Engineering Design and Operational Analysis of a Civil Protection Shelter Integrated in Hospital Infrastructure

Proiectare inginerească și analiză operațională a unui adăpost de protecție civilă integrat în infrastructura spitalicească

Lucian Mihoc[1], Mircea Marinescu[1], Răzvan Zamfira[1], Andrei Dună[2]

[1] ISU Banat
Timisoara, 13 Înfrățirii Street, Timiș County, Romania
Email: andreiduna13@gmail.com

[2] Dosetimpex SRL
Timisoara, Buziașului Road no. 11, Timis County, Romania
Email: andreiduna13@gmail.com

DOI: 10.37789/rjce.2026.17.3.13

Abstract: *The protection of hospital infrastructure during extreme events represents a fundamental requirement for civil protection systems. The present study evaluates the engineering design of a civil protection shelter integrated in the Mioveni Hospital project. The analysis focuses on ventilation performance, NBC filtration efficiency, sanitary autonomy and pressure control mechanisms required to maintain safe environmental conditions. Engineering calculations are presented for airflow demand, pressure losses, filtration efficiency and system reliability under conventional warfare scenarios, biological and chemical contamination scenarios and nuclear events.*

Key words: civil protection shelter, hospital resilience, NBC filtration, ventilation systems, overpressure protection

1. Introduction

Hospitals represent critical infrastructure that must maintain operational continuity even during extreme emergency conditions. Civil protection shelters integrated in hospital buildings provide protected spaces for staff and patients when external conditions become unsafe due to military actions, chemical contamination or radioactive fallout. The design of such shelters requires complex engineering solutions involving ventilation systems, filtration units, pressure control devices and autonomous sanitary facilities. The Mioveni Hospital project includes a dedicated ALA civil protection shelter designed to accommodate 160 occupants. The present research analyses the engineering parameters required to maintain a safe internal environment in this shelter.

The article was received on 07.04.2026, accepted on 11.09.2026 and published on 22.09.2026

2. Shelter Ventilation System Design

The ventilation installation of the shelter ensures continuous air renewal while preventing infiltration of contaminated air. The system includes an air intake duct equipped with anti-blast protection, pre-filtration units, NBC filtration modules and a mechanical ventilation fan capable of operating in both electric and manual modes. The system distributes filtered air through a network of ducts and diffusers positioned within the shelter space. Overpressure valves maintain a slight internal pressure higher than the external pressure in order to avoid infiltration of contaminated air masses.

3. Engineering Calculations

Airflow demand for the shelter is determined using Equation (1).

$$Q = N \times q\_p \quad (1)$$

where:
Q – total airflow demand [m³/h]
N – number of occupants
q_p – airflow rate per person

For the analysed shelter: N = 160 persons, q_p = 4.7 m³/h per person.
Therefore:

$$Q = 160 \times 4.7 \approx 752 \text{ m}^3/\text{h} \quad (2)$$

Pressure losses in ventilation ducts can be estimated using the Darcy–Weisbach equation:

$$\Delta P = \lambda \, (L/D) \, (\rho \, v^2 / 2) \quad (3)$$

Internal overpressure inside the shelter is maintained using controlled exhaust valves. The overpressure condition can be expressed using Equation (4).

$$\Delta P\_shelter = P\_internal - P\_external \quad (4)$$

4. Technical Parameters

Table 1

Technical Parameters

Parameter	Value	Unit
Shelter capacity	160	persons
Total airflow	750	m^3/h
Airflow per person	4.7	$m^3/h/pers$
Internal overpressure	10	mmH2O
Maximum overpressure	15	mmH2O

5. Graphical Analysis

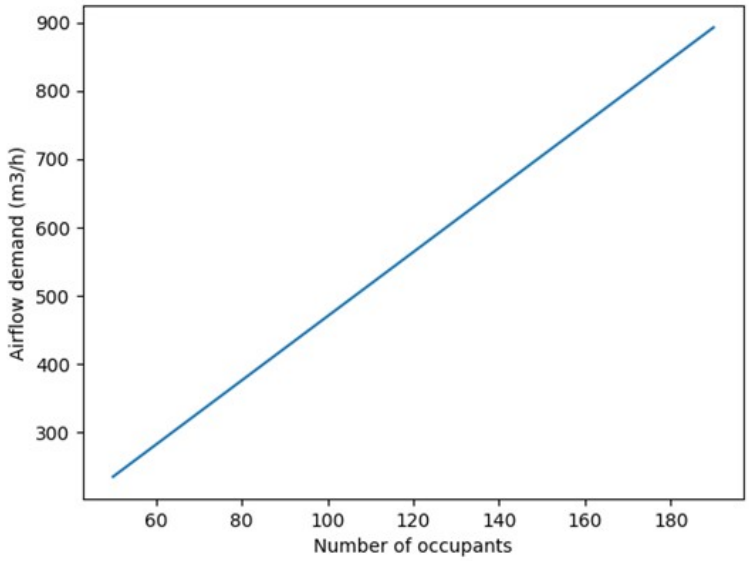

Fig. 1. Airflow demand depending on shelter occupancy

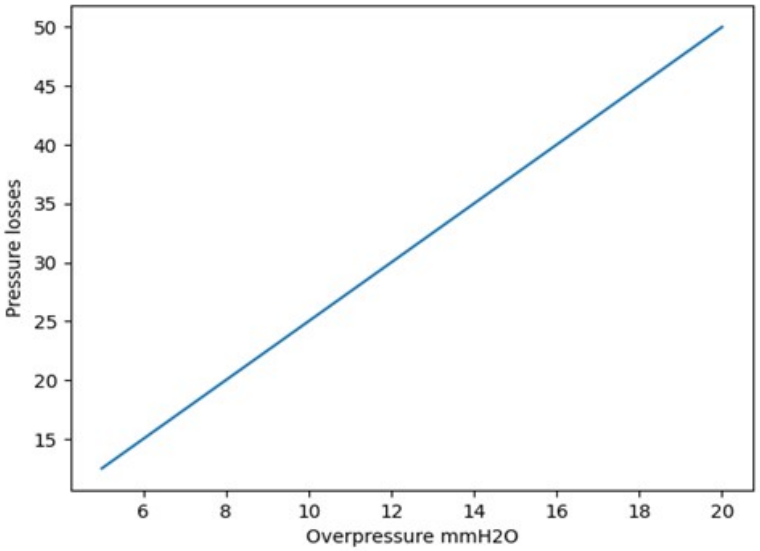

Fig. 2. Pressure losses as a function of internal overpressure

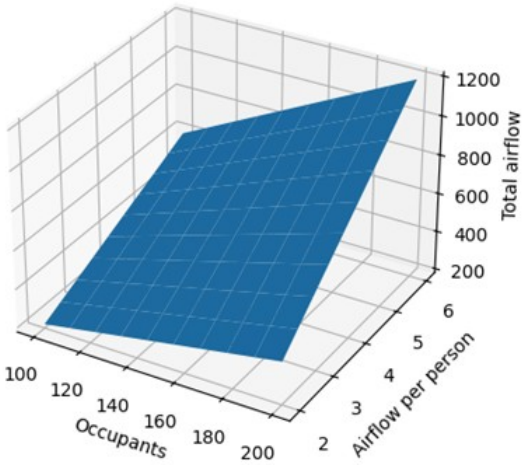

Fig. 3. Three-dimensional representation of airflow demand depending on occupancy and airflow rate per person

6. Project Drawings

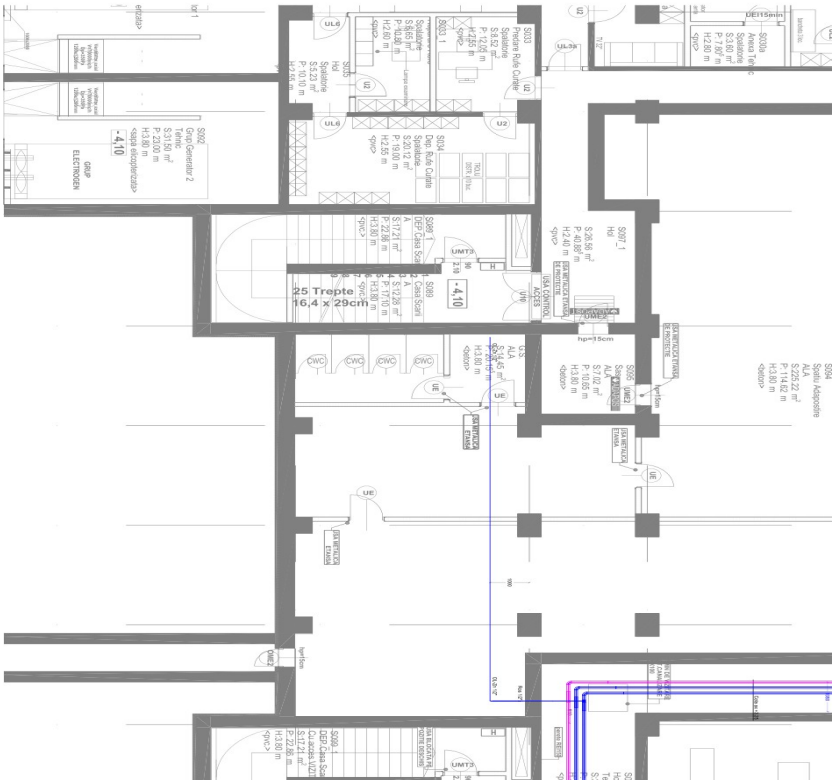

Fig. 4. Extract 1 from project drawing

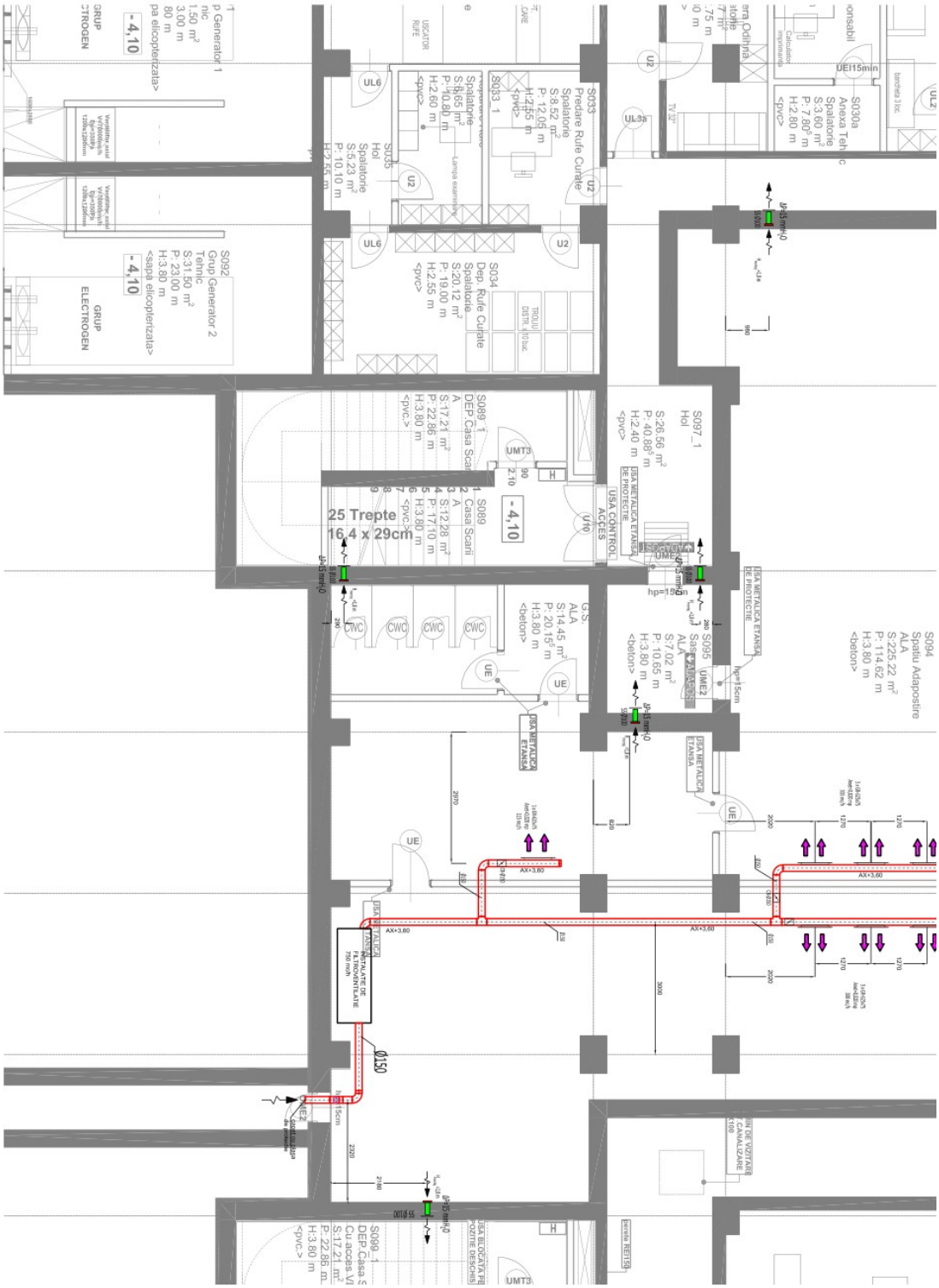

Fig. 5. Extract 2 from project drawing

7. Scenario Analysis

Two operational scenarios were analysed in order to evaluate shelter resilience. The first scenario considers conventional warfare combined with biological and chemical contamination risks. The second scenario analyses nuclear fallout conditions where filtration efficiency and pressure stability become critical parameters. In both cases the ventilation and filtration system ensures continuous protection of occupants by maintaining filtered airflow and internal overpressure.

8. Conclusions

Engineering analysis demonstrates that the shelter ventilation system combined with NBC filtration and controlled overpressure provides effective protection against contaminated air infiltration. The calculated airflow capacity satisfies the requirements for the design occupancy of 160 persons while maintaining acceptable pressure losses. The integration of autonomous sanitary systems further increases operational resilience of the shelter.

References

[1] European Commission – Guidelines for civil protection shelters.
[2] ISO 16890 Air filtration standards.
[3] Romanian civil protection regulations for protective shelters.
[4] Engineering Handbook for NBC filtration systems.
[5] Mioveni Hospital Development Project – Technical Documentation