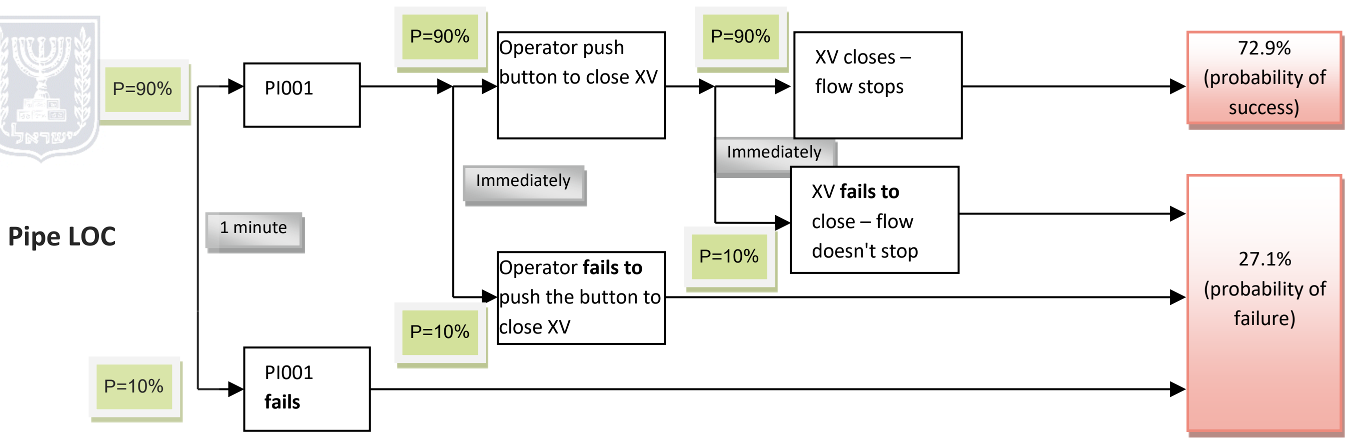
Source		NG probability of direct ignition
Continuous	Instantaneous	
<10 kg/s	<1000 kg	0.02
10-100 kg/s	1,000-10,000 kg	0.04
>100 kg/s	>10,000 kg	0.09

(from table 4.5, as defined in the purple book)

- Probability of delayed ignition is ($1-P_{im.ig}$) x 0.9 (taken from table 4.A.1, purple book, for chemical plant).
- Probability of success in closing the XV valve- 0.729 (according to event tree analysis)
- Probability of failure in closing the XV valve- 0.271 (according to event tree analysis)

3.4 Event tree analysis (ETA)



3.5 Pipeline diameter

NG average diameter: 15.34'' (mean diameter)

3.6 Pipeline length

NG Line length is 16 m within one skid

3.7 Meteorological conditions

Condition	Wind velocity (m/s)	T°C*	Cloud cover
Bm	4	21.5	25%
Dl	2	18	75%
Dm	4	18	75%
Dh	8.5	18	100%
Em	4	15	25%
Fl	2	15	0%

- The meteorological conditions refer to the definitions of Pasquil-
    - Unstable conditions- B
    - Neutral condition- D
    - Stable condition- E
    - Very stable condition- F
- The small letters refer to the wind velocity:
    - Low wind velocity- l
    - Medium wind velocity- m
    - High wind velocity- h
- The temperature was determined according to the atlas of climate:
    - For stability condition D an average temperature of 18°C
    - For stability conditions E and F an average temperature of 15°C
    - For stability condition B an average temperature of 21.5°C

The models were run with each of the meteorological conditions, described above. There was no significant difference in the distances obtained for the various reference values. Therefore, the scenarios where conducted in a representative meteorological condition as in separation distances section above.

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3.8 Passive safeguards

The station will be located under a shed.

3.9 Determining the thermal radiation end point

Determining the thermal radiation end point takes into consideration the risk of 1% lethality. A heat radiation model analysis (Effects version 8.0) determined that the value of heat radiation that may cause 1% lethality is 10 kW /m^2. The heat radiation was checked in every grid cell.

3.10 Acceptability criteria

IR- The acceptability criteria is IR < 10^{-6}

SR- The acceptability criteria is mortality of 10 individuals in a probability of 10^{-5}, mortality of 100 individuals in a probability of 10^{-7} etc. The risk is considered acceptable if the societal risk graph is below the acceptability criteria graph

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5. Results

5.1 Individual Risk

Source	Scenario		Distance to 1% lethality (10kW/m^2)
NG Pipeline Section	Leak through a hole in pipe	Immediate ignition (80 barg) , failure and success* in closing the valve-Jet Fire	Less than 20 meters
		Immediate ignition (50 barg), failure and success* in closing the valve-Jet Fire	Less than 5 meters
		Delayed ignition (80 barg), failure in closing the valve-Flash fire	46 meters
		Delayed ignition (50 barg), failure in closing the valve-Flash fire	11 meters
		Delayed ignition (80 barg), success in closing the valve-Flash fire	43 meters
		Delayed ignition (50 barg), success in closing the valve-Flash fire	10 meters

* Jet fire scenarios are influenced by heat flux and release rate but not by the release duration, therefore the distance calculated is the same for the success and failure in closing the valve (which affects the release duration only).

The individual risk along the pipeline was also calculated. The pipeline section has an individual risk contour of 10^{-6} at 80 meters from the pipeline.

5.2 Societal Risk

Assuming the detailed planning of the PRMS will include passive protection by shed roof facing HCS (taking into account the required ventilation as discussed in HAC document 1489-1-R1), the 10^{-8} contour will be at a distance of 110 meters from the pipeline (after mathematical calculations including probabilities in each grid cell). The only plant outside the planned ammonia plant within 110 meters is HCS

The societal risk was calculated for an hourly average population of maximum 5 people at 110 meters distance from the PRMS.

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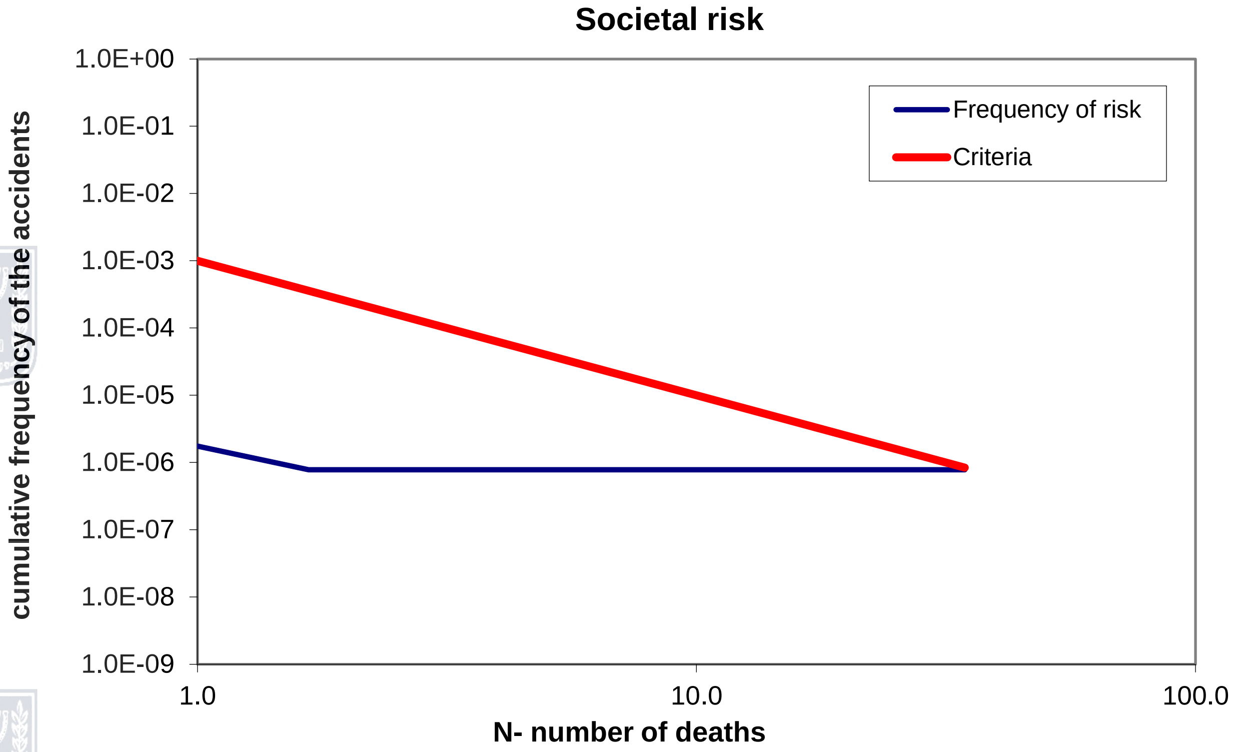
The F-N curve for the societal risk analysis is presented below:



As shown in the figure above, the societal risk is low and acceptable, since the societal risk graph (blue line) is below the acceptability criteria graph (red line).

6. Conclusions

6.1 The individual risk along the pipeline was also calculated. The pipeline section has an individual risk contour of 10^{-6} at 80 meters from the pipeline, and 10^{-8} contour at a distance of 110 meters from the pipeline (after mathematical calculations including probabilities in each grid cell.

6.2 As shown in the results, for an hourly average population of maximum 5 people at 110 meters distance from the PRMS, the societal risk is low and acceptable, since the societal risk graph (blue line) is below the acceptability criteria graph (red line). Therefore, the societal risk is acceptable at the current situation.

6.3 It should be emphasized that leakage and fire incidents are short-term incidents, as long as the gas supply is connected to the gas station. That is to say that the exposure time to

thermal radiation flux is short. It should be verified that in case of a leakage, the gas supply is disconnected as fast as possible.

7. Recommendations

7.1 Firefighting and fire prevention equipment will be installed in accordance with the project's Fire prevention report.

7.2 Ignition sources near the NG PRMS station will be eliminated:

- Electrical equipment will be installed according to hazardous area classification.
- When determining the vents height verify that there are no ignition sources at least:

  2" vent: 0.4 meters beneath the vent tip, 5.5 meters beneath the vent drain hole and 19 meters horizontally from the vent tip (see Hazardous Area Classification).

- Hot work will require a permit.

7.3 The distance to a concentration of 25% of the lower explosive limit in air was calculated, for a scenario of full rupture of a 18" NG pipe line connected to infinite source, assuming the shut off valve has not been closed (see appendix 1). As can be seen from the results, at 5 meters distance, the cloud concentration is above 25%LEL at about 53.31 meters height, as long as there are no ignition sources within 5 meters and there are no ignition sources at height, the gas cloud ignition is also not expected. Nevertheless, proximity distance was calculated with a strict assumption that ignition could occur.

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Section IV – Proximity distances for the underground pipeline

1. Survey range, building proximity distance and area classification for the underground pipeline from existing PRMS to planned PRMS – were taken from SI 4665 part 2.

2. The survey range for the underground pipe line from the existing PRMS to the planned PRMS (800 meters long, with 18'' diameter and a pressure of 80 barg), is 75 meters.

3. The building proximity distance for the underground pipe line from the existing PRMS to the planned PRMS (800 meters long, with 18'' diameter and a pressure of 80 barg), is 25 meters.

4. The area surrounding the underground pipe line, according to SI 5664 part 2 is defined as area classification 4. The planner should take into account the wall thickness factor according to this classification.

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Section V – Mutual influence

1. Description

Ammonia plant will be located in the industrial zone Mishor Rotem.

The following plants are in the plant's nearby surroundings:

- "Rotem Ampert"
- "Haifa Chemicals South"
- "Periclass"
- "OPC"

2. Methodology and scenarios analyzed

The purpose of this section is to examine mutual impacts between the natural gas PRMS and other parts of the plant and / or nearby plants.

The following scenarios were analyzed:

- Leakage from full rupture of the natural gas pipe, with immediate ignition and conflagration of the gas jet resulting in Jet-Fire.
- Leakage from full rupture of the natural gas pipe, with delayed ignition of vapor cloud and conflagration at the ignition point (Flash-Fire).

3. Data used for the analysis

3.1 Software

ALOHA software was used for JET FIRE and POOL FIRE scenarios.

ALOHA software and a mathematical model were used for FLASH FIRE scenarios.

3.2 Substance

- Scenarios for natural gas were made for the substance Methane, which is the primary component of natural gas.

3.3 Pipeline diameter

Line diameter used for the analysis is 15.34'' (mean diameter)

3.4 Pipeline length

Total line length is 16 m, for each skid

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3.5 Meteorological conditions

The meteorological condition used for the analysis is based on the Ministry of Environmental Protection specifications:

Wind speed: 3 m/s at a height of 10 meters.

Terrain: Urban.

Cloud cover: 50%

Ambient temperature: 25° C

Substance temperature: process temperature.

Atmospheric stability condition: D.

Inversion: none.

Relative humidity: 50%.

3.6 Determining the thermal radiation endpoint

In order to determine the exposure threshold and the damage level (endpoint), as a result of the different scenarios, taking into account the damage threshold for building and wood.

According to the "Purple Book", Guidelines for quantitative risk assessment CPR18E, 2005 edition – "The threshold for the ignition of buildings is set at 35 kW/m^2. If the building is set on fire, all the people inside the building are assumed to die".

According to "Lees' Loss Prevention in the Process Industries" the threshold for the ignition of wood is set at 12.5 kW/m^2.

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4. Results

Source	Scenario	Distance (meters)	
		Threshold of 35 kW/m² for buildings	Threshold of 12.5 kW/m² for wood
NG Pipeline	Full rupture, 80 bar and immediate ignition, Jet Fire	Along pipeline	~135
	Full rupture, 50 bar and immediate ignition, Jet Fire	Along pipeline	~31

5. Conclusions

5.1. If Natural Gas leakage is followed by ignition, there is a risk of heat radiation of 35 kW/m^2 and 12.5 kW/m^2 at up to ~135 meters from the pipe line.

6. Recommendations

6.1 Avoid storage of flammable and combustible materials within 135 meters from the natural gas pipeline (Hazardous substances as well as normally combustible materials, such as wood, paper etc.). For example, wooden platforms or fabrics.

Section VI – Summary of conclusions and recommendations

1. Conclusions

1.1 The amount of NG in the supply line (about 109 kg) is below the threshold quantity requiring a scenario analysis according to The Ministry of Environmental Protection (5,000 kg). Nevertheless, such a scenario of gas leak and UVCE was analyzed. The scenario result shows that if there is a leak in the pipe, the threat zone is 84 meters from the pipeline (relevant only to aboveground pipeline). It should be noted that the leakage will be identified in a few minutes and the XV will be closed. There are no public receptors located within the threat zone.

1.2 The individual risk along the pipeline was also calculated. The pipeline section has an individual risk contour of 10^{-6} at 80 meters from the pipeline, and 10^{-8} contour at a distance of 110 meters from the pipeline (after mathematical calculations including probabilities in each grid cell). The only plant outside the planned ammonia plant within 110 meters is HCS.

1.3 As shown in the results, for an hourly average population of maximum 5 people at 110 meters distance from the PRMS, the societal risk is low and acceptable, since the societal risk graph (blue line) is below the acceptability criteria graph (red line). Therefore, the societal risk is acceptable at the current situation.

1.4 The survey range for the underground pipe line from the existing PRMS to the planned PRMS (800 meters long, with 18'' diameter and a pressure of 80 barg), was taken according to SI 5664 part 2 and is 75 meters.

1.5 The building proximity distance for the underground pipe line from the existing PRMS to the planned PRMS (800 meters long, with 18'' diameter and a pressure of 80 barg), was taken according to SI 5664 part 2 and is 25 meters.

1.6 The underground pipe line, according to SI 5664 part 2 is defined as area classification 4. The planner should take into account the wall thickness factor according to this classification.

1.7 The distance to a concentration of 25% of the lower explosive limit in air was calculated, for a scenario of full rupture of a 18" NG pipe line connected to infinite source, assuming the shut off valve has not been closed (see appendix 1). As can be seen from the results, at 5 meters distance, the cloud concentration is above 25%LEL at about 53.31 meters height. As long as there are no ignition sources within 5 meters and there are no ignition sources at height,

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ignition is not expected. Nevertheless, proximity distance was calculated with a strict assumption that ignition could occur.

1.8 If Natural Gas leakage is followed by ignition, there is a risk of heat radiation of 35 kW/m^2 and 12.5 kW/m^2 at up to 135 meters from the pipe line.

2. Recommendations

2.1 Ignition sources near the NG PRMS station will be eliminated:

- Electrical equipment will be installed according to hazardous area classification.
- When determining the vents height verify that there are no ignition sources at least:

  2" vent: 0.4 meters beneath the vent tip, 5.5 meters beneath the vent drain hole and 19 meters horizontally from the vent tip (see Hazardous Area Classification).

- Hot work will require a permit.

2.2 In any case, firefighting and fire prevention equipment will be installed in accordance with the project's Fire prevention report.

2.3 It should be emphasized that leakage and fire incidents are short-term incidents, as long as the gas supply is connected to the gas station. That is to say that the exposure time to thermal radiation flux is short. It should be verified that in case of a leakage, the gas supply is disconnected as fast as possible.

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Annex 1- Calculating the explosive range of the emitted gas

The distance to 25%LEL is calculated by assessing the dimensions of the emitted gas cloud, the dilution rate which is affected due to turbulent forces along the path and the effect of buoyancy forces.
At the outlet point of the gas, the gas concentration is 100%, there is still no air.

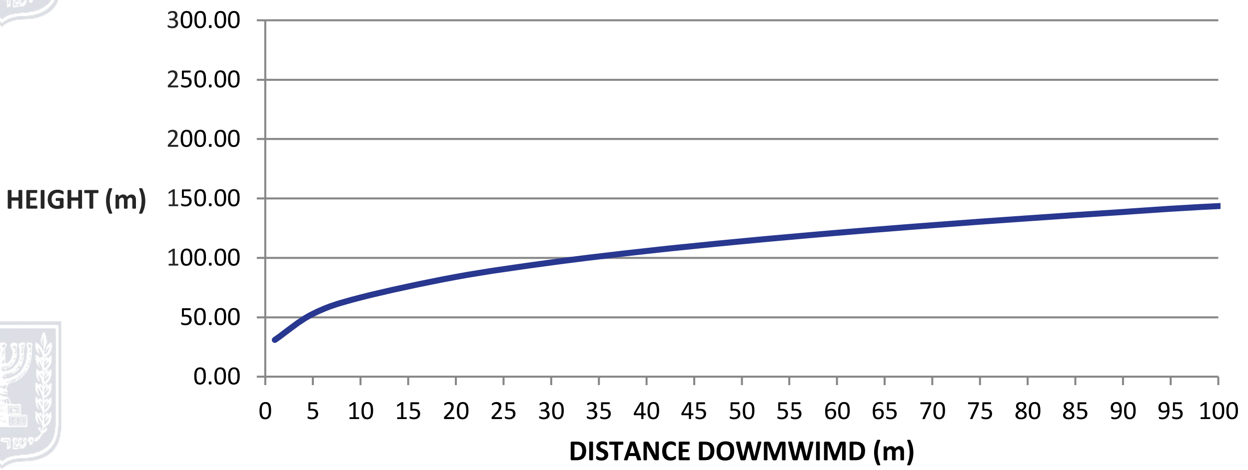
From the emitting point and onward, drifting of air begins. The drifting occurs due to turbulence, lift forces and diffusion of methane in the air.

The turbulent forces are dominant close to the emission point according to the velocity, temperature and composition at the outlet; and later on become dependent on the wind speed in the three directions.

The weaker the wind, the higher is the effect of buoyancy and diffusion forces on the rate of dilution in the cloud.

The following graph shows the cloud center height at varying distances from the emission source.

The graph represents a scenario of full rupture in an 18" NG pipe line, connected to infinite source, assuming the shut off valve has not been closed.



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The following parameters were used in order to calculate the cloud dimensions:

Parameters	Value	Units
Molecular weight	16.04	gm/mol
Ts-exit temperature	20	°C
Emission rate	1299	kg/sec
Reference conc	7.2	g/m^3
h0-Initial height	0	Meter
Ts-exit temperature	293	°K
Gas density	0.74	kg/m^3
Ta-ambient temperature	25	°C
Ta-ambient temperature	298	°K
Air density	1.18	kg/m^3
q3-Water vapor density	0.74	kg/m^3
Relative gas density	0.566	air=1
r_s - exit radius	18	Inches
	0.4572	M
Cross section area	0.1641	m^2
Emission flow rate	1948	m^3/sec
vs - vertical exit speed	430 (speed of sound in Methane)	m/sec
wind speed	3	m/sec
Cp-air (in R units!)	3.5	R units!

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Results (in the worst-case scenario- meteorological stability condition F)

For safety reasons, distance was calculated to a concentration of 25% the lower explosive limit of NG:

distance from source	F
1	31.02
5	53.31
10	67.42
20	85.42
30	98.21
40	108.49
50	117.25
60	124.95
70	131.88
80	138.22
90	144.07
100	149.53
200	191.34
300	225.52

The distance to a concentration of 25% of the lower explosive limit in air was calculated, for a scenario of full rupture of a 18" NG pipe line connected to infinite source, assuming the shut off valve has not been closed (see appendix 1). As can be seen from the results, at 5 meters distance, the cloud concentration is above 25%LEL at about 53.31 meters height. As long as there are no ignition sources within 5 meters and there are no ignition sources at height, the gas cloud ignition is also not expected. Nevertheless, proximity distance was calculated with a strict assumption that ignition could occur.

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Annex 2- ALOHA and Effects outputs

1. Proximity distance

Case description: JET FIRE 80 barg-rupture

Model: Gas Jet Fire (Chamberlain model)

version: 5.12 (07/03/2018)
Reference: Reference not available yet

Parameters

Inputs	
Chemical name	Methane (YAWS)
Type of release	Release from vessel through (a hole in) pipe
Pipeline length (m)	16
Pipeline diameter (inch)	18
Hole diameter (inch)	18
Hole rounding	Sharp edges
Discharge coefficient (-)	*0.62*
Initial temperature in vessel (°C)	20
Initial (absolute) pressure in vessel (bar)	80
Outflow angle in XZ plane (0°=horizontal; 90°=vertical) (deg)	90
Release height (Stack height) (m)	1
Wind speed at 10 m height (m/s)	2
Percentage of the flame covered by soot (%)	0
Distance from release (Xd) (m)	185
X-coordinate of release (m)	0
Y-coordinate of release (m)	0
Predefined wind direction	N
Wind comes from (North = 0 degrees) (deg)	*0*

Results	
Initial source strength (kg/s)	1354.2
Type of flow of the jet	Choked flow
Exit velocity of expanding jet (m/s)	911.11
Angle between hole and flame axis (alpha) (deg)	2.8411
Frustum lift off height (b) (m)	43.022
Width of frustum base (W1) (m)	2.6345
Width of frustum tip (W2) (m)	60.833
Length of frustum (flame) (Rl) (m)	180.94
Tilt angle central axis flare (alpha_b) (deg)	2.2955
Surface area of frustum (m2)	21183
Surface area of a cylinder (m2)	19621
Surface emissive power (max) (kW/m2)	417.96
Surface emissive power (actual) (kW/m2)	417.96
Atmospheric transmissivity (%)	66.919
View factor (%)	3.1325
Heat radiation at Xd (kW/m2)	8.7616

Other information	
Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

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Case description: JET FIRE 50 barg rupture

Model: Gas Jet Fire (Chamberlain model)

version: 5.12 (07/03/2018)
Reference: Reference not available yet

Parameters

Inputs	
Chemical name	Methane (YAWS)
Type of release	Release from vessel through (a hole in) pipe
Pipeline length (m)	16
Pipeline diameter (inch)	6
Hole diameter (inch)	6
Hole rounding	Sharp edges
Discharge coefficient (-)	*0.62*
Initial temperature in vessel (°C)	20
Initial (absolute) pressure in vessel (bar)	50
Outflow angle in XZ plane (0°=horizontal; 90°=vertical) (deg)	90
Release height (Stack height) (m)	1
Wind speed at 10 m height (m/s)	2
Percentage of the flame covered by soot (%)	0
Distance from release (Xd) (m)	45
X-coordinate of release (m)	0
Y-coordinate of release (m)	0
Predefined wind direction	N
Wind comes from (North = 0 degrees) (deg)	*0*

Results	
Initial source strength (kg/s)	87.175
Type of flow of the jet	Choked flow
Exit velocity of expanding jet (m/s)	880.87
Angle between hole and flame axis (alpha) (deg)	3.8488
Frustum lift off height (b) (m)	13.004
Width of frustum base (W1) (m)	0.43926
Width of frustum tip (W2) (m)	18.434
Length of frustum (flame) (Rl) (m)	54.774
Tilt angle central axis flare (alpha_b) (deg)	3.1107
Surface area of frustum (m2)	1912.6
Surface area of a cylinder (m2)	1763.7
Surface emissive power (max) (kW/m2)	302.14
Surface emissive power (actual) (kW/m2)	302.14
Atmospheric transmissivity (%)	76.767
View factor (%)	3.8833
Heat radiation at Xd (kW/m2)	9.007

Other information	
Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

Case description: JET FIRE 80 barg-hole

Model: Gas Jet Fire (Chamberlain model)

version: 5.12 (07/03/2018)
Reference: Reference not available yet

Parameters

Inputs	
Chemical name	Methane (YAWS)
Type of release	Release from vessel through (a hole in) pipe
Pipeline length (m)	16
Pipeline diameter (inch)	18
Hole diameter (inch)	1.8
Hole rounding	Sharp edges
Discharge coefficient (-)	*0.62*
Initial temperature in vessel (°C)	20
Initial (absolute) pressure in vessel (bar)	80
Outflow angle in XZ plane (0°=horizontal; 90°=vertical) (deg)	90
Release height (Stack height) (m)	1
Wind speed at 10 m height (m/s)	2
Percentage of the flame covered by soot (%)	0
Distance from release (Xd) (m)	15
X-coordinate of release (m)	0
Y-coordinate of release (m)	0
Predefined wind direction	N
Wind comes from (North = 0 degrees) (deg)	*0*

Results	
Initial source strength (kg/s)	13.965
Type of flow of the jet	Choked flow
Exit velocity of expanding jet (m/s)	911.11
Angle between hole and flame axis (alpha) (deg)	4.6438
Frustum lift off height (b) (m)	5.733
Width of frustum base (W1) (m)	0.14613
Width of frustum tip (W2) (m)	8.1011
Length of frustum (flame) (Rl) (m)	24.102
Tilt angle central axis flare (alpha_b) (deg)	3.752
Surface area of frustum (m2)	368.01
Surface area of a cylinder (m2)	338.94
Surface emissive power (max) (kW/m2)	249.52
Surface emissive power (actual) (kW/m2)	249.52
Atmospheric transmissivity (%)	83.93
View factor (%)	4.6985
Heat radiation at Xd (kW/m2)	9.8397

Other information	
Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

Case description: JET FIRE 50 barg -hole

Model: Gas Jet Fire (Chamberlain model)

version: 5.12 (07/03/2018)
Reference: Reference not available yet

Parameters

Inputs

Chemical name	Methane (YAWS)
Type of release	Release from vessel through (a hole in) pipe
Pipeline length (m)	16
Pipeline diameter (inch)	6
Hole diameter (inch)	0.6
Hole rounding	Sharp edges
Discharge coefficient (-)	*0.62*
Initial temperature in vessel (°C)	20
Initial (absolute) pressure in vessel (bar)	50
Outflow angle in XZ plane (0°=horizontal; 90°=vertical) (deg)	90
Release height (Stack height) (m)	1
Wind speed at 10 m height (m/s)	2
Percentage of the flame covered by soot (%)	0
Distance from release (Xd) (m)	5
X-coordinate of release (m)	0
Y-coordinate of release (m)	0
Predefined wind direction	N
Wind comes from (North = 0 degrees) (deg)	*0*

Results

Initial source strength (kg/s)	0.96979
Type of flow of the jet	Choked flow
Exit velocity of expanding jet (m/s)	880.87
Angle between hole and flame axis (alpha) (deg)	6.4362
Frustum lift off height (b) (m)	1.7382
Width of frustum base (W1) (m)	0.033255
Width of frustum tip (W2) (m)	2.4608
Length of frustum (flame) (Rl) (m)	7.3154
Tilt angle central axis flare (alpha_b) (deg)	5.2018
Surface area of frustum (m2)	33.808
Surface area of a cylinder (m2)	31.102
Surface emissive power (max) (kW/m2)	190.6
Surface emissive power (actual) (kW/m2)	190.6
Atmospheric transmissivity (%)	89.857
View factor (%)	3.7589
Heat radiation at Xd (kW/m2)	6.4378

Other information	
Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

Case description: FLASH FIRE - 80 barg rupture-open

Model: Gas Release From Vessel

version: 5.09 (07/03/2018)
Reference: Yellow Book, CPR-14E, 3rd edition 1997, Paragraph 2.5.2.3 and Yellow Book, CPR-14E, 3rd edition 1997, Paragraph 2.5.2.3

Parameters

Inputs	
Chemical name	Methane (YAWS)
Use which representative step	First 20% average (flammable)
Type of release	Release from vessel through (a hole in) pipe
Pipeline length (m)	16
Pipeline diameter (inch)	18
Hole diameter (inch)	18
Hole rounding	Sharp edges
Discharge coefficient (-)	*0.62*
Initial temperature in equipment (°C)	20
Initial (absolute) pressure in vessel (bar)	80
Vessel volume (m3)	1E05
Type of calculation	Calculate until device is empty
Time t after start release (s)	

Results	
Initial mass in vessel (kg)	5.2657E06
Mass flow rate at time t (kg/s)	
Time needed to empty vessel (s)	18036
Total mass released (kg)	5.0577E06
Pressure at pipe exit at time t (bar)	
Temperature at pipe exit at time t (°C)	
Density gas at pipe exit at time t (kg/m3)	
Maximum mass flow rate (kg/s)	1354.2
Representative release rate (kg/s)	1299
Representative outflow duration (s)	1800
Representative temperature (°C)	16.75
Representative pressure (bar)	76.292
Representative density (kg/m3)	50.779

Other information	
Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

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HAZMAT Since 1985

Case description: Flash fire - 80 barg rupture open (linked to Gas Release From Vessel - FLASH FIRE - 80 barg rupture-open)

Model: Neutral Gas Dispersion: Explosive mass

version: 5.14 (11/03/2018)
Reference: Yellow Book (CPR-14E), 3rd edition 1997, Chapter 4

Parameters

Inputs	
Chemical name	Methane (YAWS)
Type of release	Continuous
Total mass released (kg)	
Mass flow rate of the source (kg/s)	1299
Duration of the release (s)	
X-coordinate of release (m)	0
Y-coordinate of release (m)	0
Z-coordinate (height) of release (m)	0
Pasquill stability class	F (Very Stable)
Wind speed at 10 m height (m/s)	2
Roughness length description	Low crops; occasional large obstacles, x/h > 20.
Predefined wind direction	N
Wind comes from (North = 0 degrees) (deg)	*0*
Time t after start release (s)	
Concentration averaging time (s)	20

Results	
Total explosive mass (kg)	3.8025E06
Height to LEL (m)	49.9
Length of cloud (between LEL) (m)	11592
Width of cloud (between LEL) (m)	193.87
Offset between release location and LEL (m)	0.51
Area of explosive cloud (m2)	1.7514E06
Inverse Monin-Obukhov length (1/L) used (1/m)	0.073006
Mixing height used (m)	50
Stand. dev. of turbulent velocity in vert. direction used (m/s)	0.18956
Stand. dev. of turbulent velocity in horiz. direction used (m/s)	0.1297

Other information	
Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

Case description: FLASH FIRE - 50 barg rupture open

Model: Gas Release From Vessel

version: 5.09 (08/03/2018)
Reference: Yellow Book, CPR-14E, 3rd edition 1997, Paragraph 2.5.2.3 and Yellow Book, CPR-14E, 3rd edition 1997, Paragraph 2.5.2.3

Parameters

Inputs

Chemical name	Methane (YAWS)
Use which representative step	First 20% average (flammable)
Type of release	Release from vessel through (a hole in) pipe
Pipeline length (m)	16
Pipeline diameter (inch)	6
Hole diameter (inch)	6
Hole rounding	Sharp edges
Discharge coefficient (-)	*0.62*
Initial temperature in equipment (°C)	20
Initial (absolute) pressure in vessel (bar)	50
Vessel volume (m3)	1E05
Type of calculation	Calculate until device is empty
Time t after start release (s)	

Results

Initial mass in vessel (kg)	3.291E06
Mass flow rate at time t (kg/s)	
Time needed to empty vessel (s)	1.5435E05
Total mass released (kg)	3.1114E06
Pressure at pipe exit at time t (bar)	
Temperature at pipe exit at time t (°C)	
Density gas at pipe exit at time t (kg/m3)	
Maximum mass flow rate (kg/s)	87.175
Representative release rate (kg/s)	86.73
Representative outflow duration (s)	1800
Representative temperature (°C)	19.595
Representative pressure (bar)	49.71
Representative density (kg/m3)	32.764

Other information

Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

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Case description: Flash fire - 50 barg rupture (linked to Gas Release From Vessel - FLASH FIRE - 50 barg rupture open)

Model: Neutral Gas Dispersion: Explosive mass

version: 5.14 (08/03/2018)
Reference: Yellow Book (CPR-14E), 3rd edition 1997, Chapter 4

Parameters

Inputs

Chemical name	Methane (YAWS)
Type of release	Continuous
Total mass released (kg)	
Mass flow rate of the source (kg/s)	86.73
Duration of the release (s)	
X-coordinate of release (m)	0
Y-coordinate of release (m)	0
Z-coordinate (height) of release (m)	0
Pasquill stability class	F (Very Stable)
Wind speed at 10 m height (m/s)	2
Roughness length description	Low crops; occasional large obstacles, x/h > 20.
Predefined wind direction	N
Wind comes from (North = 0 degrees) (deg)	*0*
Time t after start release (s)	
Concentration averaging time (s)	20

Results

Explosive mass at time t (kg)	36636
Height to LEL at time t (m)	15.6
Length of cloud (between LEL) at time t (m)	1547.2
Width of cloud (between LEL) at time t (m)	39.767
Offset between release location and LEL at time t (m)	0.51
Maximum area of explosive cloud (m2)	47140
Inverse Monin-Obukhov length (1/L) used (1/m)	0.073006
Mixing height used (m)	50
Stand. dev. of turbulent velocity in vert. direction used (m/s)	0.18956
Stand. dev. of turbulent velocity in horiz. direction used (m/s)	0.1297

Other information

Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

Case description: FLASH FIRE - 80 barg rupture-close

Model: Gas Release From Vessel

version: 5.09 (08/03/2018)
Reference: Yellow Book, CPR-14E, 3rd edition 1997, Paragraph 2.5.2.3 and Yellow Book, CPR-14E, 3rd edition 1997, Paragraph 2.5.2.3

Parameters

Inputs	
Chemical name	Methane (YAWS)
Use which representative step	First 20% average (flammable)
Type of release	Release through hole in vessel
Pipeline length (m)	
Pipeline diameter (inch)	
Hole diameter (inch)	18
Hole rounding	Sharp edges
Discharge coefficient (-)	*0.62*
Initial temperature in equipment (°C)	20
Initial (absolute) pressure in vessel (bar)	80
Vessel volume (m3)	2.08
Type of calculation	Calculate until device is empty
Time t after start release (s)	

Results	
Initial mass in vessel (kg)	109.53
Mass flow rate at time t (kg/s)	
Time needed to empty vessel (s)	0.36267
Total mass released (kg)	105.29
Pressure at pipe exit at time t (bar)	
Temperature at pipe exit at time t (°C)	
Density gas at pipe exit at time t (kg/m3)	
Maximum mass flow rate (kg/s)	1396.5
Representative release rate (kg/s)	1237.7
Representative outflow duration (s)	0.085065
Representative temperature (°C)	10.736
Representative pressure (bar)	69.774
Representative density (kg/m3)	47.423

Other information	
Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

Case description: Flash fire - 80 barg rupture close (linked to Gas Release From Vessel - FLASH FIRE - 80 barg rupture-close)

Model: Neutral Gas Dispersion: Explosive mass

version: 5.14 (08/03/2018)
Reference: Yellow Book (CPR-14E), 3rd edition 1997, Chapter 4

Parameters

Inputs	
Chemical name	Methane (YAWS)
Type of release	Instantaneous
Total mass released (kg)	105.29
Mass flow rate of the source (kg/s)	
Duration of the release (s)	
X-coordinate of release (m)	0
Y-coordinate of release (m)	0
Z-coordinate (height) of release (m)	0
Pasquill stability class	F (Very Stable)
Wind speed at 10 m height (m/s)	2
Roughness length description	Low crops; occasional large obstacles, x/h > 20.
Predefined wind direction	N
Wind comes from (North = 0 degrees) (deg)	*0*
Time t after start release (s)	0.085065
Concentration averaging time (s)	*20*

Results	
Explosive mass at time t (kg)	0.19751
Height to LEL at time t (m)	2.8
Length of cloud (between LEL) at time t (m)	0.20385
Width of cloud (between LEL) at time t (m)	5.3589
Offset between release location and LEL at time t (m)	2.6764
Maximum explosive mass (kg)	96.238
...at time tmem (s)	18.858
Length of cloud (between LEL) at time tmem (m)	24.289
Width of cloud (between LEL) at time tmem (m)	7.9851
Offset between release location and LEL at time tmem (m)	25.571
Maximum area of explosive cloud (m2)	290.05
...at time tmac (s)	50.287
Explosive mass at time tmac (kg)	58.975
Length of cloud (between LEL) at time tmac (m)	42.618
Width of cloud (between LEL) at time tmac (m)	8.5972
Offset between release location and LEL at time tmac (m)	79.266
Offset between release centre and cloud centre at time tmac (m)	100.57
Inverse Monin-Obukhov length (1/L) used (1/m)	0.073006
Mixing height used (m)	50
Stand. dev. of turbulent velocity in vert. direction used (m/s)	0.18956
Stand. dev. of turbulent velocity in horiz. direction used (m/s)	0.1297

Other information	
Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

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HAZMAT Since 1985

Case description: FLASH FIRE - 50 barg rupture close

Model: Gas Release From Vessel

version: 5.09 (08/03/2018)
Reference: Yellow Book, CPR-14E, 3rd edition 1997, Paragraph 2.5.2.3 and Yellow Book, CPR-14E, 3rd edition 1997, Paragraph 2.5.2.3

Parameters

Inputs

Chemical name	Methane (YAWS)
Use which representative step	First 20% average (flammable)
Type of release	Release through hole in vessel
Pipeline length (m)	
Pipeline diameter (inch)	
Hole diameter (inch)	6
Hole rounding	Sharp edges
Discharge coefficient (-)	*0.62*
Initial temperature in equipment (°C)	20
Initial (absolute) pressure in vessel (bar)	50
Vessel volume (m3)	2.08
Type of calculation	Calculate until device is empty
Time t after start release (s)	

Results

Initial mass in vessel (kg)	68.454
Mass flow rate at time t (kg/s)	
Time needed to empty vessel (s)	2.8331
Total mass released (kg)	64.759
Pressure at pipe exit at time t (bar)	
Temperature at pipe exit at time t (°C)	
Density gas at pipe exit at time t (kg/m3)	
Maximum mass flow rate (kg/s)	96.98
Representative release rate (kg/s)	86.12
Representative outflow duration (s)	0.75197
Representative temperature (°C)	10.882
Representative pressure (bar)	43.706
Representative density (kg/m3)	29.69

Other information

Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

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Case description: Flash fire - 50 barg rupture close (linked to Gas Release From Vessel - FLASH FIRE - 50 barg rupture close)

Model: Neutral Gas Dispersion: Explosive mass

version: 5.14 (08/03/2018)
Reference: Yellow Book (CPR-14E), 3rd edition 1997, Chapter 4

Parameters

Inputs	
Chemical name	Methane (YAWS)
Type of release	Instantaneous
Total mass released (kg)	64.759
Mass flow rate of the source (kg/s)	
Duration of the release (s)	
X-coordinate of release (m)	0
Y-coordinate of release (m)	0
Z-coordinate (height) of release (m)	0
Pasquill stability class	F (Very Stable)
Wind speed at 10 m height (m/s)	2
Roughness length description	Low crops; occasional large obstacles, x/h > 20.
Predefined wind direction	N
Wind comes from (North = 0 degrees) (deg)	*0*
Time t after start release (s)	0.75197
Concentration averaging time (s)	*20*

Results	
Explosive mass at time t (kg)	1.581
Height to LEL at time t (m)	2.6
Length of cloud (between LEL) at time t (m)	1.8805
Width of cloud (between LEL) at time t (m)	4.721
Offset between release location and LEL at time t (m)	2.2777
Maximum explosive mass (kg)	59.777
...at time tmem (s)	14.635
Length of cloud (between LEL) at time tmem (m)	19.303
Width of cloud (between LEL) at time tmem (m)	6.7032
Offset between release location and LEL at time tmem (m)	19.616
Maximum area of explosive cloud (m2)	203.64
...at time tmac (s)	43.904
Explosive mass at time tmac (kg)	33.794
Length of cloud (between LEL) at time tmac (m)	35.749
Width of cloud (between LEL) at time tmac (m)	7.205
Offset between release location and LEL at time tmac (m)	69.935
Offset between release centre and cloud centre at time tmac (m)	87.809
Inverse Monin-Obukhov length (1/L) used (1/m)	0.073006
Mixing height used (m)	50
Stand. dev. of turbulent velocity in vert. direction used (m/s)	0.18956
Stand. dev. of turbulent velocity in horiz. direction used (m/s)	0.1297

Other information	
Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

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Case description: FLASH FIRE - 80 barg HOLE

Model: Gas Release From Vessel

version: 5.09 (07/03/2018)
Reference: Yellow Book, CPR-14E, 3rd edition 1997, Paragraph 2.5.2.3 and Yellow Book, CPR-14E, 3rd edition 1997, Paragraph 2.5.2.3

Parameters

Inputs	
Chemical name	Methane (YAWS)
Use which representative step	First 20% average (flammable)
Type of release	Release from vessel through (a hole in) pipe
Pipeline length (m)	16
Pipeline diameter (inch)	18
Hole diameter (inch)	1.8
Hole rounding	Sharp edges
Discharge coefficient (-)	*0.62*
Initial temperature in equipment (°C)	20
Initial (absolute) pressure in vessel (bar)	80
Vessel volume (m3)	2.08
Type of calculation	Calculate until device is empty
Time t after start release (s)	

Results	
Initial mass in vessel (kg)	109.53
Mass flow rate at time t (kg/s)	
Time needed to empty vessel (s)	36.045
Total mass released (kg)	105.21
Pressure at pipe exit at time t (bar)	
Temperature at pipe exit at time t (°C)	
Density gas at pipe exit at time t (kg/m3)	
Maximum mass flow rate (kg/s)	13.965
Representative release rate (kg/s)	12.384
Representative outflow duration (s)	8.4956
Representative temperature (°C)	10.783
Representative pressure (bar)	69.821
Representative density (kg/m3)	47.448

Other information	
Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

Case description: Flash fire - 80 barg hole (linked to Gas Release From Vessel - FLASH FIRE - 80 barg HOLE)

Model: Neutral Gas Dispersion: Explosive mass

version: 5.14 (07/03/2018)
Reference: Yellow Book (CPR-14E), 3rd edition 1997, Chapter 4

Parameters

Inputs

Chemical name	Methane (YAWS)
Type of release	Continuous
Total mass released (kg)	
Mass flow rate of the source (kg/s)	12.384
Duration of the release (s)	
X-coordinate of release (m)	0
Y-coordinate of release (m)	0
Z-coordinate (height) of release (m)	0
Pasquill stability class	F (Very Stable)
Wind speed at 10 m height (m/s)	2
Roughness length description	Low crops; occasional large obstacles, x/h > 20.
Predefined wind direction	N
Wind comes from (North = 0 degrees) (deg)	*0*
Time t after start release (s)	
Concentration averaging time (s)	20

Results

Explosive mass at time t (kg)	1518
Height to LEL at time t (m)	6.8
Length of cloud (between LEL) at time t (m)	448.76
Width of cloud (between LEL) at time t (m)	13.079
Offset between release location and LEL at time t (m)	0.51
Maximum area of explosive cloud (m2)	4528
Inverse Monin-Obukhov length (1/L) used (1/m)	0.073006
Mixing height used (m)	50
Stand. dev. of turbulent velocity in vert. direction used (m/s)	0.18956
Stand. dev. of turbulent velocity in horiz. direction used (m/s)	0.1297

Other information

Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

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Case description: FLASH FIRE - 50 barg HOLE

Model: Gas Release From Vessel

version: 5.09 (07/03/2018)
Reference: Yellow Book, CPR-14E, 3rd edition 1997, Paragraph 2.5.2.3 and Yellow Book, CPR-14E, 3rd edition 1997, Paragraph 2.5.2.3

Parameters

Inputs	
Chemical name	Methane (YAWS)
Use which representative step	First 20% average (flammable)
Type of release	Release from vessel through (a hole in) pipe
Pipeline length (m)	16
Pipeline diameter (inch)	6
Hole diameter (inch)	0.6
Hole rounding	Sharp edges
Discharge coefficient (-)	*0.62*
Initial temperature in equipment (°C)	20
Initial (absolute) pressure in vessel (bar)	50
Vessel volume (m3)	2.08
Type of calculation	Calculate until device is empty
Time t after start release (s)	

Results	
Initial mass in vessel (kg)	68.454
Mass flow rate at time t (kg/s)	
Time needed to empty vessel (s)	281.8
Total mass released (kg)	64.711
Pressure at pipe exit at time t (bar)	
Temperature at pipe exit at time t (°C)	
Density gas at pipe exit at time t (kg/m3)	
Maximum mass flow rate (kg/s)	0.96979
Representative release rate (kg/s)	0.86161
Representative outflow duration (s)	75.104
Representative temperature (°C)	10.916
Representative pressure (bar)	43.731
Representative density (kg/m3)	29.702

Other information	
Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

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Case description: Flash fire - 50 barg hole (linked to Gas Release From Vessel - FLASH FIRE - 50 barg HOLE)

Model: Neutral Gas Dispersion: Explosive mass

version: 5.14 (07/03/2018)
Reference: Yellow Book (CPR-14E), 3rd edition 1997, Chapter 4

Parameters

Inputs	
Chemical name	Methane (YAWS)
Type of release	Continuous
Total mass released (kg)	
Mass flow rate of the source (kg/s)	0.86161
Duration of the release (s)	
X-coordinate of release (m)	0
Y-coordinate of release (m)	0
Z-coordinate (height) of release (m)	0
Pasquill stability class	F (Very Stable)
Wind speed at 10 m height (m/s)	2
Roughness length description	Low crops; occasional large obstacles, x/h > 20.
Predefined wind direction	N
Wind comes from (North = 0 degrees) (deg)	*0*
Time t after start release (s)	
Concentration averaging time (s)	20

Results	
Explosive mass at time t (kg)	20.013
Height to LEL at time t (m)	2.2
Length of cloud (between LEL) at time t (m)	81.48
Width of cloud (between LEL) at time t (m)	2.8589
Offset between release location and LEL at time t (m)	0.51
Maximum area of explosive cloud (m2)	185.34
Inverse Monin-Obukhov length (1/L) used (1/m)	0.073006
Mixing height used (m)	50
Stand. dev. of turbulent velocity in vert. direction used (m/s)	0.18956
Stand. dev. of turbulent velocity in horiz. direction used (m/s)	0.1297

Other information	
Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

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Model: Heat radiation; consequences to Individuals

version: 4.02 (06/03/2016)
Reference: Green Book 1st edition 1992, chapter 1 (Heat radiation); pages 11-36

Parameters

Inputs	
Heat radiation level at X (kW/m2)	10.915
Take effects of clothing into account	No

Results	
Nr. of first degree burn injuries at X (%)	94.898
Nr. of second degree burn injuries at X (%)	4.6975
Nr. of lethalities due to heat radiation at X (%)	2.4184

Other information	
Main program	Effects 8.0.1.3218

Effects report created by ALINA-PC\alina at 13/03/2016 15:12:27

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2. Separation distances

Leakage from a hole 1" in diameter and gas cloud explosion UVCE (instantaneous leak)

Model: Gas Release From Vessel

version: 5.09 (07/03/2018)
Reference: Yellow Book, CPR-14E, 3rd edition 1997, Paragraph 2.5.2.3 and Yellow Book, CPR-14E, 3rd edition 1997, Paragraph 2.5.2.3

Parameters

Inputs

Chemical name	Methane (YAWS)
Use which representative step	First 20% average (flammable)
Type of release	Release through hole in vessel
Pipeline length (m)	
Pipeline diameter (inch)	
Hole diameter (inch)	1
Hole rounding	Rounded edges
Discharge coefficient (-)	*1*
Initial temperature in equipment (°C)	25
Initial (absolute) pressure in vessel (bar)	80
Vessel volume (m3)	0.57
Type of calculation	Calculate until device is empty
Time t after start release (s)	

Results

Initial mass in vessel (kg)	29.511
Mass flow rate at time t (kg/s)	
Time needed to empty vessel (s)	19.661
Total mass released (kg)	28.356
Pressure at pipe exit at time t (bar)	
Temperature at pipe exit at time t (°C)	
Density gas at pipe exit at time t (kg/m3)	
Maximum mass flow rate (kg/s)	6.8933
Representative release rate (kg/s)	6.1117
Representative outflow duration (s)	4.6395
Representative temperature (°C)	15.601
Representative pressure (bar)	69.803
Representative density (kg/m3)	46.642

Other information

Main program	Effects 8.0.1.3218
Chemical database	YAWS database
Chemical database path	C:\Program Files (x86)\TNO\Effects 8.0\Shared data\Databases\Purple Book (1999).rdb
Chemical database date	12/02/2009

NG SEPARATION DISTANCE ALOHA

SITE DATA:

Location: ISRAEL, ISRAEL

Building Air Exchanges Per Hour: 0.41 (unsheltered single storied)

Time: October 29, 2014 1033 hours ST (user specified)

CHEMICAL DATA:

Chemical Name: METHANE

CAS Number: 74-82-8 Molecular Weight: 16.04 g/mol

PAC-1: 2900 ppm PAC-2: 2900 ppm PAC-3: 17000 ppm

LEL: 50000 ppm UEL: 150000 ppm

Ambient Boiling Point: -161.6° C

Vapor Pressure at Ambient Temperature: greater than 1 atm

Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)

Wind: 3 meters/second from e at 10 meters

Ground Roughness: urban or forest Cloud Cover: 5 tenths

Air Temperature: 25° C

Stability Class: D (user override)

No Inversion Height Relative Humidity: 50%

SOURCE STRENGTH:

Direct Source: 6.1133 kilograms/sec Source Height: 0

Release Duration: 1.2 minutes

Release Rate: 367 kilograms/min

Total Amount Released: 440 kilograms

Note: This chemical may flash boil and/or result in two phase flow.
Use both dispersion modules to investigate its potential behavior.

THREAT ZONE:

Threat Modeled: Overpressure (blast force) from vapor cloud explosion

Type of Ignition: ignited by spark or flame

Level of Congestion: congested

Model Run: Gaussian

Red : 84 meters --- (0.1 atmospheres)

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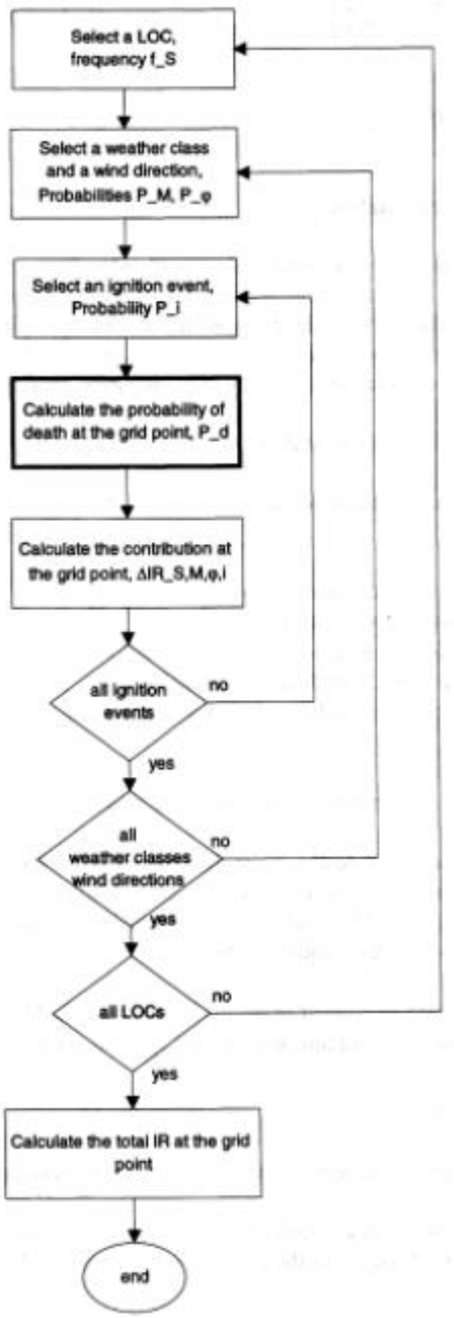
Annex 3- Individual Risk, IR, calculation

The following figure shows the procedure to calculate the Individual Risk, IR, at a grid point (figure 6.1 in the "purple book"):



The contribution of each scenario at a grid point is calculated by:

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$$\Delta IRS, M, \varphi, i \quad = fs \quad \cdot P_M \cdot P_\varphi \cdot P_i \cdot P_d \quad [y^{-1}]$$

Where:

$fs \quad [y^{-1}]$ is the failure frequency of the loss of containment event (LOC), S.

P_M is the probability of a whether class M.

P_φ is conditional probability, the probability to obtain the wind direction φ, given the weather class M.

P_i is conditional probability, the probability of an ignition event, in case of the release of flammables.

P_d is the probability of death at the grid point, given loss of containment event S, the weather class M, the wind direction φ and the ignition event i.

After repeating the calculation for all ignition events, all weather classes all wind directions and of containment events, the total IR at the grid point is calculated as:

$$IR = \sum_S \sum_M \sum_\varphi \sum_i \Delta IR_{S,M,\varphi,i}$$

Ammonia Plant
Rotem Industrial Park
PRMS

Hazardous Area Classification

By: Hazmat, Risk Eng. Department

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Classification	Department	Reference	Project no.
Commercial	**Risk Engineering**	**1489-1-R2**	**070024**

The quality of the report has been inspected by the quality system of Haz-Mat according to Haz-Mat QA procedures and according to the international quality standard ISO:9001-2008

Ref./Revision	Date	Created by	Q.A by	Client Confirmation date
R1	March 2018	Lior Sarraf	Anat Tzur	
R2	October 2018	Anat Tzur	Alex Cohen	

This file was created for: Tamar local authority

Created by:
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Version: R2

Date: October 2018

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INTRODUCTION

Background

Hazardous area classification is the term used to indicate the areas where flammable atmosphere may occur in various modes of operation. In classified areas, electrical equipment must be protected to prevent unwanted ignition of a flammable atmosphere. The level of protection is proportional to the potential of formation of a flammable atmosphere.

Scope

The scope of the report is to identify the hazardous area of the natural gas supply line designed by Baran for the ammonia plant in Rotem industrial park.

According to the Israeli legislation hazardous area classification in NG installations should follow the IEC 60079 part 10.1 standard or IGEM/SR/25 standard.

Reference

- Hazardous Area Classification of Natural Gas Installations, Institution of Gas Engineering and Managers (IGEM) /SR/25 edition 2 2010.
- No drawings have been submitted at the time the study has been written. Correspondence with the station designers as for work assumption such as the pressure in the station etc.

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HAZARDOUS AREA CLASSIFICATION METHOD

Hazardous area classification is based on IGEM/SR/25 and defines six possible zones in which there is or could be an explosive gas atmosphere in levels which require special precautions to be taken. The zones are specified according to the frequency and duration of the explosive gas atmosphere:

- **Zone 0**, an area in which an explosive atmosphere consisting of a mixture with air of gas, vapor or mist is present continuously, or for long periods or frequently.
- **Zone 1**, an area in which an explosive atmosphere consisting of a mixture with air of gas, vapor or mist is likely to occur in normal operation occasionally.
- **Zone 2**, an area in which an explosive atmosphere consisting of a mixture with air of gas, vapor or mist is not likely to occur in normal operation but, if it does occur, will exist for a short period only.
- **Zone 0 NE**, an area in which an explosive atmosphere consisting of a mixture with air of gas, vapor or mist is present continuously, or for long periods or frequently, but would be of negligible extent.
- **Zone 1 NE**, an area in which an explosive atmosphere consisting of a mixture with air of gas, vapor or mist is likely to occur in normal operation occasionally, but would be of negligible extent.
- **Zone 2 NE**, an area in which an explosive atmosphere consisting of a mixture with air of gas, vapor or mist is not likely to occur in normal operation but, if it does occur, will exist for a short period only and would be of negligible extent.

The area zoning depends upon the degree of release and availability of ventilation.

The standard defines tree grades of release:

- **Continuous** – a release (from certain valve actuators, analyzers, instrument vent pipe terminations, gas-powered controllers) which is continuous or is expected to occur frequently or for long periods.

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- **Primary** – a release (from purge vent pipe terminations, drains and sample point, if operating frequently or if not capped when not in use) which can be expected to occur periodically or occasionally during normal operation.

- **Secondary** – a release (from sources with a nominal hole size of 0.25 mm^2, or larger e.g. purge vents, drain and sample points if operating infrequently, relief valve vent when operating, process, machinery and instrument vent, if operating infrequently) which is not expected to occur in normal operation and, if it does occur, is likely to do so only infrequently and for short periods.

The standard defines availability and degrees ventilation as follows:

- **Natural ventilation** – ventilation through an enclosed space where the flow of air is motivated by wind and/or buoyancy.

- **Artificial ventilation** - ventilation through an enclosed space where the flow of air is forced or induced by mechanical means.

- **More than adequate ventilation** – any means of ventilation that is sufficient to ensure that a gas concentration is excess of 10% LFL (lowest flammable limit) is unlikely outside of the classified zones.

- **Adequate ventilation** – any means of ventilation that is sufficient to ensure that a gas concentration is excess of 25% LFL is unlikely outside of the classified zones.

- **Inadequate ventilation** – any lesser level of ventilation than required to achieve the objective of "adequate ventilation".

- **Poor ventilation** – levels lower than "inadequate ventilation".

- **Dilution ventilation** – correctly distributed forced or induced ventilation, to provide sufficient air change rate through any potentially hazardous area to dilute a defined leak to a level that is sufficiently low as to not pose a significant hazard.

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1. Hazardous area classification around equipment – Fittings, Flanges, Screw Connections, Valves, etc.

1.1 Electrical installations around the gas pipe line will be explosion proof in accordance with the area classification and adjusted to each zone that will be determine.

1.2 In order to determine the explosive atmosphere zones around the planned NG pipe line at the PRMS station in the ammonia plant, the line was defined according to the standard. It is assumed that the skid will be under a shed. According to IGEM/SR/25, this section is defined as a building (**indoor installation**). According to the standard, a building is an enclosed space which by design allows people to enter, characterized by presence of a roof and may have any number of walls including none at all.

1.3 The line is divided into two different operating pressures- 80 barg and 50 barg (after reduction).

1.4 In order to determine the zoning for indoor installation, the degree of ventilation should be determined first.

1.5 Since there is no specific design it is assumed that the ventilation will be "more than adequate". Ahead is the calculation for the openings area required to create "more than adequate" ventilation in the PRMS station.

1.6 **Natural ventilation:**

1.6.1 According to IGEM/SR/25 standard, the degree of ventilation and the zoning determination are a function of a few parameters:

- Number of walls (% free ventilation)
- Openings area (total free ventilation area of cross sectional area) (A)
- Number of primary and secondary release sources (N_P, $N_{SN/A}$)
- Frequency of failure per year for each source (fi)
- Period between inspection ($T_{SN/A}$)
- Release rate from each source ($G_{P/SN}$)
- Total release rate in the enclosed space (G)
- Cross-section area of orifice ((A) – for G calculation) – For secondary a nominal hole size of 0.25 mm^2

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- Height of the enclosed space and distance from another structure ($H_{1/2}$)
- Distance from the enclosed space to another structure (D)
- Average wind speed (U)

1.6.2 Ammonia plant station ventilation

1.6.2.1 The degree of ventilation in the shed is obtained by measuring the area of natural ventilation and comparing it to mathematical expressions which describe the level of ventilation:

1.6.2.2 The ventilation is "More than adequate" if $A \geq A_{b,10}$

$A_{b,10}=7762*G*L^{-0.5}=$**70 m²**

A= openings area (total free ventilation area of cross sectional area)

A - Is the sum of openings area in the station

L=Vertical distance between the center of high level and low level ventilators, as mentioned before because there are no ventilators, the distance L was defined as the height of the openings (m) = **2 m**

G= Total release rate in the enclosed space - The sum of 4 secondary release rates (G_{SN}) at a time (according to IGEM/SR/25 standard, Appendix 7, A7.1.2-4).

The total release rate is **G=0.012755**

If the plant fails to maintain normal conditions the release rate might be increased as indicated in the note beneath the table 2 (for adverse conditions - the hole cross-section area shall be taken as 2.5 mm^2). For this purpose, *adverse conditions*: such as – the gas is not clean, the gas is not dry, vibrating equipment, corrosive atmosphere etc.

1.6.2.3 "Adequate" if $A \geq A_{b,25}$

$A_{b,25}=1964*G*L^{-0.5}=$**17.7 m²**

1.6.2.4 "Inadequate" if $A_{b,25} \geq A \geq A_{b,50}$

$A_{b,50}=694*G*L^{-0.5}=$**6.3 m²**

1.6.2.5 "Poor" if $A_{b,50} > A$

$A_{b,50}=694*G*L-0.5=$**6.3 m²**

1.6.2.6 Minimum total free ventilation area that will ensure adequate wind-driven ventilation in an enclosure that is provided with natural ventilation (A_W) = $K*G*(U_{10\text{-}50}*H_1^{0.17})^{-1}$ (for non-sheltered enclosure). Assuming that the height of the enclosure is 3 meters, the wind speed is 3 m/sec and the number of walls with openings is either 2 or 3 walls.

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Table 1 -Degree of ventilation in Ammonia plant station - section (c).

Location	G (kg/sec)	$A_{b,10}$ (m^2)	$A_{b,25}$ (m^2)	A_W Openings in 2 walls (m^2)	A_W Openings in 3 walls (m^2)	Level of ventilation
Ammonia plant	0.012755	70	17.7	71	34	More than adequate

1.7 In order to have "more than adequate" ventilation it is required that A, the sum of openings area in the station should be 71 m^2.

1.8 According to Clause 5.3.2.2, if the ventilation is "**more than adequate**" and the gas releases are obstructed (the leak location may lie within one meter of three or more obstructions (two walls, floor and roof), the zoning distance X, for indoor installation, shall be determined according to table 2 of sub-section 5.2 in the IGEM/SR/25 standard.

1.9 The zoning distance (X) is indicated in figures 1(a) to 1(f)* and table 2 in the IGEM/SR/25 standard.

*Figures 1(e) and 1(f) are irrelevant for this pipe line.

1.10 In light of the result obtained above, and in accordance with IGEM/SR/25 standard, the classification around the entire pipe line installation shall be as specified in table 2, below. Zoning around vent terminations, shall be as detailed in clause 2.

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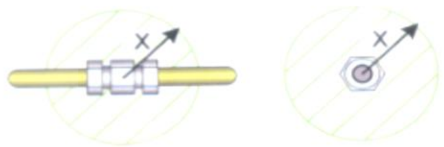
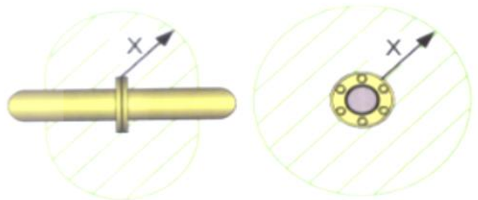


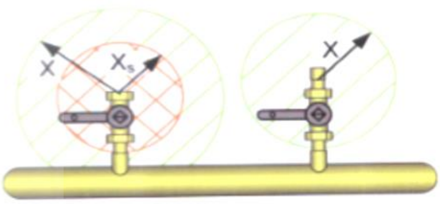
Determine the zoning distance from the centre of the fitting.

Figure 1(a) - Screwed fittings and joints up to 50 mm nominal size



Determine the zoning distance from the edges of the flange.

Figure 1(b) - Flanges



Determine the zoning distance from the centre for the opening of the valve. Where the valve is not capped or plugged, there will also be a Zone 1 area X_s (see Table 5 and 18) associated with the valve seat. Where the valve is capped or plugged, the threads of these components are treated as in Figures 1(a) or 1(b). In both cases all other flanges or screwed connectors follow Figures 1(a) or 1(b).

Figure 1(c) - Valve connections

Determine the zoning distance from where the spindle enters the valve body. For flanges or screwed connectors follow Figures 1(a) or 1(b).

Figure 1(d) - Valve glands

Colour Key:
Zone 0 —— red
Zone 1 —— orange
Zone 2 —— green

The actual zone will depend upon the assessed frequency and duration of release

Note: *For values of X, see Table 1 for freely ventilated installations or Table 2 for congested or confined installations.*

FIGURE 1 - EXTENT OF THE HAZARDOUS AREA SURROUNDING FLANGES, SCREWED FITTINGS, JOINTS, VALVE GLANDS AND REGULATORS WITH THEIR COMPONENTS (SECONDARY GRADE RELEASES OUTDOORS) (Cont overleaf)

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Table 2 – Zoning around pipe installation

Important notes:

1) Zoning refers to fittings, flanges, screw connections, valves, etc under normal conditions. If the plant fails to maintain normal conditions the zoning area might be increased. For this purpose, *adverse conditions*: such as – the gas is not clean, the gas is not dry, vibrating equipment, corrosive atmosphere etc.
2) The NG system and pipeline are located in surrounding where normal conditions are maintained.

Sign	Description	Zone	Zoning distance from the source	Installations
	Gas pipe line	0	Entire area Inside the gas pipe line.	
X	Radius from valves and fittings in the **outdoor congested** pipe- (Clause 5.2.1 and TABLE 2) – **OP=80 barg**	**Zone 2**	2 m	This is for normal condition (For adverse condition - Any non-exproof electrical installation (including inside power plant and transformer) within 6.5 meter radius, in all directions, from manual valves, drain and sample points if operating infrequently, flanges, orifices, and any un welded connections.)
X	Radius from valves and fittings in the **outdoor congested** pipe- (Clause 5.2.1 and TABLE 2)- **OP=50 barg**	**Zone 2**	2 m	This is for normal condition (For adverse condition - Any non-exproof electrical installation (including inside power plant and transformer) within 5.5 meter radius, in all directions, from: SSVs, PCVs, manual valves, drain and sample points if operating infrequently, flanges, orifices, and any un welded connections.)

2. Hazardous area from Natural gas vents

2.1 It is assumed that there will be at least one HP vent (80 barg). The vent in the planned NG pipe line is assumed to be defined as an ideal vent (according to figure 13 in IGEM/SR/25 Standard). Zoning distances for an ideal vent pipe are as indicated in appendix 9 in the standard.

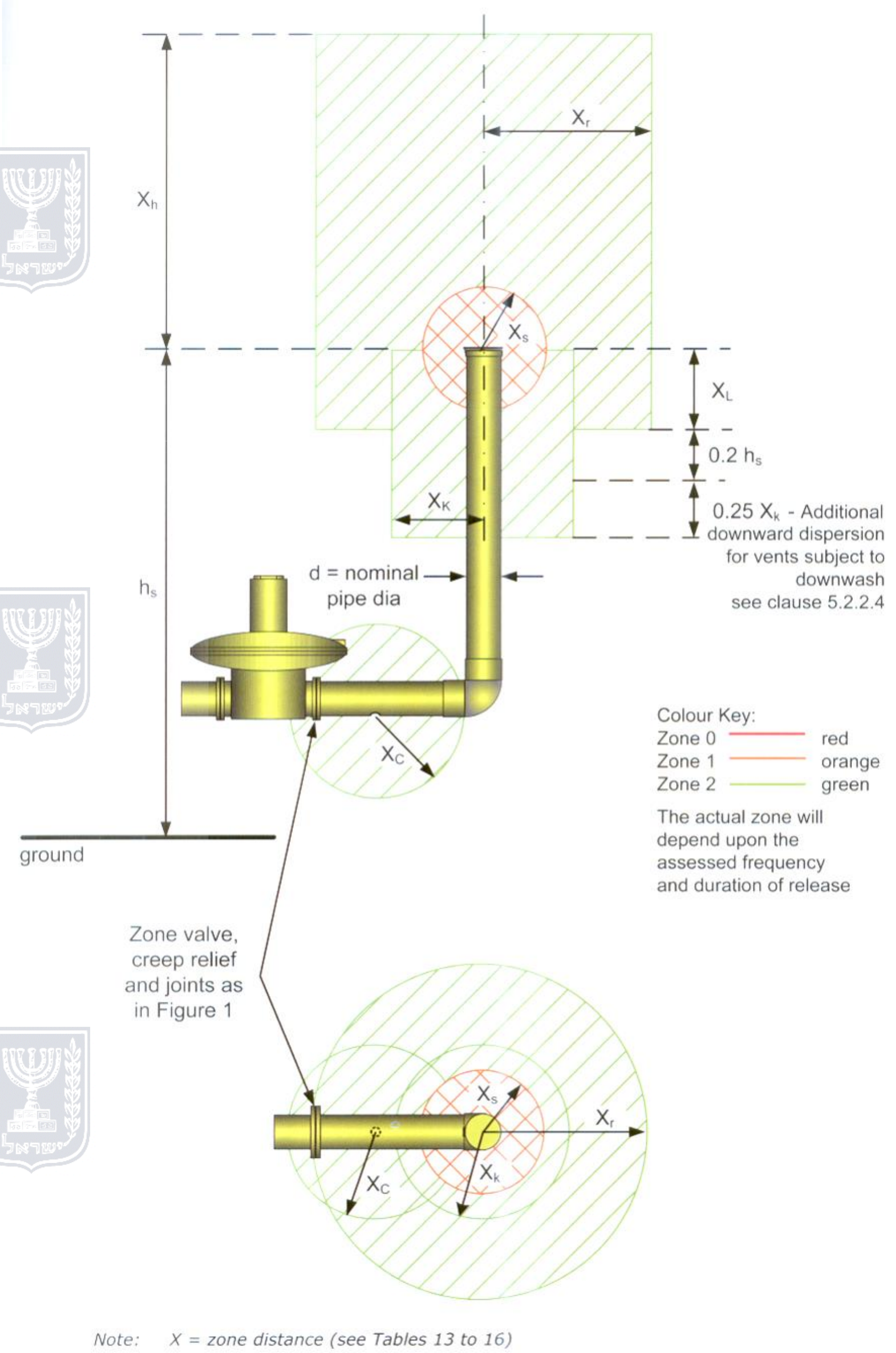

Figure 13 – Extent of hazardous areas for vent pipe terminations. Ideal venting

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2.2 X_s is the radius of the hazardous Zone 1 from a vent pipe. According to clause 5.2.3 in the standard, Xs will be **1 meter** radius to cover the possibility of leakage of gas via the seat of a closed valve.

2.3 In order to determine Zone 2 radius from the vent termination, the standard requires defining some parameters and performing some calculations.

G - Mass flow rate from the vent (kg/sec)

C_d - coefficient of discharge of orifice

X_r - The radius of the horizontal zone from a vent pipe

X_h - is the vertical height/length of the hazardous area extending from the vent pipe

h_S - Height of vent tip above ground level or roof line

X_c - Radius from Vent drain holes

2.4 Dispersion distance X_r and X_h were selected from table 14 and 15 in the standard for the appropriate flow rate and vent pipe termination diameter.

2.5 IGEM/SR/25 standard clause 5.2.2.2 describes two equations for vent pipe flow rate, according to the relevant OP (Operating Pressure): OP≥850 mbar or OP<850 mbar. The operating pressure is 80 barg and 50 barg after reduction and the equation for systems with Operating Pressure (OP) equals or above 850 mbar was used:

$$G = 675\ C_d\ A\ M^{0.5}\ T^{-0.5}\ (P+1.1013)^{1.05}$$

Table 3 –Vent pipe 2 " HP vent- G calculation

OP≥	850 mbar	HP vent {above ground} [m]
OP	Operating Pressure (bar)	80
G	Mass flow rate (kg/sec)	25.85
M	Molecular Weight (kg/kmol)	16.05
T	Gas temperature upstream of orifice (K)	293
P	Gas pressure (bar)	80
C_d	coefficiant of discharge of orrifice	0.8
A	Cross-section area of oriffice (m^2)	0.00202683
d	Cross-section diameter (m)	0.051
G=	**kg/sec**	**25.85**

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Therefore, the HP vent pipe 2" obtained flow rate is **25.85 Kg/sec**

2.6 According to the vent pipe termination, flow rate, parameters and other calculation, the zoning around the vent termination shall be according to table 5, below:

Table 5 – Zoning around Vents termination

Parameter	Description	HP Vent {Vent diameter 2"} [m]	Taken from IGEM/SE/25 clause
X_L	Downward dispersion	0.10	5.2.2.3 (a)
d	Cross-section diameter (m)	0.0508	
X_K	Radial dispersion distance	10.00	TABLE 16
	Downward dispersion distance X_L+0.2h_S or X_k whichever is the smaller	0.40	5.2.2.3 (b)
h_S	Height of vent tip above roof line (m)	1.5	
X_r	Horizontal radius of the momentum-drive hazardous area	19.0	5.2.2.4 and TABLE 14
	Total downward dispersion distance X_L+0.2h_S + 0.25X_k or X_k whichever is the smaller	2.90	5.2.2.4
X_c	Vent drain holes	5.50	5.2.2.5 and TABLE 13 and TABLE 19

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Parameter	Description	HP Vent {Vent diameter 2"} [m]	Taken from IGEM/SE/25 clause
X_h	Vertical dispersion distance	100.00	app.9 and TABLE 15
X_S	Radius of the hazardous Zone 1 from a vent pipe (m)	1.00	5.2.3
G	Mass flow rate (kg/sec)	25.85	

2.7 A work assumption is that the vents will be located 1.5 meter above the shed.

2.8 The horizontal dispersion X_r distance:

- For HP 2" vent line – is 19 meters, according to table 14 in the IGEM standard.

2.9 The vertical dispersion distance (upward from vent ending) X_h:

- For HP 1.5" vent line – is 100 meters according to table 15 in the IGEM standard.

2.10 The radius of the hazardous **Zone 1**, X_s – from the vent pipes termination more than 7 barg is 1 meter according to clause 5.2.3 TABLE 18 and TABLE 5.

2.11 The distance **Xc** from the drain hole of the vent is 5.5 meters.

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