Things to consider when working with C-class civil defense shelters

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Laurea University of Applied Sciences **Abstract**

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The goal of this thesis was to provide the working life partner, RTF Services, with theoretical knowledge and practical tips to use when working with the C-class civil defense shelter. Working includes procedures like yearly maintenance and inspections to complete renovations and updating of a C-class civil defense shelter. The C-class civil defense shelters were built 1959-1970, and the condition of these shelters is varying. Providing theoretical knowledge, and tips on procedures to pursue with the shelters, RTF Services will be able to provide better customer service and work more efficiently.

The theoretical framework of this work consists of history of civil defense shelters in Finland, today's requirements on civil defense shelters, and technical requirements of the C-class civil defense shelter. The framework is mainly based on legislation. The thesis is a research-based project, as the aim is to improve procedures by using theory and knowledge from experts in the field. To gather data, a semi-structured form of interview was used. The gathered data was transcribed, and the content analyzed and put into key themes, presented in the results.

In the results, the concepts of determining the starting point when working with the C-class shelter, the options of updating, modernizing, and restoring, and finally practical aspects of working with the shelters are presented. It is concluded that there is an ethical aspect to consider when working with civil defense shelters, and that there is a need of national guidelines on how to choose course of actions for a shelter that does not meet legal requirements.

Keywords: Civil defense shelter, C-class, Sand filter, Technical requirements

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1 Introduction

Many different types of civil defense shelters have been built in Finland since the 1940’s. The shelters differ in size, some are built by concrete while others are created in solid rock. This work focuses mainly on the commonly occurring civil defense shelter built between 1959 and 1970, the C-class shelter. There are around 10000 C-class civil defense shelters in Finland, and they provide around 880 000 shelter spots. (Rajajärvi 2016, 154, 297)

The responsibility of building and maintaining civil defense shelters lies with the owner and holder of the property. Rescue authorities supervise civil defense and preparedness in society. (Rescue Act 2011.) Milla Tuominen (2017) studied the level of preparedness to take civil defense shelters into use in case of an armed conflict for example. The conclusion was that the way rescue departments control civil defense shelters is varying between rescue department districts in Finland, and this might be an indicator that the level of preparedness to take them into use is not entirely clear in all districts. The varying ways of controlling civil defense shelters are thought to be due to legislation, not putting clear responsibility on any party nor giving guidance on how to maintain and control civil defense shelters.

This development project is made in cooperation with RTF Services, a private company with about 16 employees located in Mustasaari, Finland conducting inspections and maintenance of civil defense shelters in Finland as part of their services. RTF Services specialize in fire safety, industrial maintenance jobs, and lift- and transport services. They aim to continuously improve customer service. Being able to work efficiently with the civil defense shelters, while providing the customer with the information they need in order to make decisions, will ultimately be beneficial for both customer and service provider. I have been employed by the company, and therefore have insight in their working processes. Through the company, I had the opportunity to participate and gain basic knowledge of civil defense shelters through the Civil defense inspector’s course in 2016, provided by the Emergency Services Academy Finland (Pelastusopisto 2022). The role of the company in this project was to provide the idea of what kind of knowledge and what kind of practical problems they encounter as they inspect and maintain C-class civil defense shelters. Knowing the contact person for the project made communication with the working life partner easy. In addition to the support I had from my working life partner, I received huge help from two other civil defense shelter experts during the process. I thank all the people who provided guidance and valuable insight for this thesis.

The project started in the end of 2021, and the aim was to finish and graduate by December 2022. For this project, professionals and experts in civil defense shelters are interviewed, and the goal is to gather legal requirements and to clear up what options there are and what to consider when working to maintain legal requirements of C-class civil defense shelters. This project will not only benefit my working life partner, but also property managers, architects, individuals responsible for the maintenance of smaller shelters, and construction workers. Working to maintain legal requirements include yearly maintenance, 10-year inspections and pressure tests, restorations, modernizations, and updates. In this project, the legal and technical requirements are gathered in the theory, making it easier for the working life partner to find information without having to look through legislation from different years. Data acquired through interviews is presented in the results, with reflections to theory of the subject.

2 Civil defense shelters then and now

In 1949, Finland signed the agreement of the fourth Geneva convention relative to the protection of civilian persons in time of war 12 of August 1949. In chapter two article 88 of the agreement, the civilian protection against air raids by building shelters is decided. The Geneva convention agreement has been signed by more than 180 states. (Shaw 2021.) However, the history of building civil defense shelters in Finland goes further back than 1949, and the building of civil defense shelters is continuing in Finland. (Spek 2017b, 8.)

With a long history of building civil defense shelters in Finland, the challenge of maintaining these shelters has been highlighted recently after statements of older shelters being in bad condition and not accountable for proper usage due to lack of maintenance (Ristimäki 2020). In 2005, an inspection of the condition of civil defense shelters concluded that shelters built before 1958 were in general not suitable for civil defense purposes. Shelters built before 1963 were in bad condition. Shelter built 1963-1971 were in okay condition, and shelters built after 1971 were in good condition. The reason for why the condition of older shelters has decreased is thought to be lack of spare parts to use for maintenance, and also lack of knowledge in how to maintain them. (Rajajärvi 2016, 395.) Knowing the history and specifications of older civil defense shelters as well as requirements of today’s shelters, will be of help when conducting maintenance, as the specifications and requirements have changed several times during years of systematic construction. It can be concluded that the C-class shelter and today’s S1-shelters require similar maintenance, because they do not differ from each other radically in any other aspect than the filter for the ventilation machine. The sand filter needs its own attention, and this is highlighted in this chapter, in order to provide guidance on C-class defense shelter maintenance. (Temet 1979; Spek 2017b.)

2.1 History of civil defense shelters in Finland

Finland started building versions of what we today call civil defense shelters around 1930 following the First World War, because of an increase in use of gas weapons. The primary purpose of defense shelters, called gas shelters at that time, was to protect civilians against gas attacks. (Rajajärvi 2016, 22.) After designing the first gas shelters, it was realized that air raids and intrusion by armed forces were posing a threat. The need for a more divers defense shelter protecting against blasts and shrapnel was needed. (Rajajärvi 2016, 132.)

The first systematically built civil defense shelters in Finland were built in 1938, and in 1939 the first act on civil protection came into force (Väestönsuojelulaki 374/1939). This law required larger buildings, both old and new, to be supplemented with civil defense shelters. During this time, Finnish cities were divided into different "protected targets areas", and the building of defense shelters was not mandatory in all parts of the country. In 1945, when the war had ended, the interest in building civil defense shelters went down. In 1951, the building of civil defense shelters in Finland was put completely on hold, and it was not continued until 1955. (Rajajärvi 2016, 62-63; Spek 2017b, 8.)

Civil defense shelters in Finland have continued to develop with the changing nature of threat. Beginning with airtight gas shelters, developing into shelters that could protect against bombings, shrapnel and collapsed buildings, and then to protects against chemical, nuclear and radiant threats (CRNE), the civil defense shelters have evolved over a course of 90 years in Finland. Today, civil defense is not only about protecting civilians against a hostile nation, but also protecting the people against accidents like the Chernobyl nuclear plant hazard in 1986. (Rajajärvi 2016, 133.) The expenses of building civil defense shelters have been covered by the building owner throughout history, and it is also their responsibility to maintain the shelters, so that they can be taken into use within 72h if needed. (Rescue act 2011.)

Civil defense shelters are built and equipped with units used only in the civil defense shelters. These parts include the ventilation machine including special filter and sand filter, overpressure meter, pressure relief valve, a closing plate for the general ventilation, and doors for main entrance and emergency exit etc. To ensure quality of civil defense shelter units, the Ministry of the Interior required unit manufacturers to provide drawings, calculations and other documents related to the unit for an examination. The manufacturer could then get a unit type approval, marked on the units. This would then help the building control authorities to examine and approve the new civil defense shelters. (Rajajärvi 2016, 260-261.)

Since 1939, there has been several different civil defense shelter unit manufacturers on the market in Finland. In 2015, there were 11 Finnish manufacturers who specialized in civil defense shelter units. Only one of these has been active between 1959-1971, and that is Temet Finland Oy, established in 1953 manufacturing a wide range of civil defense shelter parts, including the ventilation machines. (Rajajärvi 2016, 270-271; Temet Finland Oy 2022.)

2.2 Civil defense shelters today

The building of today's civil defense shelters is regulated by the Rescue Act 379/2011, and more specified in Valtioneuvoston asetus väestönsuojista 408/2011 (The decree on civil defence shelters by the Finnish Government). New civil defense shelters today are built in buildings over 1200m^2 where people reside, or work is permanently occupied. In industrial halls and storage facilities, the obligation to build a civil defense shelter is met when the building is 1500m^2. Production facilities of farmers are excluded from this obligation. The obligation to build and maintain civil defense shelters lies with the owner of the building. After construction, civil defense shelters should be maintained to ensure the possibility to take them into use within 72 hours. (Rescue act 379/2011.) The civil defense shelter should be big enough to provide room for all building residents or permanent workers and others occupying it, in general 2% of the total area of the building, or 0,75m^2 per person occupying the building. The minimum size of a new civil defense shelter is 20m^2. (Valtioneuvoston asetus väestönsuojista 2011.) The atmosphere inside the shelter should be sufficient for people to stay there for several days. The new shelters should protect against collapsing buildings, weapons, toxic substances, and ionizing radiation. (Rescue Act 2011.) During normal times, civil defense shelters can be used for storage, social areas or in other ways be made useful, considering the 72-hour limit to get it ready to use in case of need. (SPEK 2021). Most civil defense shelters (about 85%) are located in residential and commercial facilities (Sisäministeriö 2021). The requirements on equipment and parts of civil defense shelters built 2011 and later is regulated in Valtioneuvoston asetus väestönsuojan laitteista ja varusteista 409/2011 (The decree on Civil defense shelter equipment and parts by the Finnish Government). According to the decree, manufacturers need to guarantee a 30-year serviceability of the equipment, if maintained according to manufacturers' instructions. For concrete structures, a minimum of 50 years of serviceability is required by manufacturers. (Valtioneuvoston asetus väestönsuojan laitteista ja varusteista 2011.)

Today, there are about 45000 civil defense shelters in Finland. These provide shelter for about 3.6 million people. (Sisäministeriö 2021.) However, a study conducted in 2017 concludes that preparedness to take the shelters into use varies between rescue department districts in Finland. A reason to this is thought to be the legislation, which in this case does not give clear responsibility nor guidance on how to maintain preparedness and civil defense. (Tuominen 2017). In 2017, rakennusneuvos Pekka Rajajärvi stated that shelters providing shelter sports for approximately one million people would need to update the sand filters to match today's civil defense shelter standards. (Vanhala 2017). In 2020, Väestönsuojien rakentamisyhdistys estimated that only half of the civil defense shelters in Finland were maintained and suitable for people to reside in if necessary. (Ristimäki 2020.) Karim Peltonen, Head of preparedness at SPEK, states in an interview that a probable reason to why property owners do not maintain civil defense shelters accordingly, is due to lack of knowledge and because of financial reasons. (Marjakangas 2017.) The Rescue Act 379/2011 obliges the owner of a property to maintain the shelter and equipment. Every 10th year, an inspection of the shelter should be conducted, including a pressure test to ensure the civil defense shelter is air tights when shut. The rescue act also obliges the owner of a building to renovate an older civil defense shelter to meet the standards laid down in the same act, if restoration work comparable to construction or change of intended use of the building occurs. Currently, there is no specific certification required by the person conducting the inspection or pressure test. (Pohjanmaan pelastuslaitos 2022.) The Emergency Services Academy Finland arrange a three-day long course aimed at civil defense shelter service providers (Pelastusopisto 2022).

According to a survey from 2019, citizens of Finland have a positive attitude towards building and maintaining civil defense shelters. 61% of Finns are not ready to accept the thought of ending the building of civil defense shelters, while 10% think we should end it already. (Laurikainen & Haranne, 2020.) The discussion of whether Finland should continue building civil defense shelters or not, has been going on for years (Rajajärvi 2020). The main factors considered are threats towards the nation, and the costs related to building and maintaining the civil defense shelters. The threats are constantly changing, and therefore it can be hard to predict the future need for civil defense shelters. The expenses related to building and maintaining civil defense shelters has been more relevant during recent discussions at governmental level, and the introduction of the Rescue Act 379/2011 decreased the expenses related to civil air raid shelters by approximately 21 million euros annually. (Rajajärvi 2016, 76-78.)

What we have today, is approximately 45000 civil defense shelters in Finland, out of which a large number might not meet the required standard for use. The changing level of threat to the nation does not easily allow the government to completely abandon the construction and maintenance of civil defense shelters in Finland. As a result of considering both threat level, and the financial aspect of building civil defense shelters, a decrease in construction occurred in 2011. The Rescue Act still obliges property owners to construct and maintain civil defense shelter today. Money has been invested in building the civil defense shelters already existing, and this is a good reason to maintain them accordingly. Shelters need to either be restored to meet the standards according to which they were built or updated to meet current standards. In cases when the building where a defense shelter is located gets renovated and to some extent reconstructed, a procedure requiring a building permit according to the land use and building act (132/1999), the civil defense shelter needs to get updated to meet the standards of today's civil defense shelters. The decision is made by the building control authority (Spek 2017a, 99). However, if there is no upcoming bigger renovation which would require update of civil defense shelter planned for the building, the owner still needs to make sure that the shelter is maintained and at least meets requirements from when it was built. For updating a C-class civil defense shelter, guidelines have been developed to help the work, for example Tero Huttunen's (2018) Ventilation of Civil Defense Shelters - Guide for Construction and Renovation. The purpose of this development work is to provide property owners, property maintenance staff and people inspecting, maintaining, and renovating civil defense shelters with options and theoretical knowledge to consider when choosing procedures to maintain legal standard of C-class civil defense shelters.

2.3 The C-class civil defense shelter

The C-class civil defense shelters, which this development work focuses on, were built in Finland between the years of 1959-1970. The main legislative background for C-class shelters is found in Sisäasiainministeriön päätös B- ja C-luokan väestönsuojista (The decision on B- and C-class civil defense shelters by the Ministry of the Interior), N:o 318 from 1959, and Sisäministeriön päätös B- ja C-luokan väestönsuojista, N:o 291 from 1963. It should be noted that some of the 1963 specifications were modified in the Decision of the Ministry of the Interior from 1965, and again in 1969. The Ministry of the Interior published a final version of the Sisäasiainministeriön päätös B- ja C-luokan väestönsuojista, and it was published in Väestönsuojelun tiedotuksia in 1969. This publication concludes the Decision from 1963 with all the updates done in 1965 and 1969. The specifications on C-class shelters are presented in Appendix 1 (Rajajärvi 2016,166-167).

According to decision no. 318 from the Ministry of the Interior given in 1959, all new buildings of at least 3000m² or more made of stone or similar material need to have a civil defense shelter. It is the building owner's obligation to fund and build the defense shelter. If a building of similar specifications as above went through a renovation including the base floor, the owner could be obligated to build a civil defense shelter during the renovation, if added costs and workload for this were within reasonable frames. (Sisäasiainministeriö 1959, 2§; Rajajärvi 2016, 134.) It can be noted that civil defense shelters were not built in all municipalities during this time. (Rajajärvi 2016, 248.) A civil defense shelter was to be built below the ground surface. Only under special circumstances could it be built with part of the room reaching over ground surface. In these cases, the requirement on load tolerance, generally 50kN/m² was multiplied by 1.5 or 2, depending on how far above ground the defense shelter is. Construction steel to reinforce the concrete was to be 8-15mm in diameter (St37 and V40) 1959. (Sisäasiainministeriö 1963f, 14§, 17§; Rajajärvi 2016, 144.)

According to the 1959 decision, the actual size of the shelter room was to be 2,5% out of the total area of rooms in the building. It was counted that people seeking shelter should have 0,58m² space in the defense shelter room. In 1963 the requirements changed, and the size of the defense shelter was then counted as 2% of the net floor area, and the calculated space for every person in the shelter was 0,60m². (Asetus väestönsuojeluasetuksen muuttamisesta 261/1963, 10§) A C-class shelter is made for a maximum of 150 people. The shelter can be divided into several shelter rooms, which size can range between 6m² up to 36m². The minimum height of a C-class shelter room is 2,2m. One shelter room can accommodate up to 50 people. (Sisäasiainministeriö 1959, 10§,14§; Rajajärvi 2016, 136, 140).

In the 1959 requirements, there was no mention of radiation shielding for civil defense shelters. For shelters built after 1963, the law required a C-class shelter to have 600mm reinforced concrete for radiation protection. This requirement is met by adding surrounding permanent building structures and soil to the calculation. 200mm reinforced concrete is correspondent to 50mm steel, or 200mm natural stone, or 300mm bricks, or 450mm soil. The height of the main entrance doorstep needed to be at least 50mm according to the 1959 requirements. This was changed to 70mm in 1963. The doorstep must not be removed. (Sisäasiainministeriö 1963f, 26§ & Rajajärvi 2016, 148.) Instructions on building arrangements for radiation shielding can be found in BI 085.015, Strålskydd i skyddsrum av klass C (Radiation shielding of the C-class shelter). (Finlands Arkitektförbund, 1966.)

The C-class shelters have a personnel lock through which everybody enters the room. This small space is separated from the actual shelter room by a door. The purpose of the personnel lock is to prevent toxic gas from the outside to reach the actual shelter room where people stay. In 1959, this door was a fire door made out of wood, but in 1963 the regulation changed and from then on it was always a gastight SO-K door. In decision no. 990/770/63, the Ministry of the Interior specifies requirements of the SO-K door. The minimum size of the personnel lock is 5m², and it measures at least 2m in length and width. (Sisäasiainministeriö 1959, 8§; Sisäasiainministeriö 1963f, 30§; Rajajärvi 2016, 138.)

The exit routes of a civil defense shelter are the main entrance and the emergency exit route. A shelter needs to have two exit routes if the number of shelter spots is 100 or less. If the shelter fits more than 100 persons, the shelter needs three exit routes. At least one of the exit routes should reach the outer wall. One of the exits needs to endure a building collapse. (Sisäasiainministeriö 1959, 29§, 30§; Sisäasiainministeriö 1963f, 32§; Rajajärvi 2016, 150.)

There need to be lavatories in the civil defense shelters as well, 1/25 people according to the 1959 law. The size of the lavatory should be 0,7x0,8m. In 1963, the requirements were updated, and the need of lavatories was then 1/30 persons. It was also specified in 1963 that at least half of the lavatories need to be dry closets. In early 1960, lavatories were sometimes built by concrete, but are otherwise often tents easy to assemble if needed. The intended location of the lavatory needs to be marked on the building permit drawings. (Sisäasiainministeriö 1959, 11§ & Sisäasiainministeriö 1963f, 12§ & Rajajärvi 2016, 142-143, 166.)

Water pipes should be drawn into the civil defense shelter, and the water point including a floor drain should be placed in the personnel lock, or in the service space if the shelter has one. If water pipes are not drawn into the civil defense shelter, it needs to have water buckets enough to store 5l water/person. If the shelter is equipped with water distribution, it should also have a sewer duct. The sewer duct can be replaced with a soak pit, which also needs to be made in cases where there are only water buckets in the shelter. The sewer duct needs to be equipped with a shut off valve. The sewer duct needs to have check valves, which can be stored unassembled when shelter not in active use. In 1959, the water pipe shut off valves were placed outside the defense shelter but were moved inside the shelter with the new decision in 1963. This enables water to be shut off without having to go outside the civil defense shelter. The amount of water that needed to be stored was increased to 20l/shelter spot, regardless of the water pipes that were normally installed. (Sisäasiainministeriö 1959, 48§; Sisäasiainministeriö 1963f, 55§, 56§.)

In 1959, Finland started equipping all new civil defense shelters with ventilation machines. It was concluded that many people in a small space will quickly make the air inside humid, hot and the carbon dioxide levels will rise while oxygen levels will drop. This will stress the people inside the shelter, and eventually suffocate people. Different options to manage this problem were considered, and the conclusion was that installing a ventilation machine that provides the shelter with fresh, filtered air was the best option. (Rajajärvi 2016, 122.)

The ventilation of the civil defense shelter needs to be separate from the general ventilation of the house. The goal is to keep the inside air of the shelter fresh, and to be able to maintain overpressure. To measure this, a manometer was to be placed inside every shelter room. The air is taken from the outside, through a sand filter and into the shelter rooms. The air was to be distributed through ventilation ducts to all shelter rooms, except for the personnel lock and the lavatories. The used air inside the shelter should exit through ventilation valves to the personnel lock or service space. These valves should be placed in walls of lavatories and the personnel lock, at a minimum height of 1800mm above floor level. In 1963, this was changed to a minimum height 1600mm above floor. From the personnel lock or service space, the air exits via pressure relief valves placed in the wall. The pressure relief valves in the wall can be fixed to make the shelter airtight. (Sisäasiainministeriö 1959, 36§, 43§; Sisäasiainministeriö 1963f, 38§, 50§.) The ventilation machine could have extra filters, and in that case the sand filter worked as a primary filter. In 1959 it was specified that the ventilation machine should distribute about 45l air/minute for every square meter of the shelter rooms and nursing room. In 1963, the air distribution capacity was specified into $4m^3/h$ per shelter spot. During air filtration through extra filter, the capacity needed to be $1,6m^3/h$ per shelter spot. There are three different sizes of ventilation machines. A bigger model could be replaced by two or more smaller ones. When the pressure relief valves are adjusted right, and all other doors and shut-off valves are closed, the ventilation machine should be able to produce a minimum of 3mm gauge pressure (mm on water column) when the air is filtered. In 1963, the pressure was specified to 3-6mm gauge pressure when filtered. In by-pass mode, it could go higher. The ventilation valves can be fixed to achieve a completely air-tight mode. In general, it can be concluded that all metal parts should be protected and maintained regularly to prevent rusting. (Sisäasiainministeriö 1959, 37§, 39§; Sisäasiainministeriö 1963f, 37§, 39§; Rajajärvi 2016, 152, 154, 158; Spek 2017b, 14.)

Specification on general ventilation, ventilation machines and ventilation ducts are introduced in the RT 085.18, Väestönsuojan Saniteettiteknilliset laitteet (Civil defense shelter’s sanitation technical parts) (Suomen Arkkitehtiliitto, Standardisoimislaitos, 1956), and the specification on ventilation valves and closing plates for ventilation channels is introduced in the RT 085.185, Väestönsuojan ilmanvaihtoventtiilit, -venttiilin kehykset ja laippaukset (Civil defense shelter’s ventilation valves, -valve frames and closing plates) (Suomen Arkkitehtiliitto, Standardisoimislaitos, 1956).

The ventilation machines are specified in the Decision of the Ministry of the Interior from 1963 in paragraph 39.

Ventilation machine	**I**	**II**	**III**
Maximum shelter size	30	60	90
Filtered air	80m3/h	160m3/h	240m3/h
Bypass mode	200m3/h	400m3/h	600m3/h
Ventilation valves	1	2	3
Pressure relief valves	1	2	3
Shelter spots	50	100	150

Table 1: Ventilation machine related specifications (Sisäasiainministeriö 1963f, 39§; Rajajärvi 2016, 154)

The belonging parts of the 1963-1970 civil defense shelter ventilation is described in the Decision of the Ministry of the Interior from 1963 in paragraph 38. In the following paragraphs 39-52, more details of each shelter ventilation part are described. Mikko Eklin (1967) published the book Väestönsuojat: B- ja C-luokan väestönsuojista annetut määräykset selityksineen (Civil defense shelters: regulations and explanations regarding B- and C-class civil defense shelters), where he introduces more specific instructions for the 1963 and 1965 Decisions of the Ministry of the Interior. Eklin’s work is used as a primary source for the table presented in Appendix 2.

The sand filter is characteristic for the C-class civil defense shelter. There are about 10000 shelters equipped with sand filters, and they provide shelter spots for about 880000 people. (Rajajärvi 2016, 154, 297.) There are three functions of the sand filter. It mitigates shock waves caused by explosions, it works as an isolator against heat, and it cleans the air from toxic particles. In addition to this, the sand filter is cheap and withstands moisture better than, for example, carbon filters. If the sand filter was used as a primary filter, it might extend the life span of a secondary filter. The sand filters were often placed underground and outside the building’s outer wall next to the emergency exit passage, to prevent smoke from getting into the shelter if the building is on fire. However, wet and frozen sand, which is a risk when placing the filter outside, does not work efficiently. Therefore, the sand filter needs to be isolated from water. (Sisäasiainministeriö 1963f, 38§, 41§; Rajajärvi 2016, 241-242.)

The roof, floor and walls are to be made of 15cm reinforced concrete. To enable service and changing or filling sand, a 60x60cm opening can be made in the upper wall or ceiling of the filter. If the opening is in the wall next to the emergency exit passage, no separate hatch needs to close the gap. If the filter is inside the building or in the ceiling, the hatch needs to meet the same load tolerance criteria as the filter structure. The hatch should open towards the filter, that is inwards. The filter should be anchored to the civil defense shelter structures. A minimum of 60cm of space should be left between the sand layer and the ceiling of the filter. The ratio of the sand filter walls should be 1:1 – 1:2. (Sisäasiainministeriö 1963f, 41§; Rajajärvi 2016, 154.)

The sand in the sand filter should be clean, dry, and at least 75% of the sand grains should be sized 1-3mm. Sand type should be coarse, because of its ability to bind particles. The sand should be stored in bags weighing a maximum of 50kgs. The recommended thickness of sand layer in the filter is 1m, but a range between 0,8m and 1,2m is acceptable. Every ventilation machine should have its own sand filter. The free space above the sand layer can be common for the filters. The size of the sand filter depends on the size of the ventilation machine. In 1959, the maximum size of a filter was 4m3. During that time, the amount of sand was based on the floor area of shelter room and nursing room (1m3/15m2 floor). In 1963, the maximum size for a ventilation machine III was 6m3. The floor of the sand filter should be inclined, to enable water removal through copper pipe extending through shelter wall ending in a tap inside the shelter 5cm+ above floor level. The floor of the sand filter should be at least 10cm higher than the shelter floor level. (Rajajärvi 2016, 154; Sisäasiainministeriö 1959, 39§; Sisäasiainministeriö 1963f, 41§; Sisäministeriö 1963g.)

The air gathering device is placed on the bottom of the sand filter floor. There should be a 20-30cm thick sand layer between the filter wall and the gathering device edge. The air gathering device should intake air evenly over the sand filter. In 1960, a building instruction for the air gathering device was published. This model was built out of bricks with holes and mineral wool. (Suomen arkkitehtiliitto, standardisoimislaitos 1960.) In 1964, another building instruction was published, this one advising us to use a steel grating to prevent the sand from entering the air channel of the air gathering device. It is also said in a building instruction from 1965, that if the air gathering device is built according to BI 560.183, the air gathering device should be covered by a 5-10cm layer of bigger sand sized 5-25mm, to prevent air from entering the secondary air intake duct. The device needs to be protected from rusting. (Suomen arkkitehtiliitto, standardisoimislaitos 1964; Suomen arkkitehtiliitto, standardisoimislaitos 1965.) Any version of the air gathering device should as far as possible be built to fit different sized and shaped sand filters. The air gathering device should be attachable to the secondary air intake duct, 100mm for ventilation machine I and II, and 150mm (ventilation machine III) in diameter. (Sisäasiainministeriö 1963b.)

2.4 The maintenance of a civil defense shelter

Considering that Finland has been building the civil defense shelters since 1938, regular maintenance is crucial to keep these shelters available for their sheltering purpose if Finland was threatened by a hostile nation. SPEK (2017b) published Väestönsuojan huolto ja käyttö (Maintenance and use of the civil defense shelter), a guide on maintaining civil defense shelters. This guide gives a good overview of maintenance and civil defense shelter use for any person who is responsible of maintaining a civil defense shelter. A civil defense shelter that is maintained appropriately has a life span of 50-100 years. (Spek 2017b, 14.)

The civil defense shelter should be maintained regularly on a yearly basis. During these checks, the devices and machines should be checked and serviced according to manufacturers' guidelines. The device manufacturers or construction contractor can be contacted if service procedures are unclear, or problems occur during maintenance. (Spek 2017b, 14.) Temet Oy (1979) published B- ja C- luokan väestönsuojan käyttö- ja huolto-ohje (B- and C-class civil defense shelter use and maintenance instructions), which specifies maintenance of the C-class civil defense shelter with the sand filter included. In Appendix 3, a table of parts to consider in the yearly maintenance is presented (Spek 2017b, 15-24; Päijät-Hämeen pelastuslaitos no date).

3 Methodology

This thesis project is a request from RTF Services. The company is looking to mainstream their service process conducting work with civil defense shelters, providing better service for the customer and being more time efficient, enabling an increase in profitability. Throughout the process, the communication with the company representant has been working well and they have been able to impact the process along the way.

In a rapidly changing environment, organizations need to stay up to date with developments to successfully maintain business. The increased knowledge gained from research results in a large supply of goods and services, which in turn increases competition. Predicting the demand from society becomes more challenging, and organizations need to stay agile and flexible. Organizations that contribute to developing their area of expertise are the most successful ones. Through development work an organization can for example increase profit rate, bring new innovations to the market, motivate employees, predict future demand, streamline operations, and solve problems. (Ojasalo et al. 2009, 11-13.) Hanna Vilkka (2021) highlights the common benefit of development work for the whole professional field, mentioning things such as the use of common language and terms and problem-solving techniques, resulting in possibilities to both practically and theoretically develop already established ways of conduct.

Developing work can be done in different ways, and it is important to note that there is a need for diverse methods to widely explore and develop working methods. Ojasalo et al (2009) introduce scientific research as one side of developing methods, where theories are tested by using generally approved methods, like qualitative and quantitative research. On the other side the authors introduce developing by common sense thinking. The intention is to solve practical problems or renew routines with this method. Information is gathered through various sources with little critical evaluation, and conclusions are based on an individual’s ideas. In between scientific research and developing by common sense thinking, research-based development is placed. With research-based development, the intention is to solve practical problems, renew routines and produce new knowledge regarding working life procedures, and this method suits this thesis project well, as the goal is to provide practical tips and theoretical knowledge on C-class civil defense shelter work for the working life partner. In this method, both practical and theoretical information is gathered and critically evaluated using diverse methods. Vilkka (2021) describes it as combining theory, experience and professional practice. Interaction with and presentation of work to different parties brings the development work forward (Ojasalo et al. 2009, 18).

The process of research-based projects starts by recognizing an area in need of development and specifying goals for the development work. From there the background of the topic is studied in both practice and theory. Based on background information, the development task is defined. In the following phase the knowledge base is made, and the methodology is planned. Thereafter, the development project is conducted and introduced in different ways. The final stage is to assess the development process and the results. (Ojasalo et al. 2009, 24.)

In a development project, it is recommended to use various methods of gathering information. A development project enables the use of methods that are not used in scientific research. The choice of methods to use for the development project can be made when the goal of the project and the research approach is determined. Traditionally, there have been two different options of research method; qualitative and quantitative research. (Ojasalo et al. 2009, 93-94.)

For this project, a qualitative approach was chosen. The starting aspect of a qualitative approach is real life. In qualitative research, the researcher works closely with carefully chosen participants, who can provide deep insight into a certain topic. Based on gathered data, the results are interpreted and justified in the findings. Vilkka (2021) describes the goal of qualitative data gathering as getting width of the content rather than quantity of material. For this thesis project, interviews are used to gather data. The qualitative approach is favorable for this thesis project, as the objective is to receive insight in civil defense shelter work and experts' experiences from practical work. Conducting interviews will allow the participants to express their knowledge more freely.

Any researcher should apply good research ethics to their work. Good research ethics includes using trusted sources and approved research methods. A researcher is expected to show honesty, carefulness, and accuracy in research procedures and presentation of results. Good planning of the research or development project helps when complying with research ethics. The reader should be able to easily follow the content and descriptions. (Vilkka 2021.) In this thesis, the sources used have been evaluated and found reliable. All the sources are presented and referred to in the text.

3.1 Semi-structured interview

For the interviews, a total of nine companies and professionals in civil defense shelter work were approached and requested to participate in the development project. These were picked based on their professional careers, as most of them are employees in or owners of companies that conduct service and renovations of C-class civil defense shelters. A couple of the approached people were active in second and third sector fields. In the end, three professionals working with civil defense shelters in the first, second and third sector fields agreed to be interviewed. Their experience with civil defense shelters ranged from 2-20 years. The participants have deep and diverse experience in the field, which adds value to the project. Participants were approached via telephone or email. The interview was agreed upon, and a confirming email was sent to the participant including a link to a Microsoft Teams meeting. The interviews were held remotely via Microsoft Teams. The length of the interviews varied from 45 to 75 minutes. They were recorded, and later transcribed. The participants are anonymous.

The semi-structured interview is used in this thesis project. The interview was conducted one-to-one like a conversation, blending both closed and open-ended questions with the opportunity of adding follow up questions. This suited the project, since it gave the interviewee space to freely discuss around the theme providing good insight, but also the opportunity for the interviewer to ask more specific questions regarding details of the theme. For the interviews, an interview agenda was created, containing themes to discuss and questions to address. Being closely familiar with the interview agenda allows for improvisation and exploration of unknown subjects of interest, but also the possibility to seamlessly steer the conversation back to the agenda. The agenda was carefully thought through before the interviews started. (Adams 2015.) Vilkka (2021) describes the semi-structured interview as the most used form of interview methods, where the interviewer asks questions related to predetermined themes, to find answers to research questions. The original agenda changed during the interviewing process, as new insight into the topic was achieved, allowing for improvement of the agenda. The questions and themes are on the agenda only to guide the discussion. Depending on the background of the person being interviewed, the structure of the agenda was modified to fit the interviewee.

The behavior of the interviewer impacts the interview. This is taken into consideration, and during the interviews the interviewer aims to be open-minded, friendly, and showing a similar level of knowledge to the interviewee will help them feel comfortable during the interview. (Adams 2015.) The interviews are recorded, and small notes are made during the interview to help structure and cover the topic. The participants were thanked immediately after the discussion.

3.2 Data analysis

The semi-structured interviews are recorded and transcribed and then a relational content analysis is performed. Concepts that arise from the analyzed interviews are interpreted and put into key themes presented in the result chapter. (Crosley 2021.) The use of words and phrases is analyzed to get the deeper meaning of what the interviewee wants to express conclusions are made based on that. Quantity of material will not make up for lacking quality when analyzing interviews. (Ojasalo et al. 2009, 99-100.)

4 Results

In this chapter, the results are presented in key themes based on the interview analysis done. The results are presented in the order that anyone working with a C-class shelter should consider things, starting with determining the starting point of the specific shelter, then proceeding to different courses of action to choose from to maintain legal requirements, and finally providing some practical advice for the work.

The interviews gave valuable insight that is supported by the theory and technical specifications introduced in this thesis. It is of high importance that a service provider can identify what is required for a certain shelter to meet legal requirements, and that they can explain and justify different courses of actions to the customer when dealing with an insufficient C-class shelter. It should be considered, that restoring or updating a C-class civil defense shelter can be costly for a housing cooperative. Service providers should be able to openly and honestly explain what restoration of the shelter means and what it costs and how it works, but also what updating the shelter means and costs and what the extra expense of this action gives the customer. Today, Finland lacks the information about C-class defense shelter conditions because maintenance and periodic inspections have been conducted by private companies. The quality of these inspections, including pressure tests might vary. The reporting of civil defense shelter inspections to rescue authorities might also vary between departments.

4.1 Determining the starting point

C-class defense shelters differ from each other, depending on when they were built and what decisions were in force during that time. As previously mentioned, the decisions of the Ministry of the interior that regulated building of civil defense shelters were updated twice between 1963 and 1970. When starting to work with a C-class shelter, the service provider needs to find out what year the building permit was applied for. The shelter should meet requirements from that year. It is possible for example, that the building permit was applied for in late 1962. The processing of the building permit might have taken time and the construction of the building might have taken time. The building might have been finalized in 1965 but there is no special filter in that shelter even though it had been a required part of the C-class civil defense shelter for three years then already.

When knowing what year the building permit for the building was applied for, we can find out what legal and technical requirements apply to the specific shelter. This requires the service provider to be familiar with what the shelter technical specifications are based on and how they are prioritized. Requirements of the C-class shelter are regulated, in the following order, by acts, followed by decrees and decisions, technical requirements, good building practice and finally the building industry rules. To give an example, a building that applied for a building permit in 1966 has a civil defense shelter that complies with Väestönsuojelulaki (438/1958) (Act on civil defense 438/1958), and Väestönsuojeluasetus (237/1959) (Decree on civil defense 237/1959), Sisäministeriön päätös B- ja C-luokan väestönsuojista N:o 291 (The decision on B- and C-class civil defense shelters by the Ministry of the Interior), Sisäministeriön päätös B- ja C-luokan väestönsuojista annetun sisäasiainministeriön päätöksen muuttamisesta N:o 317 (The decision of changing the decision on B- and C-class civil defense shelters by the Ministry of the Interior), and all the relevant technical requirements specified in decisions by the Ministry of the Interior from before 1966 and RT-specifications by Suomen Arkkitehtiliitto, Standardisoimislaitos from before 1966. It should be noted that decisions might only partly change the previous decision. Therefore, like in this previous example, both Sisäministeriön päätös N:o 291 and Sisäministeriön päätös N:o 317 need to be considered when working with a C-class civil defense shelter from 1966.

It should be made clear what "meeting legal requirements" means in practice. To establish that, the service provider should understand how the shelter is supposed to protect life. One interviewee explained that the shelter should protect people in two ways. The first one is against weapons. A C-class civil defense shelter should more or less protect people from the effects of CBRNE-weapons. For chemical weapons (C), the special filter provides the main protection. It should be noted that in shelters built according to standards before 1963, there is not necessarily any special filter, since this became a requirement in 1963. The B stands for biological weapons, and for this type of weapon the C-class shelter cannot provide good protection, since it often is transferred from human to human as viruses or bacteria. Biological weapons can travel with particles or as droplet transmission. The filters in the C-class shelter do effectively remove these substances, but if an infected person enters the shelter, there is no way to prevent it from spreading between people. Against radiological weapons (R) the filters prevent radioactive particles from entering the shelter. The nuclear weapon (N) effects are managed through the robust construction protecting against explosion, and the immediate radiation. Finally, against explosives (E), the shelter provides protection against collapsing buildings, shrapnel, and shock waves. When the ventilation system of a C-class civil defense shelter is inadequate, and the shelter room is not airtight, it will still provide protection against explosive weapons. The second way the shelter protects life is by maintaining sustainable conditions inside the shelter. As already explained on page 9 in this thesis, the inside air gets bad without a ventilation system, and this would eventually lead to death.

4.2 Restore, modernize or update

Restoring, modernizing or updating, these are the three options to choose from. When choosing between these three options, there are a couple of things to consider. In the end, the owner of the defense shelter usually pays for the costs, and they should be aware of what every option means in terms of what changes to expect, and costs related to the changes. A contractor should help guide the customer through the options.

Restoring is the option where the C-class shelter is restored to meet the legal requirements from the year when the building permit was applied for. In this case, all the original equipment and structures are preserved. Law requires the shelter equipment to be in functional condition, including for example air distribution ducts and water buckets. It is highlighted by one interviewee, that in C-class civil defense shelters built according to decision no. 318 by the Ministry of the Interior (Sisäasiainministeriö 1959), the requirement was to be able to maintain a shelter gauge pressure level of 3mm on water column. This equals approximately 30 pascals. In other words, the oldest versions of the C-class civil defense shelters meet requirements on air tightness if it is possible to maintain ~30 pascals while running the ventilation machine. This changed and the procedure of pressure testing changed after 1963.

It can be called modernizing of a shelter when it is partly updated. For example, getting new water buckets and lavatories and other shelter equipment would be considered modernizing of a C-class shelter. Improving a shelter is acceptable but impairing any part of legal requirements is not. Any improvements should all be of the same standard. It would not be right to pick technical specifications from different years of legal decisions, to make the job easier or cheaper. One interviewee provides a concrete example of how it would be possible to modernize the ventilation system today. “In the C-class civil defense shelter, the primary air intake was usually placed at the end of the emergency exit passage, outside the collapsing area of the building. According to today’s legislation, the primary air intake can be in the wall, ending in the building façade, equipped with splinter protection. When modernizing, it should be considered that an update of the shelter might become relevant in the future, and measures of modernization should therefore support a possible update. One interviewee mentioned that newer ventilation machines provide more air to the shelter, and that the pressure relief valves should be changed with the machine, since the carbon dioxide needs to be efficiently removed from the shelter.

Updating a C-class defense shelter is a required procedure when a building is renovated extensively, and it covers the basement area where the shelter is located. Water pipes and drainage in the building might be subjects for renovation, and this renovation might also extend into the shelter. This renovation requires a building permit, and the building authorities can demand the owner of the building to update the shelter for a cost of up to 2% of the total building renovation cost. In these cases, an architect or building planner would have to consider the update of the shelter in the building permit drawings. When updating a C-class shelter, renewing the ventilation system is a priority. Huttunen (2017) provides guidance for this in his thesis Ohjeistus väestönsuojien ilmanvaihdon suunnitteluun ja toteuttamiseen erityisesti saneerattavissa kohteissa. It is concluded by several interviewees that even though the shelter is updated to meet newer legal requirements, the shelter does not turn into an S1-civil defense shelter. Unless the building authorities grant relief, the shelter spot area does not increase from the original C-class 0,58m^2 or 0,60m^2 to today's 0,75m^2. Structures like the door for example are smaller in the older C-class civil defense shelter, but the building authorities do not necessarily require it to be bigger, even though the shelter is renewed. Regarding the sand filter, the building authorities will decide whether the sand should be removed from the sand filter or not.

4.3 The practical part of C-class civil defense shelter work

When discussing the theme of restoring or updating C-class civil defense shelters, it is concluded by the interviewees that problems in the shelter often are caused by moisture, corrosion, and unauthorized changes to structures. Because of the structure of the sand filter, determining its condition is challenging. This is also a reason why the sand filters were abandoned in newer S1 shelters from 1971.

The sand filter is exposed to moisture, since it is often located outside the outer wall of a building, and the ventilation of the space is low. During winter, a moist sand filter could freeze and consequently not work. Moist sand also does not filter particles efficiently. Inside the shelter room, there is a tap leading out water from the sand filter floor. Opening this tap during inspection will give a hint of whether the filter is dry or not. Otherwise, it is challenging to establish the status of the sand filter without removing the sand. Theoretically, a moisture measuring device could possibly be stuck down in the sand, to determine whether the sand filter is faulty or not. The special filter is also sensitive to moisture. Just as the sand filter, the special filter will not filter efficiently if it is moist. However, it is easier to establish if the special filter is damaged. The weight of the special filter should be written on the side of it. If the filter is heavier than the specified weight, one can assume that it is moist. Special filters damaged by moisture can be dried by blowing hot, dry air through them, if they have not been used for filtering dangerous particles. Newer ventilation machines are equipped with a recirculation air mechanism, which can be used to dry a moist filter. The older C-class shelter special filters are however not equipped with this mechanism. In theory, a fan heater could be used to blow hot dry air, preferably minus degree outside air through the filter.

Moisture causes corrosion, which weakens structures and causes defects to technical parts. The air gathering device constructed by angle irons is sensitive to moisture and corrosion. To establish if the irons are rusted, the sand layer needs to be removed. If there is sand visible through the secondary air intake duct, the air gathering device construction has collapsed, which makes the entire sand filter defect. The ventilation machine is also exposed to the risk of corrosion. The manufacturer of the device has provided maintenance guidelines, with precise information of what kind of oil should be used in maintenance. It is good to be aware that the ventilation machine might be filled with one type of oil for storage, and there is another type of oil intended for the use of the machine. Mixing these two oil types might cause clogging but can be prevented by carefully washing the old oil away before adding the new one. Maintaining the ventilation machine by running it oils the system, which prevents corrosion. If a ventilation machine equipped with an electric engine starts but the fan does not spin, a likely cause could be that the centrifugal clutch is stuck. Regularly running ventilation machines equipped with an electrical engine also prevents the centrifugal clutch from getting stuck. By opening the machine and cleaning the moving pieces of the clutch, often made of leather or plastic, it can start working accordingly again. One interviewee state that it is unfortunate that there are no spare parts provided by the equipment manufacturers. Corrosion is also a problem for the shut off valves in the shelter, and again regular lubrication could prolong the lifespan of them. A maintenance diary would be recommended, where change of oil and other service procedures can be noted.

According to the interview agenda, the interviewees were asked to add free thoughts related to the topic. Worth mentioning was regarding the galvanized steel tanks for water that were installed in some C-class civil defense shelters. When modernizing or updating a shelter, these might be traded for newer versions of water buckets. To get these large steel tanks out of the shelter, the service provider might need to cut it into smaller pieces. The cutting might produce zinc oxide, and this is toxic to inhale. This is important to consider in a space where ventilation is not necessarily good. Another good reminder is that all equipment needs to be working accordingly, for example if there are telecommunication sources in the shelter, these need to actually be tested for signal, because this is the way authorities will communicate to people in the shelters.

5 Conclusions

The goal of the thesis was to provide my working life partner with knowledge and practical options and tools for them to consider when conducting C-class civil defense shelter maintenance and restoration work. I think that the results combined with the tables provided in the appendices will provide clarity on legal requirements and help with the decision-making process. As the requirements are gathered in this thesis, it will be easier to find for anyone looking for the information. In the table below, the results are summarized.

Determining the starting point	**Restore, modernize or update**	**The practical part of C-class civil defense shelter work**
What year was the building permit applied for? The legal requirements from that year apply.	Restore – preserving the shelter and equipment from the year when the building permit was applied for. Notice the pressure test requirements change in 1963.	Moisture causes inefficiencies to filters. Weigh the special filter. Open the water tap of the sand filter and check if there is visible sand in the secondary air intake duct to get a hint of whether the sand filter is dry or not.
Requirements of the C-class shelter are regulated, in the following order, by acts, decrees, decisions, technical requirements, good building practice and finally the building industry rules.	Modernize – updating parts of the shelter, for example water buckets or ventilation ducts. Improvements should be of same standards, and it should be kept in mind that an update might become relevant in the future.	Mixing different oils in the ventilation machine might cause clogging. Use a maintenance diary for the ventilation machine.
The shelter should protect life in two ways; 1) protection against weapons 2) maintenance of life sustainable conditions inside	Update – Always with new building permit. Start with ventilation system. Should meet new S1-shelter standards. The shelter spot size is not automatically increased to $0{,}75 m^2$	The centrifugal clutch of an electrical engine might be stuck if the engine runs but the fan does not spin. Regularly running the machine prevents this from happening. By opening the machine and cleaning the moving pieces it can start working accordingly again. Beware of inhaling zinc dioxide if cutting galvanized water tanks in the shelter. Test telecom sources for signal.

Table 2: Summary of results

RTF Services aim to provide the best value service for their customers, and I think that the outcome of this project gives some guidance when deciding course of maintenance actions for C-class civil defense shelters. The work proceeded nicely with support from professionals in the field. Conducting the interviews, I struggled to convince service providers to participate, but in the end, I think I gathered good quality material. In the process, I learned not only about the C-class civil defense shelter and its maintenance, but also about the newer S1 shelter, and things not directly relevant to this topic, such as the plan for taking a shelter into use. While I got the perception that the interviewees had a positive attitude towards the sand filter with its shockwave- and heat absorbing abilities, I also realized that with the design of the ventilation machines we have today, it would not be possible to benefit from the sand filters as primary filters.

I personally think that the biggest value of this thesis is the theoretical knowledge provided in this work for anyone reading it. The knowledge can be used when guiding the customer through different options they have when facing a C-class civil defense shelter that does not meet legal requirements. Exhibiting knowledge and confidence communicating with the customer will create trust, ultimately enhancing a good customer relationship, which in turn helps the company maintain and improve a sustainable business model. I would like to highlight the importance of complying with Valtioneuvoston asetus väestönsuojan laitteista ja varusteista 409/2011 (The decree on Civil defense shelter equipment and parts by the Finnish Government) when modernizing and updating civil defense shelters.

Another personal takeaway from this project is the realization of how aware a professional service provider should be of legal requirements related to civil defense shelters, to be able to provide full service of a C-class civil defense shelter, from inspections to updating shelters. There is an ethical aspect of working with civil defense shelters to consider. The shelters provide safety for people in certain states of emergency and should be working in case their use is needed. The owners of C-class civil defense shelters are often housing cooperatives, which means that expenses for shelter maintenance end up being covered by apartment owners. In my opinion, it would be wrong to suggest an expensive update of a shelter without motivation to the customer just to make good profit, if it could be adequately restored or modernized for less money. The restoration option is probably not the right course of action every time either. If the C-class shelter at hand has a severely defective sand filter, is it the most cost-effective choice to try to fix it? Every shelter is unique, the service provider needs to be skilled enough to identify the options the customer has. With clearer national guidelines and information on how to approach an inadequate C-class civil defense shelter, the service could improve. Additionally, I think certifying professional civil defense shelter inspectors could elevate the quality of civil defense shelters and inspection and maintenance service provided. As for further research suggestions, I would propose that clearer national guidelines on how to update the C-class civil defense shelters was created.

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Appendix 1: Specifications on civil defense shelters, C-class and S1-class

	C-class 1959	**C-class 1963**	**S1-class 2011**
Obligation to build a defense shelter	$3000m^2$	$3000m^2$	$1200/1500m^2$
Size of the defense shelter %	2,5% out of the combined apartment gross floor area. At industrial sites according to employee number.	2% out of the combined apartment gross floor area. At industrial sites according to employee number.	2% out of the combined apartment gross floor area. At industrial sites according to employee number.
Area/person seeking shelter	$0{,}58m^2$	$0.6m^2$	$0{,}75m^2$
Maximum shelter places	150	150	180
Distance above groundwater	1.3m	1.1m	1.0m
Personnel lock or tent	Personnel lock	Personnel lock	Personnel lock tent
Actual size of one shelter room (m^2)	$36m^2$	$36m^2$	$90m^2$
Size of lavatory (m^2)	$0{,}56m^2$	$0{,}56m^2$	$0{,}7m^2$
Amount of lavatories/shelter place	1/25 shelter places	1/30 shelter places	1/27 shelter places
Hight of shelter room	2,2m	2,2m	2,3m

Load tolerance on ceiling and walls for shelter beneath ground	50kN/m²	50kN/m²	100kN/m²
Load tolerance on ceiling and walls for shelter above ground	50kN/m²	70kN/m²	100kN/m²
Safety factor for load and material (coefficient)	2,5	2,5	1
Size of construction steel	8-15mm	8-15mm	8-20mm
Wall thickness below ground level	400mm	400mm	300mm
Roof thickness below ground level	400mm	400mm	300mm
Minimal thickness of floor	100mm	200mm	150mm
Reinforced concrete wall inside shelter	150mm	150mm	150mm
Fragment shield (concrete/steel)	N/A	250/30mm	200/30mm
Radiation shield for walls and roof	600mm	600mm	300mm
Load of concrete plate in front of entrance (shock door)	N/A	25kN/m²	25kN/m²
Space under shock door	50mm	70mm	30mm
Minimum dimension of shock door	90x175cm	90x185cm	90x200

Possibility to store shock door separately	Yes	Yes	No
Emergency exit passage collapse load	$25kN/m^2$	$50kN/m^2$	$25kN/m^2$
Dimension of emergency exit passage	0,75x1,5m	0,75x1,3m	0,8x1,2m
By-pass situation air flow rate	$6{,}7m^3/m^2$	$6{,}7m^3/m^2$	$7{,}3m^3/m^2$
Filtered air flow rate	$2{,}7m^3/m^2$	$2{,}7m^3/m^2$	$2{,}4m^3/m^2$
Sand filter (S) **Gas filter (G)**	S	S/G	G
Ventilation machine per actual m^2	N/A	$1/30m^2$	$1/45m^2$
Minimum shelter gauge pressure (mm of water column)	3mm	3-6mm	5mm
Fuse box (yes/no) IP-rating and cable mm^2	YES	$2x2{,}5mm^2$	IP34
Telecom requirements	N/A	Radio/TV/Phone	Mobile phone/ Radio/TV
Water volume/person	5l/person	20l/person	30l/person
Soak pit volume ***Outside of shelter**	100l	10l/shelter spot	*3,8l/shelter spot
Water pipe shut-off valves inside/outside	Outside	Inside	Inside
Equipment acquisition in regulation	No	No	Yes

Appendix 2: Parts of the C-class civil defense shelter ventilation system

Part	Function	Specification
Primary air intake duct (Ilmantuloputki)	Bringing air from the outside, often via emergency exit channel, to the sand filter.	Standard SFS.B.VIII.22 Changes Decision 1969, 40 § Nominal sizes: Machine I – 200mm Machine II – 200mm Machine III – 250mm -Placed at the far end of emergency exit channel. -Extends 1m above ground level. -Common pipe for several machines. -Can be stored unassembled during times of no emergency conditions
Sand filter (primary)	Filter toxic particles	Sand specified in decision 993/770/63 by the Ministry of the interior Changes Decision 1965, 41 § Amount of sand: Machine I – 2m3 Machine II – 4m3 Machine III – 6m3 (Before 1963 --> 1m3 sand/15m2 shelter and nursing room area) -Filter floor 10cm higher than shelter floor -Sand layer 80-120cm -Sand size 1-3mm (>75%)
Air gathering device	Gather clean air post sand filtering	Specified in decision 991/770/63 by the Ministry of the Interior RT 085.184, 1960 BI 560.183, 1964 -20-30cm of sand between sand filter wall

		and air gathering device sides. -Supported against filter bottom -The air gathering device should withstand 4x the weight of 1m3 sand -Should function with degrees ranging from -30 to +80°C -A copper pipe, (10-20mm in diameter) is placed at the filter bottom for water removal
Secondary air intake duct (ilmanottoputki)	Bring filtered air from air gathering device to the special filter or ventilation machine	Standard SFS.B.VIII.22 Nominal sizes: Machine I – 100mm Machine II – 100mm Machine III – 150mm
Special filter (secondary)	Filter toxic particles and gas	-Specified in decisions 994/770/63 and 382/770/65 by the Ministry of the Interior -Carbon and particle filter -Placed in the shelter close to ventilation machine. Connection to secondary air intake and ventilation machine with connection hose. -Tightly sealed in storage
Ventilation machine	Distribute air inside shelter	Specified in decision 996/770/63 by the Ministry of the Interior Changes Decision 1965, 56 § See table 1 -Air flow meter required -Mounted to floor or wall, close to sand filter -Powered by hand and by electric motor
By-pass air duct	Lead unfiltered air to shelter room	Standard SFS.B.VIII.22 Changes Decisions 1965 and 1969 45§

	Primary air intake> Emergency exit route> By-pass air duct> Ventilation machine	Nominal sizes: Machine I – 200mm Machine II – 200mm Machine III – 250mm -Equipped with pressure valve, closable from shelter room (specified in decision 992/770/63 by the Ministry of the Interior) -Common pipe for several machines -Connection to ventilation machine by connection hose -By-pass air duct should not decrease shelter gauge pressure by more than 30mm of water column
Connection hose	Enable switching between by-pass ventilation and filtered ventilation	-Specified in decision 995/770/63 by the Ministry of the Interior -Elastic hose that is attached to ventilation machine and either special filter or by-pass air duct. -Same dimension as secondary air intake duct
Ventilation ducts	Distribution channel for air inside shelter	Changes Decision 1969, 47§ -Attached to ventilation machine -Should be made of hot-dip galvanized steel or similar steel to resist rusting. -air flow valves in the duct to enable even air distribution to all parts of shelter room. -Fresh air should not be distributed straight to personnel lock, service space nor lavatories. -Common duct for several ventilation machines -Ventilation ducts should not decrease by-pass air flow gauge pressure by more than 15mm of water column

Ventilation valves	Through these valves air exits from shelter room and lavatories into personnel lock and service space	Specified in decision 998/770/63 by the Ministry of the Interior -Placed in walls between personnel lock/service space and shelter room -160cm above floor level -Should be adjustable from air flow direction (inside)
Pressure relief valves	Through these valves the air exits from personnel lock and service space. Air leaves defense shelter completely through these. The pressure relief valve prevents shockwaves to enter shelter room (check valve)	Specified in decision 999/770/63 by the Ministry of the Interior -Placed in personnel lock and service space. -Should be adjusted to open when gauge pressure reaches 30mm of water column -Should be adjustable from inside shelter
Air flow meter	Shows how much air the ventilation machine brings into the defense shelter	Attached to ventilation machine
Manometer	Shows the difference between shelter pressure and outside pressure (Gauge pressure)	Specified in decision 997/770/63 by the Ministry of the Interior Changes Decision 1965, 48 § -Placed on wall close to ventilation machine -Attached to copper pipe that extends through wall to the outside air. Pipe should be 10mm in diameter, 1mm thick and the outside protected to prevent water and dirt from getting into the copper pipe.

Appendix 3: Parts to consider in yearly maintenance

Personnel lock/personnel lock tent	-Check that personnel lock doors are closable. -Check that personnel lock tent stored appropriately. -Check that ribs for the tent are attached appropriately.
Defense shelter walls	-Check that feed throughs are sealed.
Shut off valves for water and drainage	-Open and close shut off valves to secure water supply/drainage and shut off function. -Lubrication of valves.
Doors	-Lubrication of door hinges and latches. -Paint to resist rusting (according to SFS 4962)
Seals (doors and valves)	-Check that they are appropriately attached to door/valve. Treat with silicone. -If seals are stored unattached, check that bag is airtight.
Ventilation	-Open and lightly close pressure valve. Lubricate -Special filter sealed. Lid not bulging out. Never open it. -Ventilation machine working by hand and by machine. Check oil and empty water. -Check that air flow switch is set on “Ohitus” (By-pass air) -Check that air valves and ducts with belonging parts are clean and protected from rusting. Empty water. See that general ventilation closing plates are stored, bolts included. -Check that air gathering device has not collapsed in C-class shelter. -Check that sand is clean and dry.

	-Empty leakage water from sand filter and emergency exit route.
Manometer	-Check that pipe stays open by blowing into it. -Check that there is fluid in the manometer, and that there is extra fluid stored in the shelter.
Lavatories/Dry closets	-Check the amount of dry closet buckets is enough. -Check that the dry closet walls are stored, and that the assembling point is marked.
Water buckets	-Check that the amount of water buckets is enough (l/shelter spot), and that they are clean and intact.
Shelter temperature	-Check that the temperature of the shelter is +10 - +25°C, and that the air is not very humid (max 80%).
Communication	-Check that radio point is working. -Check that shelter phone or mobile phone works.
Electric equipment	-Check distribution board for extra fuses. -Check all lights and socket outlets.
Other equipment	-Check civil defense shelter signs. -Check that safety equipment and tools are available.