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THE EFFECT OF AMBIENT TEMPERATURE ON THE DELAY TIME OF PERIMETER PROTECTION

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Abstract. Perimeter security defines the private space from the public space and also serves as the first barrier between the intruder and the protected interest. Delay time is one of the input parameters used in a quantitative approach to the design of a physical protection system. The objective of the physical protection system is to delay the intruder long enough for the law enforcement to arrive on the scene and apprehend the intruder. Perimeter protection is located in the exterior and is affected by various factors such as ambient temperature. In cold temperatures, the technical parameters deteriorate and the delay time for penetration into the protected object decreases. The paper points out that the delay time is longest at 0 °C and that the delay time decreases as the ambient temperature increases. A further perspective is mentioned on the adaptation of the tests and increasing the degree of subjectivity of the test results.

Keywords: Physical protection system, security barrier, perimeter protection, burglary, delay time.

1. Introduction

While it may seem that security is considered a relatively modern phenomenon, the reality is that people have been interested in protecting property, people, and other valuable assets since time immemorial. For millennia, mankind has used mechanical barriers of various kinds to protect entire nations, cities, towns, and villages, as well as individual dwellings [1]. This is evidenced by the fact that safety, or feeling secure ranks second in Maslow's pyramid of needs [2, 3]. While natural barriers or simple barriers have been used in the past, the means of increasing the level of security have evolved over time. Different types of security barriers have started to be used depending on the location of the application. The development of electronics has also led to the development of means for the protection of people and property, known as active security means, such as alarm systems – intrusion and hold-up alarm systems (I&HAS) and video surveillance systems (VSS) [4–6]. Nowadays, it can be said that almost all scientific disciplines deal with the topic of security [7]. Security is a fundamental term in security terminology and is a multifactorial and multilevel phenomenon. Authors create and modify their definition of security according to their subject of study. A multiplicity of definitions and perspectives on security can lead to several misinterpretations and misguidance in setting the required level of security [8]. It is therefore recommended that a quantitative approach is used to assess the security of an object. The quantitative approach allows the justification of the proposed protection measures to be demonstrated. And based on the measurable input and output variables, it can be determined whether the protection system is under- or over-estimated [9].

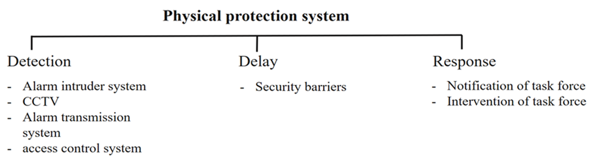

Figure 1. Physical protection system [14].

2. Technical background

When it comes to the protection of people and property, we are talking about a physical protection system (PPS), also referred to as physical protection. A PPS is a set of mutually combined system elements designed to achieve the desired level of protection [10, 11]. The objective of a PPS is to protect property or facilities from theft, sabotage, or other anthropogenic attacks through the integration of people, procedures, and equipment [12]. PPSs are rarely identical in different locations due to differences in objects, targets, and threats. In addition to protecting property and people, PPS can also be used to protect critical infrastructure elements [13]. The aforementioned integration and the individual functions of the PPS are shown in Figure 1.

Detection is the first function of the PPS. The intruder can be detected by a security guard, I&HAS, or VSS [15]. Delay is the second function of the PPS. Once the intruder has been successfully detected, it is necessary to delay the intruder for as long as it

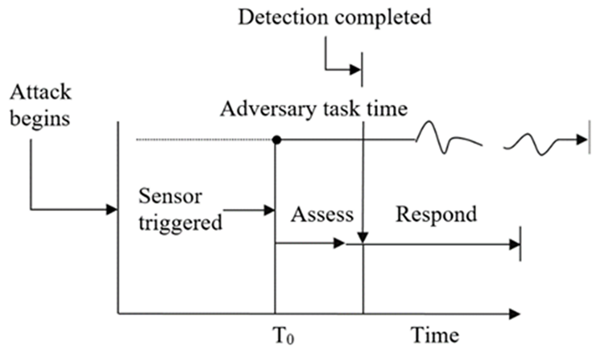

Figure 2. Adequancy of PPS [10].

takes the law enforcement to arrive at the scene of the crime. The intruder can be delayed by security barriers [10, 16]. The last function is response, which is a necessary function of the object protection system to prevent an intruder from successfully breaking into the protected object. The action of response, i.e. reacting to an intruder, can be carried out by a task force whose strength must be greater than that of the intruder [17, 18]. All the functions of the PPS must work without error since the failure of even one of the functions leads to the failure of the whole system [17, 18]. The adequacy of the PPS function is shown in Figure 2.

2.1. Delay time of security barriers

The delay time of security barriers indicates how long it takes an intruder to overcome the security barrier. In general, the delay time can be calculated using the Formula 1 [19–21]:

$$t_d = t_2 - t_1\,, \qquad (1)$$

where:

- t_d – delay time,
- t_1 – attack start time,
- t_2 – attack end time.

It should be noted that the above formula only determines the delay time of the security barrier. It gives the additional time it takes the attacker to overcome the barrier. It should be noted that the delay of the attacker through the security barriers is included in the total delay time only if the security barriers are placed after the detection point T_0. Any security barriers before detection point T_0 are only a deterrent.

The delay time of security barriers depends on the design of the security barrier, the material of which the security barrier is made, the size of the breakthrough hole, and the skill of the attacker [20, 22]. Delay times of security barriers are obtained from implemented tests, scientific publications, or approximations of data from literature or tests that are not primarily concerned with obtaining breakthrough resistance times [18]. Delay times of security barriers

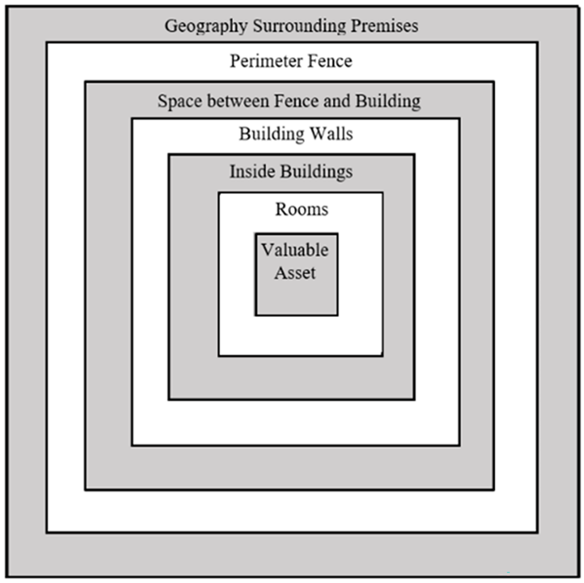

Figure 3. Defence-in-depth principle [18].

can also be found in some technical standards, such as EN 1627 or EN 1303. The above-mentioned technical standards describe six safety classes and the corresponding delay time that should be achieved with the specified set of tools. Although security barriers can be placed outdoors, technical standards specify a test room temperature in the range of 15–30 °C [23, 24]. The justification or importance of the delay time is already evident from the delay function of the PPS. It is necessary to fulfill the condition that the task force arrives to the place of the attack faster than the intruder can break through the barriers and escape. In simple terms, it can be said that several security barriers are needed to meet the basic requirements. If the barriers are arranged in a row, it is called a defence-in-depth system [17, 18, 21]. The defence-in-depth system is a classic defence strategy based on ancient military principles (see in Figure 3), which is a series of physical barriers arranged in layers. Nowadays, the defence-in-depth system is used to slow down the intruder rather than to stop him. Based on the research, it can be concluded that defence-in-depth is reliable and supported theoretically by both Routine Activity and Rational Choice theories from the opportunity paradigm of crime prevention theory. It should be noted that the total delay time of the whole system should be measured from the point of detection. Measures should be designed to preclude the possibility of an insider using the barriers to delay response to malicious activity such as sabotage [8, 18].

2.2. Perimeter protection

Perimeter security barriers form the first barrier between the intruder and the protected object. Their primary function is to physically seperate public space from private space. The role of perimeter protection is also to deter intruders from attacking. An impor-

Level of protection	Objective	Possible solution (informative)
1	Deterring, delay	Mechanical solution
2	Dettering, detect, delay	Mechanical solution + single intrusion detection
3	Dettering, detect, delay, retract	Mechanical solution + single intrusion detection, including alarm and verification
4	Dettering, detect, delay, retract	Multiple mechanical solutions + alarm verifications

Table 1. Objectives of perimeter protection [25].

tant parameter for perimeter barriers in residential areas is also their architectural aspect. In general, perimeter security can be defined as a system that protects people and property within a building and its grounds by preventing the entry of unauthorised persons around the perimeter [19, 20].

Perimeter security barriers can be divided into groups according to a number of criteria, including the material used, the structural design, architectural aspects, and many others.

The six basic groups of perimeter security barriers are:

- classic wire fencing,
- security fencing,
- high security fencing,
- top barriers,
- anti-scaling barriers,
- entrances, driveways, and other units [26].

Perimeter protection can be divided into groups according to their security level requirements depending on the type of object:

- barriers with low passive security,
- barriers with increased passive security,
- barriers with guaranteed passive security [27].

A similar division is also be found in the technical standard for perimeter security barriers TNI CEN TR 16705. However, the standard defines four levels of protection. In additon, each level is supplemented with a possible solution, which is only informative and can be adjusted in practice [25]. The individual objectives can be found in Table 1. The division into four security levels corresponds to the requirements of the National Security Authority of Slovakia, which also defines four types of protected premises. Each level is associated with an objective that the level should achieve [28]. The standard also defines three groups of tools, namely hand tools, electric tools, and petrol tools. However, it does not specify specific types of tools in terms of their size and power [25].

(a). (b).

Figure 4. (A) Welded fence N2D D5/4/5 mm; (B) 24” bolt cutters.

As Table 1 shows, the aim of any level of protection is to delay the intruder. However, the standard does not further specify the exact delay time, or how it should be determined using an experimental test. It was therefore agreed at the PACITA project workshop that for the purpose of standardisation, the EN 1630 technical standard would be followed for testing and determining the delay time of perimeter security barriers. The test is to make a breakthrough hole in the barrier as quickly as possible, through which a 400×250 mm template can be pushed [20]. The disadvantage of these tests is the degree of subjectivity as the method of overcoming, the force to be used to overcome or the cutting of each part of the barrier separately are not defined in the standard. However, in addition to the force, the overall handling of the tool must also be taken into account, which also increases the delay time. It can be said that the overall results of the test depend primarily on the test operator.

3. Materials and methods

The aim of the paper is to find out if the ambient temperature affects the delay time of the perimeter security barrier. This type of test was chosen because perimeter security barriers are exposed to different thermal influences from the environment, either low minus temperatures or high plus temperatures and the technical standard does not take this

Figure 5. Test procedure.

factor into account. A perimeter security barrier – welded fence N2D D5/4/5 mm was used for the tests. The wire diameter of the fence is 4 mm. The vertical wires are spaced 5 cm apart and the horizontal wires 20 cm apart. The panel surface is Zn+PVC (zinc+polyvinyl chloride) [29]. To overcome it, i.e. to create a 400×250 mm breakthrough hole, 24” bolt cutters were used. Figure 4 shows the welded panel and the bolt cutters. A Vötsch VCL 7010 climate chamber [30] was used to simulate the effect of ambient temperature. The tests are not carried out on complete fence fields, but under laboratory conditions. Therefore, only 600×600 mm samples are tested, which are fixed in the test frame.

The objective of the first test was to determine the delay time at the laboratory ambient temperature of 21.7 °C. This time was used as a benchmark for the comparison with the delay time at other temperatures. A total of 14 tests were carried out. The temperature range tested was -70 °C to +70 °C. The temperature of -70 °C was chosen because it is the lowest temperature that can be set on the Heraeus Vötsch 7010 climate chamber, although it is not equal to the lowest temperature measured on Earth, which was -82.9 °C [31]. The first test was carried out at -70 °C and for each subsequent test, the temperature was increased by 10 °C until a temperature of +70 °C was reached. The 20 °C test was omitted as it was similar to the benchmark test. The samples were left in the climate chamber for 15 minutes to reach a set temperature. They were then quickly removed, attached to the test frame, and the test began. 24” bolt cutters were used to break through the barrier. The breakthrough hole was made by a single operator to eliminate any differences in influencing factors such as force, technique, etc. The complete test procedure is shown in the Figure 5.

4. Results and discussion

Figure 6 below shows the results of the tests. The benchmark test time at a test temperature of 21.7 °C was 61 s. The delay time for the first test at -70 °C was 30 s. For the next tests, the delay time increased as

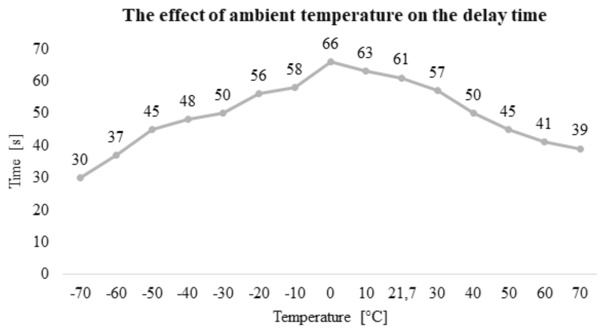

Figure 6. Test results.

the temperature increased up to 0 °C when the delay time was the longest at 66 s. Subsequently, the delay time began to decrease as the temperature increased. In the final test, at a temperature of 70 °C, the delay time was measured to be 39 s.

These test results indicate that the environment in which the perimeter security barrier is to be installed should be considered when designing the PPS. Alternatively, several variants of the PPS should be designed for different seasons. It should be noted that only 600×600 mm samples were tested, not complete fence arrays. The 24” bolt cutters are another variable to consider, as they are hand tools and require strength and skill to use. The actual attack must also take into account the tools used, as the results of the PACITA and VEGA 1/098/11 projects have already shown that electric and petrol tools are much quicker to overcome individual fences than hand tools.

After completing the tests to determine the effect of ambient temperature on the delay time, the wire specimen was subjected to ultimate tensile strength test. A maximum force of 5 430.464 N was required to break the specimen wire. The speciemen has an elongation of 28.77 mm.

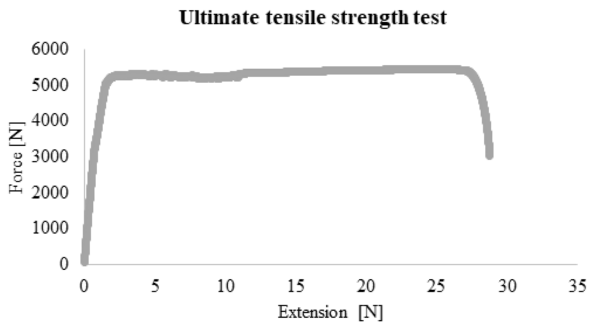

Figure 7. Ultimate tensile strength test result.

Sigma (σ) will be calculated according to the following formula:

$$\sigma = \frac{5430.464}{(\pi \times 2 \times 2)} = 432.132\,\mathrm{MPa}\,. \tag{2}$$

Figure 7 shows the results of the ultimate tensile strength test.

5. Conclusions and future work

The aim of the article was to determine whether the ambient temperature has an effect on the delay time. The article was solved through experimental testing on a perimeter security barrier – welded fence. The tests were chosen to cover a temperature range of -70 °C to +70 °C. The 20 °C temperature was omitted as the benchmark test was performed at 21.7 °C. The result of the tests was that the longest delay time was at 0 °C, with the delay times decreasing both as the temperature increased and as the temperature decreased. The shortest delay time of 30 s was achieved at the lowest test temperature of -70 °C. Based on the results obtained in this paper, it should be said that the ambient temperature factor should also be taken into account when designing the PPS. In the future, the perimeter barrier should also be classified on the basis of environmental classes, as is the case with intruder alarm and CCTV systems. This is because they are used in different geographical locations with different temperatures. It would also be worthwhile to test the effect of humidity and therefore corrosion on the delay time of the perimeter barrier. It is also necessary to change the methodology of the tests, as the subjectivity of the test results needs to be reduced or completely eliminated. One such possibility is the use of robotic arms, which would provide a constant force used to cut individual wires and a constant time to manipulate the tools.

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