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Enforcement of the safety culture in the LPG and LNG sector: findings of Seveso controlling activities

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The paper concerns the results that emerged from the analysis of the control activities carried out by ISPRA in the context of the Italian implementation of the Directive 2012/18/EU aiming at the control of major accidents (so-called "Seveso III"), on industrial establishments in the LPG and LNG sector. Starting from the presentation of the European and Italian technical regulation, a sample of the following types of establishments are analysed in terms of technical and organizational aspects: urban storage and distribution of LPG; underground storage of LPG; multi-site LPG storage company; LNG storage and regasification terminal. The main conclusions of the assessments of Safety Reports and inspections on Safety Management Systems carried out on some national case studies are explained, aimed at emphasizing the return of experience and the lessons learned for the Competent Authorities activities. Finally, some types of non-compliances found during the control activities are provided, in terms of organizational and management aspects aimed at the enforcement of the safety culture of the industrial establishments. They regard the evaluation of: Safety Reports, from a structural, organizational, and documentary completeness point of view; Safety Management System inspections, in terms of training, operational control and emergency management activities.

Keywords: Safety Reports, Safety Management Systems, LPG, LNG, Controlling activities, Safety culture.

1. Introduction

The Seveso III Directive 2012/18/EU (EU. 2012), implemented in Italy by a legislative decree issued in 2015 - D.Lgs. 105/2015 (GU. 2015), is aimed at the prevention of major accidents involving dangerous substances. The D.Lgs. 105/2015 covers establishments where dangerous substances may be present (e.g. during processing or storage) in quantities exceeding certain thresholds. Operators of the establishments are obliged to take all necessary measures to prevent major accidents and to limit their consequences for human health and the environment.

Depending on the amount of dangerous substances present, establishments are categorised in lower and upper tier, with different obligations. The requirements include, among others: notification of all concerned establishments; deploying a Major Accident Prevention Policy (MAPP) through the implementation of a Safety Management System for Prevention of Major Accident (SMS-PMA); producing a Safety Report (SR) for upper-tier establishments; producing an Internal Emergency Plan (IEP) for upper tier establishments; providing information in case of accidents.

2. The LPG and LNG sector

2.1. *The Italian situation*

The dangerous substances LPG and LNG are included among the forty-eight substances set out in Annex 1 - Part 2 of Legislative Decree 105/2015, or the so-called "named dangerous substances", according to the following quantitative thresholds (see Table 1): the industrial installations are Lower-Tier (LT) or Upper-Tier (UT) establishments.

Table 1. Threshold limits for LPG and LNG.

Column 1 Dangerous substances	CAS	Column 2 Qualifying quantity (t) for the application of LT	Column 3 UT
…	…	…	…
18. Liquefied flammable gases, Category 1 or 2 (including LPG) and natural gas	—	50	200
…	…	…	…

Assuming an average density for LPG and LNG equal to 530 kg/m^3 and 460 kg/m^3 respectively, it is possible to roughly estimate the following requirements for the application of:

- LT: 94 m^3 (LPG) / 109 m^3 (LNG).
- UT: 377 m^3 (LPG) / 435 m^3 (LNG).

According to the National Inventory of Seveso establishments (ISPRA. 2023), managed by ISPRA, 985 industrial sites fall under the D.Lgs. 105/2015, with 476 LT establishments and 509 UT establishments:

- 244 sites belong to the LPG sector (production, bottling, distribution and storage).
- 6 sites belong to the LNG sector (storage, regasification and distribution).

The entire LPG and LNG sector represents a quarter of the country's Seveso establishments (approximately 25%), a significant portion of the Italian production reality, as indeed indicated in the following Figure 1, which shows the main industrial sectors subject to the D.Lgs. 105/2015.

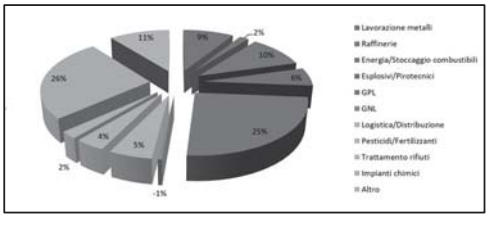

Fig. 1.The Italian situation for the Seveso establishments.

2.2.*Types of establishments*

For the purposes of the analysis conducted on the results of the evaluation on the SRs and SMS inspections, in the LPG and LNG sector, the main functional characteristics of a sample of five types of establishments are shown below:

- LPG storage and city distribution (300 t of LPG)
  - Receiving of LPG by tanker (20 t), carried out by compressors
  - LPG (propane-butane-mix) storage in mounded tanks
  - Possibility of LPG mixing through internal transfer of product from one tank to another
  - LPG vaporization by hot water vaporizers and odourisation
  - Pressure reduction and city distribution of LPG through pumps
- LPG underground storage (22.000 t of LPG)
  - Receiving of LPG by refrigerated vessels (3.000 t – 21.000 t) through on-board pumps
  - Heating and measurement of the product
  - LPG storage in underground tanks (caves in a layer of clay)
  - Denaturation and odorization of the LPG extracted from underground tanks
  - Shipping of tankers (22 t) and railway tanks (45 t)
  - LPG transfer to nearby establishment
- Multi-site LPG storage company (400 t of LPG)
  - LPG receiving by tanker through compressors
  - LPG (propane-butane-mix) storage in above-ground mounded tanks
  - Bottling in LPG cylinders and cylinders maintenance
  - Shipping of LPG tankers and cylinders by pumps
- Offshore LNG storage and re-gasification terminal (120.000 t of LNG)
  - LNG receiving by refrigerated vessels through on-board pumps and racking arms
  - LNG cryogenic storage in tanks on a Gravity Based Structure (GBS)
  - Vaporization of LNG by sea water vaporizers (Open Rack Vaporizers - ORV) and glycol-water exchanger (Waste Heat Recovery - WHR)

- Sending and measurement of NG onshore by undersea pipeline (sea-line of 15 km)

In the following Figure 2 and 3 schemes of a common LPG plant are shown (logical units and above-ground mounded tank), taken from the DM 13/10/1994 referred to below (GU. 1994).

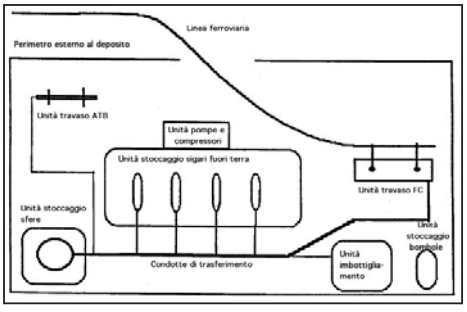

Fig. 2.The logical units of a LPG plant.

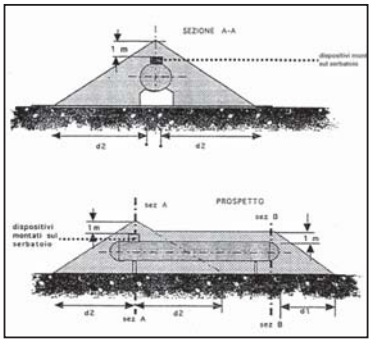

Fig. 3.The above-ground mounded tank.

In relation to the LNG, in the Figure 4 a simplified scheme of a regasification terminal is shown (UNI. 2021).

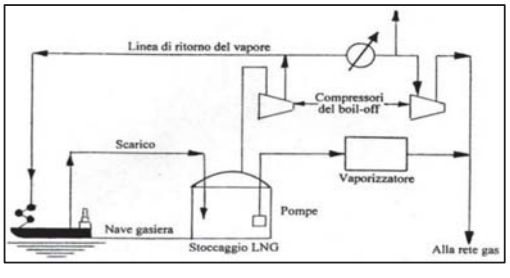

Fig. 4.The scheme of an LNG regasification terminal.

3. Control activities on the LPG and LNG sector: Safety Reports assessments

3.1.*The national technical regulation*

In the SR, the site operator produces a risk assessment with the description of a risk analysis and measures for the prevention of major accident hazards. The technical evaluation, carried out by the Italian Competent Authorities (The Regional Technical Committee (CTR), under the Regional Fire Brigade), identifies accident scenarios, damage distances and frequencies of occurrence, as well as the safety measures adopted, for the purposes of External Emergency Planning (EEP) and Land Use Planning (LUP). The examination conclusions include the final evaluations, any supplementary requirements and, if the measures taken to prevent and limit the consequences of major accidents are insufficient, the limitation or prohibition of use is foreseen.

As regards the technical assessments and evaluation of the SR, the main legislative instruments are highlighted below:

- Annex C of the D.Lgs. 105/2015. The criteria for drafting the SR are reported, including information on the plant, plant safety, emergency, and intervention measures.
- DM 9/05/2001 (GU. 2001). It deals with the issues of land use planning for all types of establishments, with specific attention to the categorization of the installations and the threshold values for the different impacts.
- DIRETTIVA 7/12/2022 (GU. 2023). It gives guidelines for drawing-up External Emergency Plans, informing the public concerned and the emergency drills.

With specific reference to the LPG sector, in consideration of the productive weight it has in the national industrial panorama, as said before, there are specific legislative instruments, as:

- DM 13/10/1994 (GU. 1994). It is the technical regulation of fire prevention for the design, construction, installation and operation of LPG depots in fixed tanks. The main features are:
  - Definition of hazardous elements of the plant: Loading arms; Tanks; Areas of storage (empty or filled cylinders);

Pumps, compressors, liquid meters; Bottling equipment; Vaporizers; Tankers and railcars. These elements are used to define different safety distances to be respected in design and operation phases
    - Definition of organizational measures: a strong commitment to staff training is required with specific programs for key figures and roles. There are mandatory requirements for main loading/unloading activity and for bottling activities
- DM 15/05/1996 (GU. 1996). It reports the criteria of analysis and evaluation of the SR for LPG, with the characterization of storage, the evaluation of the scenarios, the threshold values, the plant adjustments for risk control.

Based on the indications given above it is possible to demonstrate how the advanced state of evolution of the technical regulation in place in Italy for the LPG and LNG sector, issued in implementation of the Seveso directive for the Safety Reports assessment, is important, contributing to the safety of industrial establishments.

3.2. *The evaluation of the SRs*

As regards the controls on the LPG and LNG sector, the technical results that emerged from the evaluation of the SRs are summarized below, extrapolating the main critical issues for the sample of establishments coming from practical examples of control activities carried out by the Competent Authorities.

The Figure 5 reports the damage distances of the accident scenarios hypothesized in the SRs, which emerged at the conclusion of the assessments.

ESTABLISHMENTS	SCENARIOS AND DAMAGE ZONES (m)											
	UVCE (bar)			Flash Fire (-)		Jet Fire (kW/m2)			Pool Fire (kW/m2)		
	I (0.3)	II (0.07)	III (0.03)	I (LFL)	II (½ LFL)	I (12.5)	II (5)	III (3)	I (12.5)	II (5)	III (3)
LPG storage and city distribution				70	110						
LPG underground storage	360	370	450	260	350	150	160	170	70	70	70
Multi-site LPG storage company				70	110	40	50	70			
Offshore LNG storage and re-gasification terminal				290	420	60	100	130	20	40	60

Fig. 5.Scenarios and damage zones

In the following the main non-compliances are summarized, concerning the plant - structural sphere of the establishment, the organizational - management system, the completeness and documentary verification:

- LPG storage and city distribution
    - Plant and structural: Control system of the tanks static alignment; Manual shutoff valves, upstream of the tank safety valves, which are freely operable and non-plumbed; Double valve on the sample points of the pipes downstream of tanks; Maintenance interventions on the tanks covering system
    - Organizational and management: Communication and alarm system to ensure the traffic block on the road (high lethality area); Emergency procedure for the introduction of water into the tanks.
- LPG underground storage
    - Plant and structural: Technical interventions to improve safety conditions of the vessel unloading point and the fire control room at the dock
    - Organizational and management: Emergency procedure for the vessel unloading point and connection with local fire brigade
    - Documentary (completeness check): Qualification and professional experience of design consultants; Seismic analysis of underground storage; Historical accident analysis at underground storage sites; Hazard operability for the vessel unloading point; Domino effects on nearby coastal establishments.
- Multi-site LPG storage company
    - Plant and structural: Doubling the connection between the firefighting pumps and the water reserve; Raise the threshold of the room with the electric transformer containing thermal oil
    - Documentary (completeness check): Deepening the presence of all vulnerable elements around the establishment; Correct location referencing of source points of the accident scenarios with impact outside the establishment.
- Offshore LNG storage and re-gasification terminal
    - Plant and structural: Restoring the safety locks of the Boil Off Gas crane

- Organizational and management: Computerized controls of the calibration of the flammable fuel tank detectors; Training activities of fire-fighting personnel employed in the helipad
- Documentary (completeness check): Technical documentation relating to filter anchorages of the fire-fighting sea water; Possible effects on the risk scenarios associated with the "Low Send-out" speed to the national gas network.

4. Control activities on the LPG and LNG sector: Safety Management System inspections

4.1.*The national technical regulation*

The SMS-PMA inspection are carried out by a Commission, made up of three members belonging to National Institute for Environmental Protection and Research (ISPRA - Istituto Superiore Protezione e Ricerca Ambientale), National Fire Brigades (CNVVF – Corpo Nazionale Vigili del Fuoco) and National Workers' compensation Authority (INAIL – (Istituto Nazionale Assicurazione Infortuni sul Lavoro), to verify the suitability of the operator MAPP carrying out a planned and systematic examination of the systems being employed at the establishment, whether of a technical, organisational or managerial nature.

As regards the SMS-PMA inspections, the main legislative instrument is the Annex H of the D.Lgs. 105/2015. Criteria and procedures for conducting inspections are provided, being present, among others, a specific checklist for the inspections in high standardization plants (LPG deposits).

With specific reference to the LPG sector, in consideration of the productive weight it has in the national industrial panorama, as said before, there are specific legislative instruments, as:

- DM 15/5/1996 (GU. 1996). There are references to the procedure for the transfer from LPG and Tanker, with specific attention to the positioning of vehicles, to the firefighting protection systems, to the operating manual.
- D.Lgs. 128/2006 (GU. 2006). It imposes the enlargement of some obligations connected to the implementation of the Seveso Directive (MAPP and SMS), to the filling, transfer and storage systems of LPG (below the 50 t threshold), imposing also the inspections regime.

Based on the indications given above it is possible to demonstrate how the advanced state of evolution of the technical regulation in place in Italy for the LPG and LNG sector, issued in implementation of the Seveso directive for the implementation of the SMS, is important, contributing to the safety of industrial establishments.

4.2.*The results of the SMS inspections*

Taking the elements of the SMS-PMA as a reference, for the establishments belonging to the LPG and LNG sector some significant elements that emerged from the analysis of the inspection reports on a national basis were examined. About the sample of establishments taken into consideration, the main non-compliances coming from practical examples of control activities carried out by the Competent Authorities are indicated for the elements of staff training, operational control and maintenance, emergency planning:

- LPG storage and city distribution
  - Training activities: Systematic distribution to workers of updated documentation; Consultation of the worker's representative; Compliance with the established periodicity of programs; Verification of learning for workers and contractors
  - Operational control and maintenance: Identification of critical technical systems and consequent planning of maintenance programs; Update maintenance procedures; Update the operating manual with fault conditions; Deepening and implementing the Permit to Work procedure
  - Emergency planning: Review of the IEP and consultation of the workers; Definition of roles of all units involved in the emergency; Definition of all Personal Protective Equipment (PPE)

provided for workers; Technical support documentation in all departments.

- LPG underground storage
  - Training activities: Highlight aspects related to the "Seveso and MAPP" issues in training activities; Training activities also following regulatory developments and improvement of technical and managerial knowledge
  - Operational control and maintenance: Updating the "document management" procedure with references to the technical documentation at all departments
  - Emergency planning compliances: Procedure for site management following an accident; Supporting external investigations including accident reporting and the safeguarding of objective evidence.
- Multi-site LPG storage company
  - Training activities: Systematic distribution to workers of updated documentation; Compliance with the established periodicity of programs; Verification of learning for contractors; Criteria for qualification of trainers
  - Operational control and maintenance: Ensure digital recording of maintenance interventions; Update the operating manual with references to technologies actually present; Indicate in the Permit to Work procedure the roles and responsibilities of all personnel involved
  - Emergency planning compliances: Review of the IEP (intervention procedures; emergency team); Procedures in night hours (time of intervention; communication); Availability of PPE and devices provided for workers; Correct definition of establishments exit routes.
- Offshore LNG storage and re-gasification terminal
  - Training activities: Systematic distribution to workers of updated documentation; Program training by specifying periodicity and issues; Consultation of the worker's representative; Verification of learning for contractors
  - Operational control compliances: Identification of critical technical systems as a result of the SR and consequent planning of maintenance programs; Ensure digital recording of maintenance interventions; Update the operating manual with fault conditions; Complete the modules provided by the Permit to Work procedure
  - Emergency planning compliances: Review of the IEP and consultation of the workers; Criteria about the number of personnel in the emergency team; Site emergency simulation planning; Positioning of lifeboats provided for workers.

5. Conclusions

The analysis conducted on the technical assessments of the SRs of establishments of the LPG and LNG sector, belonging to some common types of national installations, allowed to extrapolate a series of main aspects that emerged from the activities carried out by the Competent Authorities.

As far as the scenarios and damage zones are concerned, following the technical assessments carried out on these installations, it is possible to state that explosions (UVCE – Unconfined Vapour Cloud Explosion) are in the order of 500 m, while fires vary between 100 m and 400 m (flash fire), 100 m and 200 m (jet fire), and 100 m (pool fire).

In relation to the requests and requirements that emerged from these assessments, the following non-compliances can be drawn in terms of:

- Plants and structures: pumps and safety valves; safety equipment at the product transfer points; checks on storage tanks
- Organization and management: emergency procedures at transfer points and tanks; communication systems
- Documentation: seismic analysis; domino effects; vulnerable elements and external impacts; risk scenarios associated with the distribution of Natural Gas.

About the SMS-PMA inspections carried out by the Competent Authorities, it is possible to highlight a series of common aspects

concerning both technical and managerial non-compliances (EU. 2018):

- Training activities: updated documentation; periodicity of the programmes; consultation of workers; verification of learning
- Operational control: identification of critical technical systems; registration of maintenance interventions; update of the operating manual; completeness of the Permit to Work procedure
- Emergency planning: IEP review and consultation; emergency team and simulation; PPE and protection systems for workers; management and post incident investigation.

Finally, it is possible to underline that the non-compliances found, in terms of technical, organizational and management aspects, showed the importance of the control activities on LPG and LNG sector, based on practical examples of control activities carried out by the Competent Authorities. Through these activities, in fact, the site operators could learn some lessons, with the relative return of experience, about corporate safety culture and relative enforcement for the correct evaluation of the major accidents and the consequent implementation of the Safety Management System (MAHB. 2015).

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