Design and safety organization for explosives environmental test facility

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- Abstract -

When designing an explosives facility, French manufacturers must refer to the basic principle of French safety regulation, which states:
"Buildings must be designed and built in a manner such that any accidental explosion shall not generate a major risk for persons other than those who, due to their work, must remain exposed to the possible effects of a potential accident".

This paper shows the concrete application of this principle when designing a missile warhead environmental test facility, setting the safety organisation, stipulating the operating rules and justifying the options and decisions to the Official French Agencies.

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I. Introduction

The major principles for explosive safety are well-known to the international technical community. In each country, they are subject to the rules and regulations in force which mainly differ in form but are similar as regards their technical content.

In France, however, the situation may be considered as rather particular. Indeed, a national regulation which is applicable to the entire French explosive products and items industry defines the principles, the resulting technical arrangements and the conditions according to which manufacturers must demonstrate the validity of the steps taken to the administration ensuring the safety of the personnel and the environment.

At the 23rd, E.S.S., I spoke on this regulation, and its application by MATRA DEFENSE in the context of a MISTRAL missile production facility. In particular I indicated the means installed to control the safety of the establishment and the environment.
As MATRA DEFENSE develops and manufactures missile systems, we have designed and constructed a new workshop intended for environmental testing of missile components and munitions. This installation is a good example of the method chosen by MATRA DEFENSE to provide the best safety level for the operators as well as for neighboring installations, in accordance with criteria fixed by the French regulation.

II. Explosive safety rules

Before starting studies on a new munitions test facility, it is appropriate to outline the basic principles the designer must adhere to in preparing his study.

In the United States the principle of facility safety is illustrated by a paragraph of the DOD document : Ammunition and explosives safety standards 6055-9 :
"Construction features and location are important safety considerations in planning facilities that are to be P.E.S., or exposed to the damaging effects of potential explosion (that is E.S.). The effects of potential explosions may be altered significantly by construction features that limit the amount of explosives involved, attenuate resultant blast overpressure or thermal radiation, and reduce the quantity and range of hazardous fragments and debris. Proper location of exposed sites in relation to P.E.S. ensures against unacceptable damage and injuries in event of an accident".

In France, the applieable regulation (Decree N° 79-846) stipulates :
"Buildings must be designed and built in a manner such that any accidental explosion shall not generate a major risk for persons other than those who, due to their work, must remain exposed to the possible effects of a potential accident".

These general requirements are completed by the Zi/Pj/ak formula which establishes maximum risk exposure conditions. Using this approach, operator safety is evaluated according to the following criteria :

- Hazard zones (Zi), representing the consequences of an accident exposing personnel to overpressures, fragment projections, and thermal effects :

Zi	PERSONAL INJURY	PROPERTY DAMAGE
Z1	LETHAL INJURIES IN MORE THAN 50 % OF CASES	VERY SEVERE DAMAGE
Z2	SERIOUS INJURIES WHICH MAY BE LETHAL	SEVERE DAMAGE
Z3	INJURIES	MEDIUM AND SLIGHT DAMAGE
Z4	POSSIBILITY OF INJURIES	SLIGHT DAMAGE
Z5	VERY LOW POSSIBILITY OF SLIGHT INJURIES	VERY SLIGHT DAMAGE

- Probability of an explosive accident (Pj). This point is determined by an analysis of operations carried out, that is, stimuli liable to affect the munitions, the sensitivity of the munitions to these stimuli and the preventive measures to be implemented.

Pj	LEVEL	EXAMPLES
P1	EXTREMELY RARE	STORAGE AND HANDLING
P2	VERY RARE	FABRICATION OPERATIONS-PACKING
P3	RARE	MACHINING OF SENSITIVE, ENERGETIC MATERIAL, COMPLETE ROUND TEST OPERATIONS
P4	RATHER FREQUENT	OPERATIONS ON VERY SENSITIVE MATERIALS, PRODUCTION OF PRIMARY EXPLOSIVES
P5	FREQUENT	MIXING, COMPRESSION OF PRIMARY EXPLOSIVES

- **Risk exposure :** for the facility under study-considered as risk donor or potential explosion site (P.E.S), called "ao", the different types of installations and personnel risk receivers - or exposed sites (E.S.) - are succinctly classified in three categories :

1. Facilities inside the plant

- a_1 Explosive facilities having to be located near "ao"
- a_2 Other explosive facilities and inner roads
- a_3 Inert buildings

2. Roads outside the plant

- b_1 Traffic < 200 vehicles/day
- b_2 Traffic between 200 and 2000 vehicles/day
- b_3 Important traffic > 2000 vehicles/day

3. Buildings or other places outside the plant

- c_1 Uninhabited, short presence
- c_2 Inhabited by, or with, plant personnel present
- c_3 Other facilities, houses...
- c_4 Public places : markets, schools, hospitals, dense built-up areas.

According to the product of Zi × Pj, limits are established for risk exposure to both operators and installations. These possibilities are indicated in the following table :

probability / hazard zone	P1	P2	P3	P4	P5
Z1	a_0	a_0	a_0(x)	a_0(xx)	a_0(xx)
Z2	a_1 a_2	a_1 a_2(x)	a_1	a_1(x)	a_1(xx)
Z3	a_1 b_1 c_1 a_2 a_3	a_1 b_1 c_1 a_2	a_1 a_2	a_1	a_1(x)
Z4	a_1 b_1 c_1 a_2 b_2 c_2 a_3	a_1 b_1 c_1 a_2 b_2 c_2 a_3	a_1 b_1 c_1 a_2	a_1 a_2	a_1
Z5	a_1 b_1 c_1 a_2 b_2 c_2 a_3 b_3 c_3	a_1 b_1 c_1 a_2 b_2 c_2 a_3 b_3 c_3	a_1 b_1 c_1 a_2 b_2 c_2 a_3 b_3 c_3	a_1 b_1 c_1 a_2 b_2 c_2 a_2 b_3 c_3	a_1 b_1 c_1 a_2 b_2 c_2 a_3 b_3

NOTE : (*) Indicates that the personnel required to operate the facility concerned shall not be subjected for more than 10 % of their working time to risks equalling to those to which they are exposed in this installation.

(**) Indicates, that no person shall be present in the zone and installation concerned, in application of the requirements of Article 27 of Decree No.79-846 of September 28, 1979.

A minimum number of persons shall be allowed to gather simultaneously in zones Z1 and Z2.

The number of persons simultaneously present throughout installation "ao" exhibiting a probability of explosive accident greater than P1 shall not normally exceed 5.

Thus, it clearly appears that when environmental tests, such as climatic, vibration, impact and so on, are conducted in a facility, the probability of an explosive accident will be at least P3 and that special measures should be taken to protect operators.

One of the essential aspects of the French regulation is that the analysis briefly described must be conducted in the form of a safety study on which the opinion of the personnel or its representatives is given. The study is then submitted for approval to the competent governmental authorities.

III. Design of the "Environmental test" facility

To begin the study for the facility, a preliminary 3-step examination should be undertaken :

1 - **Precisely defining needs**, in other words, the type of munitions concerned, net explosive quantity (N.E.Q.) of the maximum credible event, and the various operations that will be carried out. For example : munitions with explosive charges rated at 15 kg N.E.Q. and climatic or mechanical testing (impact, vibration, acceleration tests).

2 - **Defining facility characteristics which will ensure personnel safety environment and worktool protection.** For this, the workshop must :
   . Withstand the effects of an accidental explosion during testing ;
   . Contain hazardous fragments, and
   . Reduce the effects of such an explosion to an acceptable level for the environment.

3 - **Defining the number of rooms required** - this kind of installation necessitates test cells, a storage cell, a corridor, and a facility control center.

The principle of limiting personnel risk exposure, combined with the previous three steps, means the building layout should be based on the following criteria :
   . Maximum risk separation,
   . Containing the effects of an explosion, and
   . Designing each room to the risk level of the operations carried out in it.

3.1. Facility general layout

The facility requires 4 kinds of workspaces which can be split into two parts :

a) **Explosive Area**
   - Contiguous cells for test (1) and one cell for storage (2).
   - A corridor (3) for transportation of explosive charges and for personnel movement.

b) **Facility control and processing section**
   Several rooms needed for facility control, instrumentation and management (4).
   This arrangement makes it feasible to easily examine the impact of each risk donor (P.E.S.) on the others, considered as risk receivers (E.S.).

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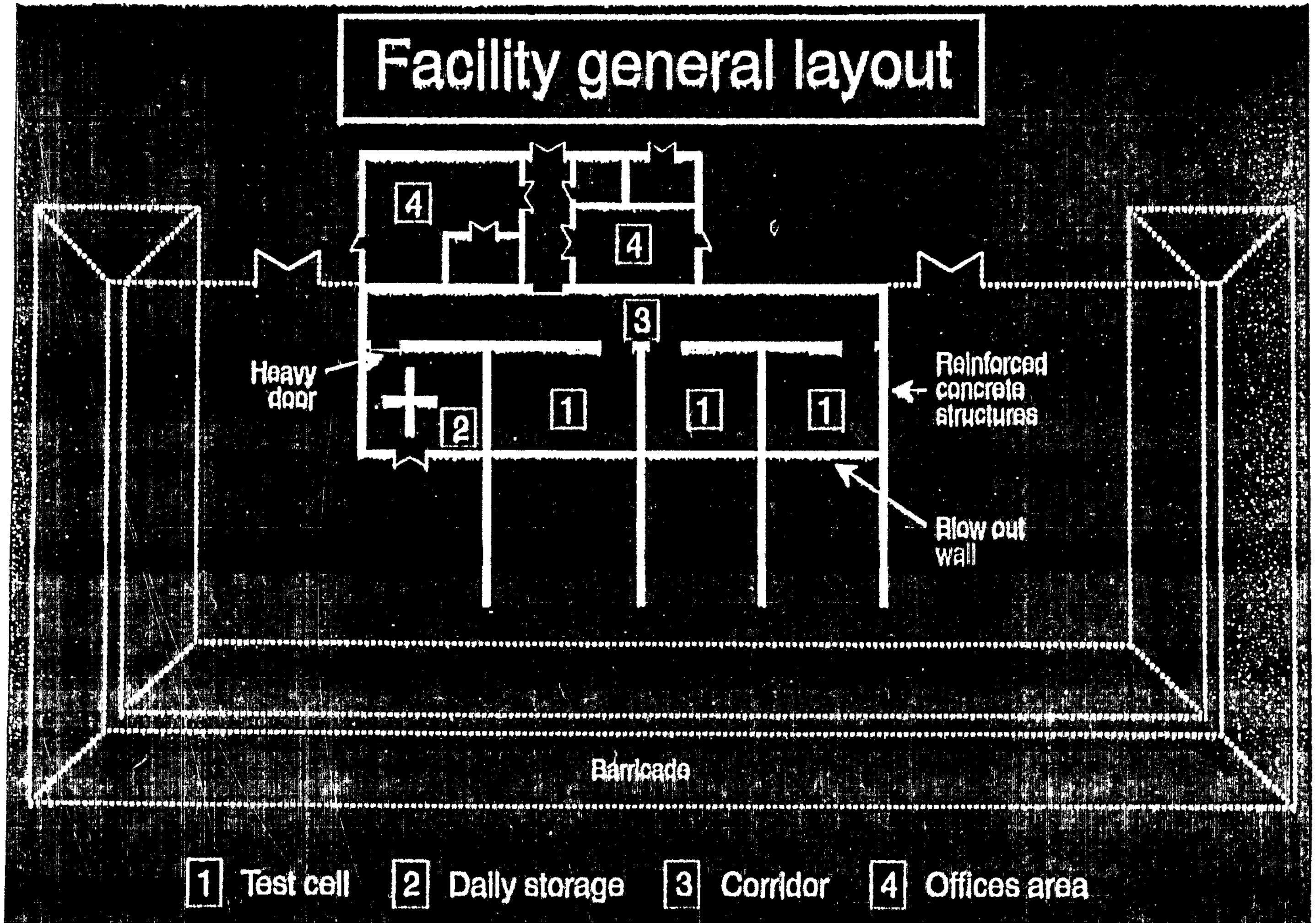
Facility general layout
4
4
3
Heavy door
2
1
1
1
Reinforced concrete structures
Blow out wall
Barricade
1 Test cell
2 Daily storage
3 Corridor
4 Offices area

3.2. Design of Explosive Area (P.E.S.)

The cells in the explosive area are composed of five blast resistant walls and one blow-out wall. The lateral walls extend in the direction of a barricade. At their upper parts shield plates are bolted for arresting fragments or channeling them towards the barricade and damping the shock wave. A heavy, sliding, electronically-controlled door enables entry to each cell.

The corridor is composed of the strong walls of the cells and a strong vertical wall separating the explosive area from the inert zone. It acts as an airlock between the inert zone and the test cells. As the risk level in the corridor is low the roof is light but capable of resisting the back-pressure wave coming from a blow-out wall of one of the cells. It is equipped with meshing to protect the personnel from falling roof fragments.

3.3 Design of the control and processing section (E.S.)

This part of the building adjoins the corridor. Its construction is designed to withstand the effects of an accident produced in one of the P.E.S.s and consequently to guarantee the safety of personnel in this area. A sliding heavy door provides access to the corridor which, in turn, provides access to other parts of the building.

IV Internal safety organization

4.1 Safety equipment

Risk management requires the implementation of checking, surveillance, and intervention devices, such as :

- A communication network linking all facility cells to the control center.
- A video camera network for the surveillance of all cells and the corridor.
- A lighted panel signalling system indicating the status of each cell (explosive or inert activity).
- An emergency cut-off switch near each test machine.
- Fire protection including a high speed deluge system and conventionel fire fighting systems.
- Lightning protection.
- grounding of all conductive elements.
- building access control by means of the facility manager's control board.

The facility manager's control center provides the following capabilities :

- control of the closed circuit surveillance system.
- control of auditory signals indicating the transfer of explosive items.
- Control of lighted panels situated above the heavy doors.
- manual control of the deluge system, and
- building access control.

4.2 Operating rules

Operating rules, based on the facility characteristics adopted in the design phase, make it possible to ensure safety by determining the conditions in which the various functions will be carried out.

In an environmental test facility each risk donor (P.E.S.) should contain any possible hazard ; no propagation of any incident can be allowed.The heavy doors between the cells and the corridor should therefore be used according to strict procedures.

- When not in use, all heavy doors remain closed.

- Any particular door can be opened only if all the others are closed.

- Opening a cell door immediately cuts-off all machinery in that cell.

- Opening a cell door is accomplished through electric command units placed in the corridor and inside the cell. If necessary, doors can be opened manually from the corridor and from inside the cell.

- The door opening unit is regulated by a timer. Automatic closing of the door is prevented in case an obstacle (either a person or an object) lies in its path.

- Access to the storage cell is controlled by the facility manager, and is only possible when the test cells are not in use.

The test cells can be used in two modes :

<u>Inert mode</u> : Personnel may be inside the cell for adjustment, control, and testing operations involving inert materials.

Active mode : Operators may be present during the installation and instrumentation phases involving test equipment ; the risk level at these times is rated at P2. During the operation of test machinery, the cell is strictly off-limits to all personnel, as the risk level here reaches P3.
The cell mode is selected on the control panel located in the control center through the use of a key. The mode selected is automatically indicated on the control panel as well as on the lighted panel above the cell door.

4.2.1 -Activation of a test cell

In order to keep the test procedure under control, a single key kept in the test engineer's possession at all times enables :

- The cell mode (active or inert) to be selected,
- The activation of the test machine.

In "active mode" the machine can only be switched on from the control panel located in the control center using the unique key kept at all times in the test engineer's possession. The machine is stopped in the same way, or the event where the cell door is opened.

In "inert mode" activating the test equipment requires authorization for the necessary electrical power from the test engineer. He must insert his key into a lock on the machine, then convey the order to start-up the machine by intercom to an operator in the control center, who then activates the equipment by pressing a button. The test equipment can be stopped either from the control center or by use of the emergency cut-off switch located near the machine ; opening the cell door automatically shuts down the test equipment.

When the machine is shut down, its electrical power supply is desactivated. This means that the entire sequence must be rerun for the next startup.

4.2.2 - A normal operating sequence

a) Transporting material for the test

The person in charge of the test collects the material in the storage cell and contacts the control room by intercom. All cells are alerted by intercom and by an audible signal, of the imminent material transport. All cell doors are closed during this operation.

b) Preparing the test

The material is removed from its packing and put in place on the test machine with the specific instrumentation.

c) The test

The person in charge of the test returns to the control center, places his key in the switch and begins the test sequence. At the end of the test sequence, when the test equipment has been switched off, the test engineer removes his key from the control panel, returns to the test cell, performs the necessary verifications, repacks the material and returns it to the storage cell under the same transport conditions as before.

4.3 - Analysis of personnel risk exposure

Tests of explosive charges in the facility, under the operating rules previously cited, must be analysed to determine if the level of residual risks to which personnel are exposed is acceptable. This analysis is based on the criteria defined earlier : Hazard (Zi), and the probability of an accidental explosion (Pj).

In order to conduct this analysis we should examine 4 types of situation :

- material storage phase,
- material transport phase,
- the test preparation phase,
- the test phase.

In each of these cases, the most significant hazard lies in the accidental explosion of the charge.

4.3.1 Material being held in the storage cell

A maximum of four charges of a unitary net weight inferior or equal to the TNT equivalent weight allowed by the cell's explosion resistance rating can be stored in the cell. Steps are taken to prevent more than one charge from detonating simultaneously.

The horizontal and vertical walls are capable of withstanding the effects of an accidental explosion, with the door between the cell and the corridor closed. The blow-out wall allows for an internal overpressure, and the shock wave would be directed towards the barricade.

Personnel in all other parts of the facility would be entirely protected.

Operations are limited to simple material handling, conducted by two employees. The maximum risk exposure could be described thus, in regulation terms :

- P.E.S. - a_0 - 2 persons / Hazard zone Z1 / Probability level P1. In other words, a major hazard, but with an extremely low probability.

- E.S. - a_1 - Other cells and the inert zone - 4 persons / Hazard zone Z3 / Probability level P1. Here, the hazard is slight and the probability of an accident extremely low.

No other person or installation is exposed to a significant risk ; the situation is acceptable.

4.3.2. - Material transport phase

A charge is transported from the storage cell to a test cell, and back, in its packing and under conditions that make it possible to avoid any false handling. Only one door can be open during this phase : either the door of the test cell or the door of the storage cell, and only when the charge is being moved in and out of each cell.

All personnel informed that material is being transported are either in a cell or in the inert zone. The vertical walls of the corridor would direct any eventual blast effects and projectiles upward. The roofs of the cells and the inert areas are calculated to withstand overpressures and to support any eventual projectile fallback.

The maximum risk exposure is therefore :

- P.E.S. - a_0 - 1 (or 2 person(s) / Hazard zone Z1 / Probability level P1
- E.S. - a_1 - cells and inert zone - 5 persons / Hazard zone Z3 / Probability level P1.

No other person or installation is exposed to a significant risk ; the situation is acceptable.

4.3.3. - Test preparation phase

Test preparation operations consist of placing the charge on the test machine and installing the necessary instrumentation ; the charge is subjected to no particular stimuli, but we nonetheless consider the probability of an accident higher in this phase.

In the event of an accidental explosion, the vertical walls and heavy door would contain the blast effects. The cell's blow-out wall would be destroyed. The blast wave and projected fragments would be directed along the extended lateral walls and fragment-shielding plates toward the barricade.