FLARE NETWORK SIZING CALCULATION

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REVISION INDEX

REV. / PAGE	A	B	0	1	2	REV. / PAGE	A	B	0	1	2	REV. / PAGE	A	B	0	1	2	REV. / PAGE	A	B	0	1	2
1	X																						
2	X																						
3	X																						
4	X																						
5	X																						
6	X																						
7	X																						
8	X																						
9	X																						
10	X																						
11	X																						
12	X	X																					
13	X	X																					
14	X	X																					
15	X	X																					
16	X	X																					

LIST OF CONTENTS

1. General Introduction

1.1 Flare Information

Project: MKP Methanol Project

EPCC Contractor/Purchaser: China Tianchen Engineering Corporation (TCC)

This technical report is specified for the flare network sizing calculation of Middle East Kimiaye Pars Co. located in Bandar Assaluyeh in Iran.

As the safety facility, flare system plays a very important role. The useless flammable gas during production phase can go through flare system and combust at flare tip to reach safe discharge. The flare system is to be designed for collecting all combustible gases and liquids which are discharged in case of emergencies, equipment malfunctions, etc.

In this Flare System, one flare network will be installed for assurance of safe combustion discharge at start-up, shut-down, emergencies, or during an upset when the plant is not in balance or when part of the plant is shut down or tripped, and shall meet related environmental requirements.

In case the methanol synthesis is not able to consume the gas available, it will be flared upstream that section.

In case of a trip of either the complete plant or plant section, some release to flare will occur due to depressurisation of some sections.

In case of fire, release to flare may occur due to manual activation of trip, due to manually controlled depressurisation or due to release through safety valves.

Release through the safety valves may also occur as a result of the other contingencies considered for the safety valves, for instance blocked outlet, gas break-through, etc.

When the plant is started up, shut down or in emergency conditions, the discharging flare gas will firstly pass through one knock-out drum in the plant. Then, the flare gas will be transferred to actual flare site. In the actual flare site, one knock-out and water seal drum is necessary, with the combined set and bi-function of liquid separation and water seal.

The overall flare system includes 3 parts:

- The first part is consisted of flare network and one knock out drum inside MEKPCO Plant, which will collect emergency and continuous vent gas. TCC will be responsible for this part.
- The second part is consisted of flare main pipe between the tie-in point of plant and flare area at northeast. The mentioned flare pipe is located at west side of road I2 and after passing the utility corridor and state road, goes to the flares site. DAMAVAND will be responsible for this part.
- The third part is consisted of the flare stack package, which will be located on the north mountain. The stack will be located at: X: 652388.53, Y: 3051685.4, Z: 135. TCC will be responsible for this part.

1.2 Document Purpose

The purpose of the study is to conduct the flare lines hydraulic calculation to determine line sizing with allowable back pressure at Plant battery limit.

1.3 Design Basis

- For the actual flare piping length between the start point and the tie-in point in the methanol plant is about 305 m.
- The direct routing distance between the tie-in point location of the methanol plant and the actual flare site is about 1600 m (MEKPCO-OHTC-EL-239).
- For the flare piping routing, one stress expansion loop is set at about every 60 m distance, about 27 stress expansion loops between the tie-in point and the flare stack (MEKPCO-OHTC-EL-238).
- For the flare piping routing, the elevation change between the tie-in point location of the methanol plant and the actual flare site is 111 m (MEKPCO-OHTC-EL-238).
- For the stress expansion loop, the single distance deviation from the axis line is about 15 m.
- According to TOPSOE documents, the max discharging flowrate to flare is 510000kg/hr.
- The pressure drop in flare stack package is about 40 kPa (by vendor).

2. Flare Network Calculation

2.1 General

The objective of this part is to carry out flare lines hydraulic calculation to determine line sizing with allowable back pressure inside methanol plant. The discharge scenarios, vent gas composition and operating condition have been considered based on TOPSOE documents which have been confirmed in the step of engineering design.

Table 1 - Summary of safety and vent valves discharging to flare.

PID	Tag No.	Fluid	Contingency	Flow rate (kg/hr)	MW (g/mole)	T (°C)	LHV (kJ/Nm³)	HHV (kJ/Nm³)	Reference stream no.[1]
P01	PSV-1008 / PSV-1009	Natural gas	Inadvertent valve opening of PV-1006	2000	16.74	40	34496	38260	2005
P01	PSV-1013 / PSV-1014	Natural gas	Inadvertent valve opening of PV-1011	27700	16.74	35	34496	38260	7005
P01	PSV-1015	Natural gas	Fire around D 1001	800	16.74	85	34496	38260	2000
P04	PSV-1031	Process gas	Fire around R 1001	1200	16.54	410	33834	37542	2030
P04	PSV-1038	Process gas	Fire around R 1002 1	1200	16.54	410	33834	37542	2040
P04	PSV-1043	Process gas	Fire around R 1002 2	1200	16.54	410	33834	37542	2040
P04	PV-1045	Process gas	Valve failure at normal operating pressure/start-up	63000	16.54	365	33834	37542	2040
P07	PSV-6053	Steam + natural gas	Fire around D 6001	3800	13.14	283	7350	8900	2200
P09	PV-2073	Process gas	Valve failure at normal operating pressure/start-up	165300	17.47	262	13565	16226	2090
P09	PSV-2078	Recycle gas from C 2002	Inadvertent valve opening of FV-2079	1500	11.44	48	10367	11751	3000
P17	PSV-2354 / PSV-2355 / PSV-2356 / PSV-2357 / PSV-2358 / PSV-2359 / PSV-2360 /	Reformed gas	Blocked outlet	510000	13.14	360	7350	8900	2200
P19	PV-2406	Reformed gas	Valve failure at normal operating pressure/trip of downstream units	222400	13.17	165	7350	8900	2200

[1] Please refer to HTAS doc ”Stream tables” for composition.

PID	Tag No.	Fluid	Contingency	Flow rate (kg/hr)	MW (g/mole)	T (°C)	LHV (kJ/Nm³)	HHV (kJ/Nm³)	Reference stream no.[1]
P21	PV-2481	Reformed gas	Valve failure at normal operating pressure/trip of methanol synthesis	282200	11.44	48	10367	11751	3000
P21	USV-2482	Reformed gas	Reformer Trip	29700	11.44	48	10367	11751	3000
P22	HV-3011	Synthesis gas	Small purge (short duration)	4000	11.44	48	10367	11751	3000
P22	PSV-3021	Synthesis gas	Fire around R 3001 1/2/3	5600	9.81	120	10426	12029	3110
P27	PSV-3163	Synthesis gas	Fire around D 3001	19000	9.37	100	10441	12132	3190
P27	PV-3166	Recycle gas	Valve failure at normal operating pressure/start-up	51000	11.4	48	10441	12132	3190
P27	HV-3166	Recycle gas	Maximum flow	51000	11.4	48	10441	12132	3190
P27	PSV-3173 / PSV-3174	Purge gas	Inadvertent valve opening of FV-3169	41800	9.37	48	10441	12132	3190
P28	PSV-3196 / PSV-3197 / PSV-3206	Purge gas	Gas breakthrough from LV-3161	66900	9.37	48	9598	10975	3340
P30	PSV-5058 / PSV-5059 / PSV-5060 / PSV-5061	Methanol vapour	Reflux failure	118800	29.92	116	22076	25549	5030
P32	PV-5109	Off-gas	Maximum case	2400	43.59	48	20664	23009	5145
P34	PSV-5179 / PSV-5180	Methanol vapour	Fire around T 5002	5200	29.08	121	22077	25554	5240
P38	PSV-5250 / PSV-5251 / PSV-5261	Methanol vapour	Reflux failure	100200	27.1	141	16524	19619	5430
P40	HV-5338	Methanol vapour	Manual vent on D 5003	220	32.04	101	28473	32389	5500
P42	PSV-5384	Methanol vapour	Fire around X 5001 A	5900	32.04	174	28474	32390	5370
P42	PSV-5386	Methanol vapour	Fire around X 5001 B	5900	32.04	174	28473	32390	5370
U01	PV-2536 B	Purge gas	Trip of purge gas fuel	31800	10.64	47	10509	12189	3350
U17	PSV-2604 / PSV-2605	Hydrogen	Inadvertent valve opening of PV-2608	4000	9.37	48	10441	12132	3310

[1] Please refer to HTAS doc “Stream tables” for composition.

All valves discharging to flare header are listed in Table 1.

For design of the flare header system, simultaneous discharge from various vent points must be considered. The desulphurization, the reforming section, and downstream sections are directly connected. It is thus not possible to flare the maximum capacity from the desulphurization section simultaneously with discharge of the maximum capacity from the downstream sections.

The release source accounting for the maximum process gas flow is located downstream of the Steam Superheater E 2021 (PSV-2354, PSV-2355, PSV-2356, PSV-2357, PSV-2358, PSV-2359 and PSV-2360), which is in the case of reformed gas blocked outlet and overpressure. The scenarios mentioned in Table 1 for simulations discharge has been evaluated and the conclusion is that none of the cases gives a larger flow than this one. This release will be design giving for the flare system.

Following flaring scenarios are considered based on TOPSOE documents, and Case A considered as the basis for the flare system design:

Table 2 - Summary of flaring scenarios cases.

Scenario	Case A	Case B	Case C: Plant Trip
Case Explanation	Reformed gas blocked outlet and overpressure (Maximum discharge case)	Plant Start-up/Shut Down Failure	Valve failure at normal operating pressure/trip of methanol synthesis
Total Mass Flow (Kg/h)	510000	343700	282206
Release source	PSV-2354 PSV-2355 PSV-2356 PSV-2357 PSV-2358 PSV-2359 PSV-2360	PV-2481 USV-2482 PV-2536 B	PV-2481

2.2 Study Result

2.2.1 Calculation Tools

The available discharge scenarios were assessed utilizing “INPLANT” and API 521 method for calculating the size of discharge piping and hydraulic analysis.

The software INPLANT was used to simulate this system. INPLANT(TM) is a powerful, steady-state, multiphase fluid network simulator for investigating process plant piping.

2.2.2 Calculation Principles

The software INPLANT simulation is using through reverse solution, starting from the torch point, back to the release source. It could be commonly used for device and equipment discharge point. According to the discharge conditions of each release source (emission flow, temperature, composition, etc.), the arrangement of the discharge pipe network, the pressure of the flare point and the total discharge load can be calculated.

The application of INPLANT in flare system requires:

(1) The flare system calculation should have a clear composition;

(2) The flare system calculation needs the pressure of the torch endpoint pressure and the release flow of the discharge source;

(3) The flare system calculation adopts the inverse solution, and generally do not have the problem of network convergence;

2.2.3 Calculation Method

The software INPLANT in the design of the flare network system, usually have the following two calculation methods:

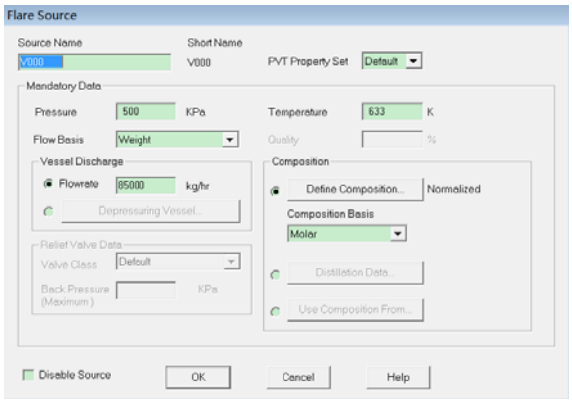
(1) Given the discharge load of each release point, the back pressure of the torch endpoint and the size of the pipe, to seek the back pressure of each discharge point;

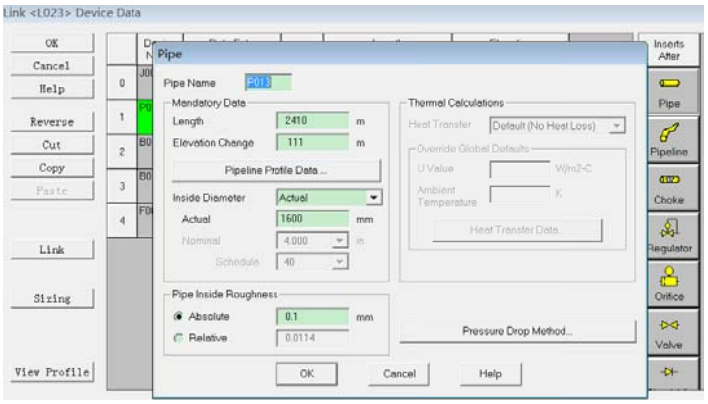
(2) The pressure of each discharge point is given, and the size of the pipe is obtained. If the calculated back pressure is greater than the discharge pressure, the pipe size can be changed to meet the requirement.

This report utilizes the first mode, the calculation steps are as following:

(1) To establish the model of pipe network;

(2) To input the basic data of the flare network, including the emission conditions of various emission sources, the back pressure of the torch endpoint, pipe size, pipe equivalent length, etc.;





(3) To output the results of the calculation (report contains the temperature of the pipe section, fluid flow rate, critical speed, inlet and outlet pressure and pressure drop and other information);

(4) To review the back pressure and Maher number according to the output report.

2.3 Hydraulic Analysis Results

2.3.1 Relief Discharge Sizing Approach

Vapour flow in relief discharge piping is characterized by rapid changes in density and velocity; consequently, the flow should be rated as compressible. Several methods for calculating the size of discharge piping have been developed using isothermal or adiabatic flow equations. Actual flow conditions in relief systems will normally be somewhere between isothermal and adiabatic conditions. For most cases, the slightly more conservative isothermal equations are recommended; however, the adiabatic flow equations may be preferable for some less common applications (for example, cryogenic conditions).

The sizing of relief discharge piping can usually be simplified by starting at the system outlet, where the pressure is known, and working back through the system to verify acceptable back pressure at each pressure relief device. Calculations are performed in a stepwise manner for each pipe segment of constant diameter.

2.3.2 Calculation Results

The flare Main Header Approximate Length is considered 2715 m for hydraulic analysis implementation, including the flare piping length 305m between the start point and the tie-in point in methanol plant, and the flare piping length 2410m between the tie-in point and the actual flare site. Then to calculate a relevant header diameter and backpressure at plant battery limit. Calculated parameters for main header is seen in Table 3 as below.

Table 3 - Calculated Parameters for Main Header.

Flaring Scenario	Main Header Size before K.O.D(in.)	Main Header Size after K.O.D (in.)	Header Exit Mach No.	Main Header Length (m)	Calc. Back Pressure of Tie-in point (kPa A)	Calc. Back Pressure of PSVs (kPa A)
Case A	56”	64”	0.129	2715	342.76	385
Case B	56”	64”	0.098	2715	220.09	238
Case C	56”	64”	0.110	2715	198.40	212

For these flaring scenarios cases, the INPLANT flare network schematic diagram and calculated parameters are showed as following:

- For Case A, the flare network schematic diagram is seen in Fig. 1 and calculated parameters in Table 4;
- For Case B, the flare network schematic diagram is seen in Fig. 2 and calculated parameters in Table 5;
- For Case C, the flare network schematic diagram is seen in Fig. 3 and calculated parameters in Table 6.

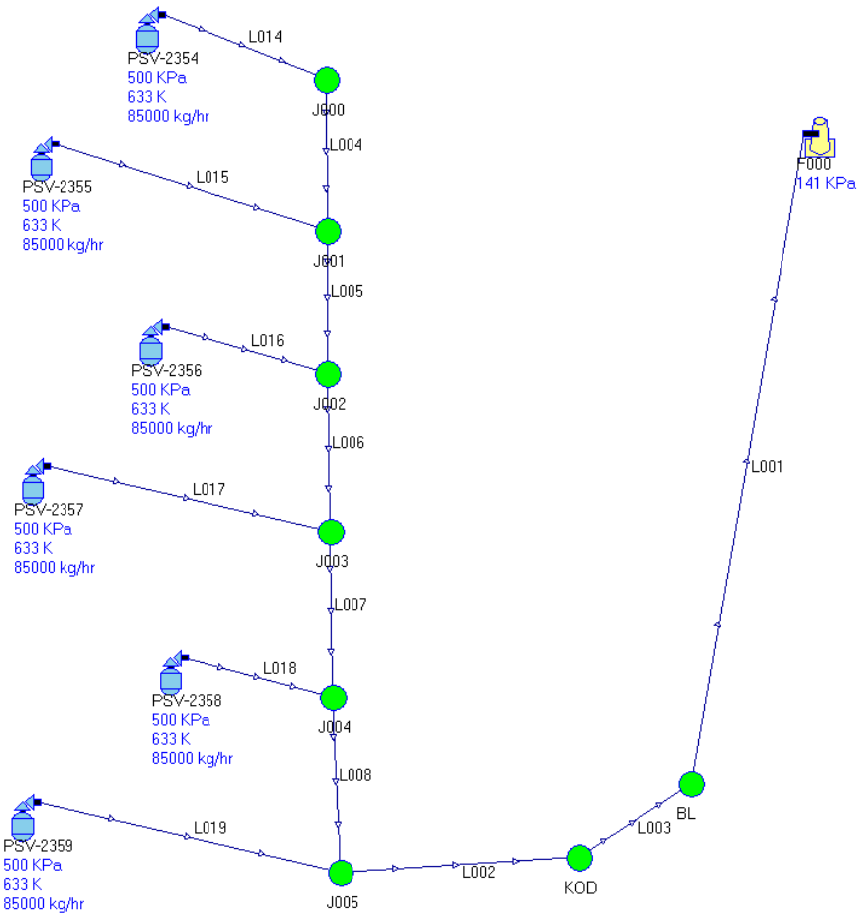


Fig. 1 - INPLANT flare network schematic diagram of Case A.

Table 4 - Calculated parameters for Case A.

Calc. Back Pressure of PSV-2354 (kPa A)	Calc. Back Pressure of PSV-2355 (kPa A)	Calc. Back Pressure of PSV-2356 (kPa A)	Calc. Back Pressure of PSV-2357 (kPa A)	Calc. Back Pressure of PSV-2358 (kPa A)	Calc. Back Pressure of PSV-2359 (kPa A)	Inlet Pressure of L003/KOD (kPa A)	Inlet Pressure of L001/BL (kPa A)	Outlet Pressure of L001 (kPa A)	Exit Mach No. of L003	Exit Mach No. of L001
383.65	383.73	383.79	384.57	384.96	385.04	347.45	342.76	141	0.110	0.129

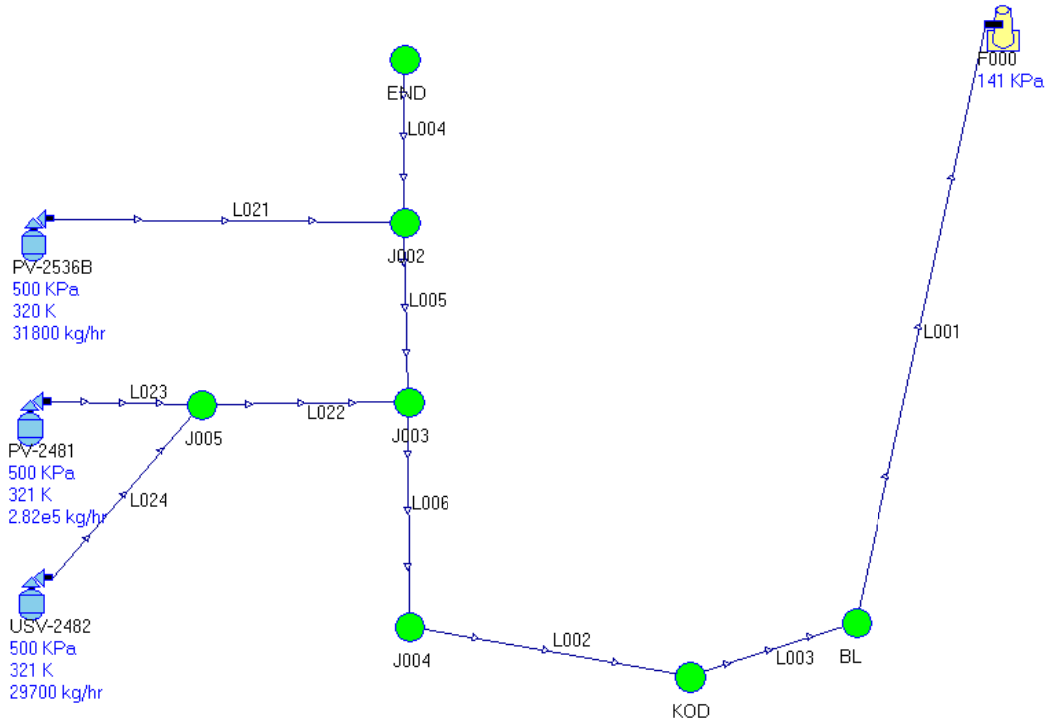


Fig. 2 - INPLANT flare network schematic diagram of Case B.

Table 5 - Calculated parameters for Case B.

Calc. Back Pressure of PV-2481 (kPa A)	Calc. Back Pressure of USV-2482 (kPa A)	Calc. Back Pressure of PV-2536B (kPa A)	Inlet Pressure of L003/KOD (kPa A)	Inlet Pressure of L001/BL (kPa A)	Outlet Pressure of L001 (kPa A)	Exit Mach No. of L003	Exit Mach No. of L001
237.32	236.24	234.79	222.58	220.09	141	0.088	0.098

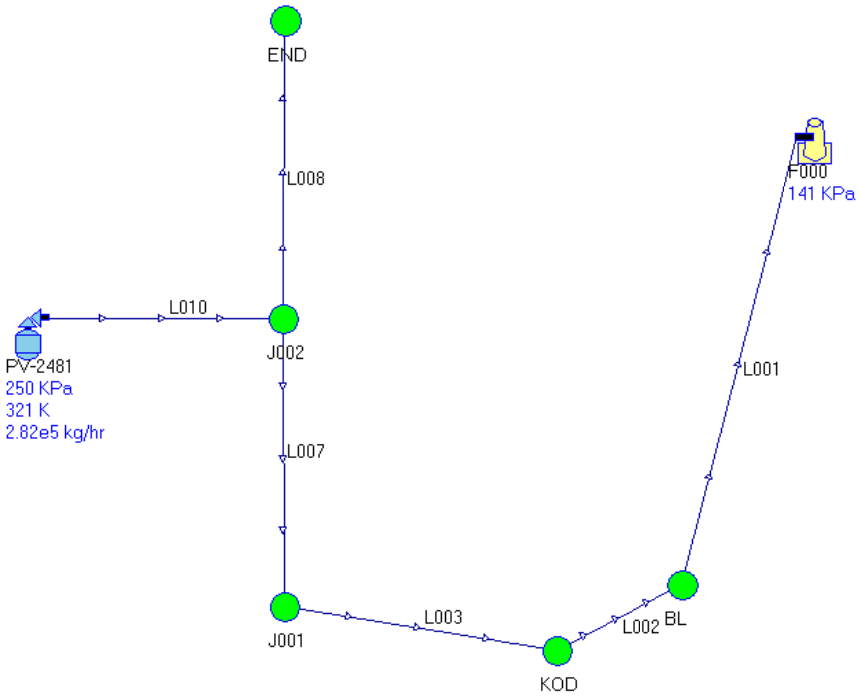


Fig. 3 - INPLANT flare network schematic diagram of Case C.

Table 6 - Calculated parameters for Case C.

Calc. Back Pressure of PV-2481 (kPa A)	Inlet Pressure of L002/KOD (kPa A)	Inlet Pressure of L001/BL (kPa A)	Outlet Pressure of L001(kPa A)	Exit Mach No. of L002	Exit Mach No. of L001
211.42	199.89	198.40	141	0.080	0.110

3. Conclusion

From the calculated results above, we could get the following information:

- For the main header size in the plant, between the start point and the tie-in point of the methanol plant, the size of 56" is reasonable.
- For the main header size outside the plant, between the tie-in point location of the methanol plant and the actual flare site, the size of 64" is reasonable.

For Case A, the minimum back pressure of PSV-2354 /PSV-2355 /PSV-2356 /PSV-2357 /PSV-2358 /PSV-2359 /PSV-2360 should be more than 385 kPa A;

For Case B, the minimum back pressure of PV-2481/ USV-2482/ PV-2536 B should be more than 238 kPa A;

For Case C, the minimum back pressure of PV-2481 should be more than 212 kPa A.

For other cases, the discharge mass flow is less than three cases above. So maximum back pressure of other cases is less than 250 kPa A.

For conventional safety relief valves, MABP is about 10% of the set pressure; For the balanced bellows safety relief valves, MABP allows for about 30% of the set pressure.

Thus, we suggest that:

- The back pressure of PSV-2354 /PSV-2355 /PSV-2356 /PSV-2357 /PSV-2358 /PSV-2359 /PSV-2360 should be 450 kPa A.
- Considering the simultaneous flaring discharge from different flaring points, the back pressure of the other safety relief valves should be 250 kPa A.

4. Appendix

No.	Description	Rev.	Data Sheet No.
1	Flare header load summary	2	4348869
2	Output calculation of Case A	-	Output calculation of Case A
3	Output calculation of Case B	-	Output calculation of Case B
4	Output calculation of Case C	-	Output calculation of Case C