# Reliability of Automatic Sprinkler Systems

## – an Analysis of Available Statistics


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**Abstract**
In this report statistics concerning the reliability of sprinkler systems from seven countries has been analysed. The objective of this report has been to determine the reliability of sprinkler systems in Sweden and to present suggestions on measures to increase the reliability. The main conclusion that has been drawn is that the reliability of sprinkler systems in Sweden is 92 percent according to the analysis of Swedish statistics, and that this figure finds support in statistics from other countries. Further results are that the quality of design, installation, maintenance and inspection of sprinkler systems has to be improved and that the Swedish incident report has to be revised.



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# Summary

The objective of this report is, based on statistics from Sweden and other countries, to determine the reliability of automatic sprinkler systems in Sweden and to present suggestions on measures to increase the reliability. Reliability can be described as the probability that a sprinkler system performs as expected. The most important conclusions and suggestions are presented here.

The analysis of statistics from the Swedish rescue services for the years 2006 and 2007 shows that:

- The reliability for automatic sprinkler systems in Sweden is 92 percent.
- The reliability is higher for industries compared to general buildings in Sweden.
- The level of detail in the statistics from the Swedish rescue services does not permit a division of the incidents into type of system.

These conclusions are based on data that has been processed by the authors. It is difficult to assess the validity of the conclusions since the data is deficient.

The suggestions on measures of this report show that:

- A higher level on fire-protection management system, including maintenance and routines is required.
- A higher standard on design, installation and inspection of sprinkler systems is required.
- Insurance companies have to make demands on policyholders and improve their interaction with inspection companies to ensure a reliable function of sprinkler systems.
- The Swedish incident report has to be revised.

Research of statistics has been carried out in other countries in earlier attempts to determine the reliability of sprinkler systems, but not for Sweden.

The approach for attaining the objective is to study, describe and analyse available statistics from fires in buildings with installed sprinkler systems. This enables an assessment to be made of the reliability of automatic sprinkler systems in Sweden. Furthermore, classification of causes of failure can show clearly where corrective actions have most impact.

Statistics from Sweden, Finland, Norway, England (London), New Zealand, Australia and the U.S. were used in this report. The reliabilities of automatic sprinkler systems from these sources vary from 38 to 99.5 percent. The variation is partly because the sources of the statistics differ in terms of validity, actuality and in design of the incident report.

In the analysis of the report the Swedish statistics is further processed to generate data with higher quality. This is done by evaluating each one of the incidents using criterions set by the authors. The analysis of statistics from the Swedish rescue services shows that sprinkler systems in Sweden have a reliability of 92 percent.

The report results in conclusions and suggestions on measures, where the latter serves both to increase reliability of sprinkler systems and to enhance the quality of statistics.

## Preface

This report has its origin in the need of information about reliability of active systems, in this case about automatic sprinkler systems. It is essential that such information is available when using analytical methods in performance based fire engineering in order to avoid harm to humans, property and to the environment.

This project is originally done in Swedish as a part of the final examination for Fire Protections Engineers at Lund University, and has now been translated into English in order to be available for a greater audience.

The guideline for the project has all along been to use international statistics, as well as Swedish statistics, to have a material as comprehensive as possible, but the objective of the project has been adjusted to fit Sweden.

However, it has been realized during the progressing work that the differences between the countries are not too big, and that we definitely can learn from each other. The international statistics are involved in the conclusions and suggestions on measures from this report. Several of the results can be applied to other countries as well.

Finally we would like to mention that this project would not have been done without the help from the Swedish Fire Sprinkler Association and Brandkonsulten Kjell Fallqvist AB

Uddevalla, October 2008

Daniel Malm and Ann-Ida Pettersson

Fire Protection Engineer Students, Lund University

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Enjoy!

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Uddevalla, October, 2008.

## Contents

# 1 Introduction

This report is the result of a project that has been carried out during the summer of 2008. The project was sponsored by the Swedish Fire Sprinkler Association (Sprinklerfrämjandet) and the work was done at Brandkonsulten Kjell Fallqvist AB.

The report is part of the course Brandtekniskt Projektarbete, VBR 131, and is part of the final exam for Fire Protection Engineers. The course, which comprises 15 ECTS-points, is given at the Department of Fire Safety Engineering and Systems Safety at Lund University.

## 1.1 Background

There is an ongoing discussion whether Swedish statistics show a correct reliability of sprinkler systems in Sweden. Several professionals within the trade say that sprinkler systems undeservedly have a bad reputation and that the reliability for this type of active system often is taken as too low.

The Swedish Fire Sprinkler Association has been in contact with statistics regarding the reliability of sprinkler systems and has realized that the statistics are deficient. Together with Brandkonsulten Kjell Fallqvist AB they have initiated this project, which purpose is to study and analyse available statistics from fires in buildings where sprinkler systems are installed.

Reliability can be described as the probability that a sprinkler system will perform as expected. There are studies of statistics carried out for a number of countries in earlier attempts to determine reliability for sprinkler systems, but not for Sweden.

It is important that persons in the sprinkler industry have knowledge about the reliability of sprinkler systems and what types of failures that may occur. This is important for primarily three groups (Budnick, 2001):

- The manufacturer – when developing sprinkler technologies.
- The designer – when performing probabilistic-based risk analysis.
- The user – when optimizing inspection and maintenance.

## 1.2 Aim and Objective

The aim of the project is to increase the knowledge about the reliability of sprinkler systems in Sweden. The intension is also that the result of this report will give ideas to, and form the basis for, further future studies and analysis within the areas mentioned in the report.

From the perspective of the university the report aims to provide insight in searching for information, scientific methods and in writing reports.

Based on statistics from Sweden and other countries, the objective is to determine the reliability of automatic sprinkler systems in Sweden and to present suggestions on measures to increase the reliability.

### Question at issue

The report also answers the following questions:

- Is the quality of Swedish statistics high enough to determine reliability of automatic sprinkler systems and to identify causes of failure?

- Can statistics from other countries be used as a supplement to Swedish statistics, despite possible sprinkler-related differences between countries?
- Do the reliability and cause of failure depend on the type of building?
- Do the reliability and cause of failure depend on the type of system?

## 1.3 Target group

The following groups have interest in the contents of this report: insurance companies, fire safety consultants, sprinkler consultants, inspection companies, contractors, sprinkler manufacturers, staff and students at the Department of Fire Safety Engineering and Systems Safety at Lund University and others in a position which requires knowledge about sprinkler. The terminology and the level of language in this report are adapted for these target groups.

## 1.4 Delimitation

The project is delimited to study available statistics. Thus, the authors themselves have not performed experiments with sprinkler systems.

The project does not include domestic sprinkler systems.

No methods are used to statistically ensure the results in this report.

In the assessment of the effect of a sprinkler system it is only considered if it has performed as expected or not. The appearance of the rate of heat release curve is not studied.

## 1.5 Definitions

The report includes terms that the authors consider as important to explain.

- **Operational reliability** refers to the probability that a sprinkler system will activate.

- **Performance reliability** refers to the probability that an activated sprinkler system contains, controls or extinguishes a fire.

- **Reliability** refers to the probability that a sprinkler system will perform as expected. Reliability is the product of operational reliability and performance reliability.

- **Perform as expected** expresses that a sprinkler system activates and contains, controls or extinguishes a fire.

- **Failure** expresses that a sprinkler system does not perform as expected. A failure can have different causes.

- **Type of system** refers to wet pipe sprinkler system or dry pipe sprinkler system.

- **Complete sprinkler protection** refers to a sprinkler system that not only protects a specific hazard in a room or building, but the whole room/building.

# 2 Methods

This section describes general methods that can be used when writing a scientific report, and which of these methods that are applied in this report to best fit its objective.

## 2.1 Scientific Procedure

A traditional research process has an objective perspective to the surroundings and intends to study the relationship between cause and effect. This traditional research process is based on different parts. Initially, a literature study serving as the basis for a problem formulation is performed. Data is retrieved from occurrences from the reality, so-called empirical occurences, which are described, analysed and interpreted. The information is then compiled in a report (Backman, 2008).

In order to have a scientific approach, methods are used that are applicable in a scientific context and that support analytical conclusions. Examples of such methods are: description, case study, classification, quantification, hypothesis testing, model building, comparison and prediction (Ejvegård, 2007).

Furthermore, a scientific report should be factual, objective and balanced. A report should reproduce data from all parties and not only present positive findings (Ejvegård, 2007).

### 2.1.1 Applied Approach

This report is based on the traditional research process. In the progress of the work the methods description, classification and comparison are used. The authors strive to maintain a transparency throughout the report.

#### Literature Study

The initial part of this project consists of a literature study based on a review of earlier retrieved knowledge in the subject. This literature study includes books, scientific papers, articles and statistics received in the form of hard data.

The ambition of the authors is to get a material that is as comprehensive as possible, both geographically and in terms of substance. By using material from other countries the received data provides support to the assessment of Swedish statistics, and may be used as a complement to the Swedish statistics in areas where it has deficiencies.

#### Description of Statistics

Relevant information from the literature study is thereafter presented for the reader and emphasis is on describing how the statistics are collected and processed. Such a description is necessary since statistics from different periods and countries are to be compared. It is taken into consideration that the gathered material may have been written with a special purpose and therefore can be biased.

The described material contains information about the reliability of sprinkler system and about causes to why a sprinkler system fails. The causes show where measures can have most impact.

#### Analysis

Collected information is organised by the scientific method classification and the authors try to find relations among data. In addition a deeper examination of the described information is carried out by the authors. The analysis render possible to answer the questions at issue.

**Interpretation**

When the information is classified it can be compared and interpreted. In the term interpretation there is room for the authors´ own reflections and for discussions about deficiencies in the report. The analysis and interpretation of the information together constitute the basis for the conclusions and suggestions on measures that end the report.

# 3 Available Statistics

The literature study of the project results in the selection of material presented in this section. The material is divided by their original source into nine subsections. The content of the statistics in each subsection vary, which results in different expressions for describing the effect of the sprinkler system: reliability, operational reliability and performance reliability. In each subsection the used expression is stated.

The first six subsections handle statistics from rescue services and from insurance companies. In these six subsections it is the level of detail in the statistics that determines which of the above mentioned expressions that is calculated.

The subsequent three subsections have their origin in scientific papers, articles and books, where the final subsection is an overview of reliabilities from several different sources. In these three subsections the expression is presented as in the source.

When the cause of failure of the automatic sprinkler system is described in the statistics this is presented under its own heading and subsection.

The statistics have been processed by the authors and it is described in each section what is done. The processing is done to get homogeneity among the subsections. The authors have proceeded in accordance with the following guidelines:

- When the effect of a sprinkler system is not indicated in the statistics the incident is not included in the data.
- At the description of foreign statistics the corresponding English terms are used to the greatest extent possible.
- The statistics is, where possible, grouped into industry and general building.
- The statistics is, where possible, grouped into wet and dry pipe systems.
- The statistics is declared to apply for either sprinkler systems or for water-sprinkler systems. If sprinkler system is stated foam, water mist, carbon dioxide and other gaseous extinguishing agents may be included in the data.

## 3.1 Incident Statistics from Sweden

Swedish incident statistics have been received from Colin McIntyre, system manager at the Swedish National Centre for Learning from Incidents & Accidents (NCO) at the Swedish Rescue Services Agency.

NCO each year collects and processes incident reports from rescue services all over the country with an exception of a few municipalities, they represent less than one percent of all municipalities (Swedish Rescue Services Agency, 2007).

The incident report used by the Swedish rescue services was revised in 2005, and the statistical data is based on that version (C. McIntyre, personal communication, 7 July, 2008). Parts of the incident report are reproduced in Appendix 1.

The data includes 690 incidents, covering all fires between the 1st January 2006 and 31st December 2007 in industries, general buildings or other buildings with automatic extinguishing systems. The data is presented in Table 3:1.

In the statistics it is not indicated which automatic extinguishing system that has been installed, neither with respect to the type of system, the extinguishing agent or if it has been done as a complete protection or a local protection. Additionally the cause of failure is not stated when the sprinkler system has not performed as expected.

Four function texts describe the effect of the automatic extinguishing system in the Swedish incident report. These are:

- extinguished
- contained - but did not extinguish
- functioned - but did not contain
- present - but did not function

Incidents where it is stated that the automatic extinguishing system extinguished or contained a fire have been assessed as successful by the authors. The reliability of the automatic extinguishing system is calculated to 69 percent according to:

$$Reliability = \frac{Number\ of\ incidents\ that\ extinguished\ and\ contained}{Total\ number\ of\ incidents}$$

**Table 3:1 The effect of automatic extinguishing systems divided into type of building for the years 2006-2007 (Incident statistics from Sweden, 2008).**

| **Effect** | **Industry** | | **General building** | | **Other building** | | **Total** | |
|---|---|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent | Number | Percent |
| Extinguished | 211 | 45 | 38 | 22 | 5 | 10 | 254 | 37 |
| Contained | 152 | 32 | 49 | 29 | 24 | 48 | 225 | 33 |
| Functioned | 43 | 9 | 25 | 15 | 10 | 20 | 78 | 11 |
| Present | 64 | 14 | 58 | 34 | 11 | 22 | 133 | 19 |
| Total | 470 | 100 | 170 | 100 | 50 | 100 | 690 | 100 |
| **Reliability [%]** | **77** | | **51** | | **58** | | **69** | |

## 3.2 Incident Statistics from Finland

The Finish incident statistics has been received from Pelastusopisto, the Finish Emergency Services College.

The data consists of fires in industries and general buildings from 2004 to 2007 and includes a total of 351 incidents. The data consists of automatic water sprinkler systems with a complete sprinkler protection. It does not differentiate between wet pipe sprinkler and dry pipe sprinkler. The data is presented in Table 3:2.

In the incident statistics it is not stated which type of automatic extinguishing system that has been installed in the building, neither whether it gives a complete or a local sprinkler protection, nor what type of extinguishing agent that was used. However, the cause of failure is registered.

Incidents where it is stated that the automatic water sprinkler system extinguished or contained a fire have been assessed as successful by the authors. The reliability of automatic water sprinkler systems is calculated to 38 percent according to:

$$Reliability = \frac{Number\ of\ incidents\ that\ extinguished\ and\ contianed}{Total\ number\ of\ incidents}$$

**Table 3:2 The effect of automatic water sprinkler systems divided into type of building for the years 2004-2007 (Incident statistics from Finland, 2008).**

| **Effect** | **Industry** | | **General building** | | **Total** | |
|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent |
| Extinguished | 43 | 17 | 15 | 15 | 58 | 17 |
| Contained | 69 | 27 | 8 | 8 | 77 | 22 |
| Function or effect not satisfactory | 10 | 4 | 4 | 4 | 14 | 4 |
| Did not function | 132 | 52 | 70 | 72 | 202 | 58 |
| Total | 254 | 100 | 97 | 100 | 351 | 100 |
| **Reliability [%]** | **44** | | **24** | | **38** | |

### 3.2.1 Cause of failure

In the incidents where the water sprinkler systems have failed cause of failure is registered. This is presented in Table 3:3. The most common cause of failure is that the sprinkler system did not have time to function.

**Table 3:3 Cause of failure divided into type of building for the years 2004-2007 (Incident statistics from Finland, 2008).**

| Cause | Industry | | General building | | Total | |
|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent |
| Did not have time to function | 93 | 64 | 55 | 74 | 148 | 69 |
| Fire outside the protected area in the building | 32 | 23 | 13 | 18 | 45 | 21 |
| Fire outside the building | 9 | 6 | 2 | 3 | 11 | 5 |
| Function or effect was deficient for other reason | 5 | 4 | 3 | 4 | 8 | 4 |
| Did not function for other reason | 3 | 2 | 1 | 1 | 4 | 2 |
| Total | 142 | 100 | 74 | 100 | 216 | 100 |

## 3.3 Incident statistics from Norway

Norwegian incident statistics is received from The Directorate for Civil Protection and Emergency Planning which collects and puts together incident reports from Norway's rescue services.

The incident statistics consist of 1262 fires in buildings with an extinguishing system. The authors have eliminated incidents where it is registered that the building was equipped with other extinguishing system than sprinkler, which leaves 736 incidents. However it cannot be guaranteed that all incidents have sprinkler systems with water as the extinguishing agent. The effect of the sprinkler systems is stated in 457 of the 736 incidents.

After the process, done by the authors, the data consists of fires in general building/industry and in other buildings between 1st January 1998 and the 31st December 2007 and includes a total of 457 incidents. The data is presented in Table 3:4.

The incident statistics do not distinguish between wet pipe and dry pipe sprinkler, but the incidents are divided into types of building. Examples of buildings in the category general buildings/industry are retirement homes, production facilities, schools and shops (Home page for Direktoratet for Samfunnssikkerhet og Beredskap, 2008). In the category other building the authors have gathered incidents that are registered as a fire in a boat, garage or in other building. Furthermore the cause of failure is stated in the incident statistics.

The reliability of automatic sprinkler systems is calculated to 74 % according to:

$$Reliability = \frac{Number\ of\ incidents\ that\ functioned}{Total\ number\ of\ incidents}$$

**Table 3:4 The effect of automatic sprinkler systems divided into type of building for the years 1998-2007 (Incident statistics from Norway, 2008).**

| **Effect** | **General building/Industry** | | **Other building** | | **Total** | |
|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent |
| Functioned | 334 | 74 | 4 | 80 | 338 | 74 |
| Did not function | 118 | 26 | 1 | 20 | 119 | 26 |
| Total | 452 | 100 | 5 | 100 | 457 | 100 |
| **Reliability [%]** | **74** | | **80** | | **74** | |

### 3.3.1 Causes of Failure

The cause of failure is registered in 17 of the 119 incidents where it is registered that the sprinkler system has failed. These are presented in Table 3:5. The most frequent cause of failure is that the sprinkler system has not activated. All 17 incidents are from general building/industry. The classification in the table is done by the authors with respect to both the name of the group and to the attribution of each incident.

**Table 3:5 Cause of failure for the years 1998-2007 (Incident statistics from Norway, 2008).**

| Cause | Number | Percent |
|---|---|---|
| Not activated | 8 | 47 |
| Out of order | 6 | 35 |
| In sufficient amount of water | 2 | 12 |
| Building partially sprinklered with deficient fire compartmentation | 1 | 6 |
| Total | 17 | 100 |

## 3.4 Incident Statistics from London

Incident statistics from London have been received from Alan Brinson, Executive Director, European Fire Sprinkler Network.

The material consists of all incidents with installed sprinkler systems that the Fire Brigade in London, with its 33 boroughs, has attended to and includes a total of 163 incidents. The material does not include fires where the sprinkler system quickly put out the fire and therefore the Fire Brigade was not summoned (A. Brinson, personal communication, 18 June, 2008).

Of the 163 incidents the effect of the sprinkler system is registered for 161 incidents.

After the process, done by the authors, the data consists of 161 incidents and includes all fires between 1996 and 2005 in industries and general buildings. The data is presented in table 3:6.

The incident statistics provide information on date, address, type of building, type of system, the effect of the sprinkler system and on cause of failure.

Incidents where it is stated that the automatic sprinkler system extinguished or contained a fire have been assessed as successful by the authors. The reliability of automatic sprinkler systems is calculated to 85 % according to:

$$Reliability = \frac{Number\ of\ incidents\ that\ extinguished\ and\ contained}{Total\ number\ of\ incidents}$$

**Table 3:6 The effect of Automatic sprinkler system divided into type of building for the years 1996-2005 (Incident statistics from London, 2008).**

| Effect | Industry | | General building | | Total | |
|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent |
| Extinguished | 15 | 23 | 50 | 52 | 65 | 40 |
| Contained | 40 | 63 | 32 | 33 | 72 | 45 |
| Not contained | 6 | 9 | 4 | 4 | 10 | 6 |
| Failed | 3 | 5 | 11 | 11 | 14 | 9 |
| Total | 64 | 100 | 97 | 100 | 161 | 100 |
| **Reliability [%]** | **86** | | **85** | | **85** | |

In Table 3.7 the incidents are divided into wet pipe and dry pipe system and their reliability is calculated to 86 percent and 92 percent respectively. Note that wet pipe and dry pipe sprinkler do not sum up to the total number of sprinkler systems since that group can include systems using other extinguishing agents.

**Table 3:7 The effect of automatic sprinkler systems divided into type of system for the years 1996-2005 (Incident statistics from London, 2008).**

| Effect | Wet pipe | | Dry pipe | | Total | |
|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent |
| Extinguished | 48 | 40 | 3 | 21 | 65 | 40 |
| Contained | 54 | 45 | 10 | 71 | 72 | 45 |
| Not contained | 8 | 7 | 1 | 7 | 10 | 6 |
| Failed | 9 | 8 | 0 | 0 | 14 | 9 |
| Total | 119 | 100 | 14 | 100 | 161 | 100 |
| **Reliability [%]** | **86** | | **92** | | **85** | |

### 3.4.1 Cause of Failure

Cause of failure is registered in 20 of the 24 incidents where it is stated that the sprinkler system has not performed as expected. In Table 3.8 cause of failure is presented divided into type of building. The most frequent cause is that the fire was too small to activate a sprinkler and that the fire was outside the protected area in the building. The classification in the table is done by the authors with respect to both the name of the group and to the attribution of each incident.

**Table 3:8 Cause of failure divided into type of building for the years 1996-2005 (Incident statistics from London, 2008).**

| Cause | Industry | | General building | | Total | |
|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent |
| Fire too small to activate sprinkler | 1 | 17 | 5 | 36 | 6 | 30 |
| Fire outside the protected area in the building | 0 | 0 | 6 | 43 | 6 | 30 |
| Inadequate designed system for present occupancy | 3 | 50 | 0 | 0 | 3 | 15 |
| System shut off | 1 | 17 | 2 | 14 | 3 | 15 |
| Insufficient amount of water | 0 | 0 | 1 | 7 | 1 | 5 |
| Dust explosion | 1 | 17 | 0 | 0 | 1 | 5 |
| Total | 6 | 100 | 14 | 100 | 20 | 100 |

In Table 3:9 the incidents are divided into wet pipe and dry pipe systems. The most frequent cause for both types of system is that the fire was outside the protected area in the building. Note that dry pipe system only is represented by one incident and that wet pipe and dry pipe systems do not sum up to the total number of sprinkler systems.

**Table 3:9 Cause of failure divided into type of system for the years 1996-2005 (Incident statistics from London, 2008).**

| Cause | Wet pipe | | Dry pipe | | Total | |
|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent |
| Fire too small to activate a sprinkler | 4 | 31 | 1 | 100 | 6 | 30 |
| Fire outside the protected area in the building | 2 | 15 | 0 | 0 | 6 | 30 |
| Inadequate designed system for present occupancy | 3 | 23 | 0 | 0 | 3 | 15 |
| System shut off | 2 | 15 | 0 | 0 | 3 | 15 |
| Insufficient amount of water | 1 | 8 | 0 | 0 | 1 | 5 |
| Dust explosion | 1 | 8 | 0 | 0 | 1 | 5 |
| Total | 13 | 100 | 1 | 100 | 20 | 100 |

## 3.5 Incident statistics from New Zealand

Incident statistics from New Zealand have been received from Neil Challands, Strategic Information Analyst, at the New Zealand Fire Service (NZFS).

The material consists of 763 fires in buildings where a sprinkler system is installed. The incident report of New Zealand is designed to register both the location of the sprinkler and how it has performed, but only one of the two options can be specified. In those cases where the location of the sprinklers is specified, its effect is not. (Neil Challands, personal communication, 19 June 2008).

Based on what is mentioned above, the authors have chosen to only use the part of the statistics handling activated sprinkler systems. After the process, done by the authors, the data consists of 483 incidents between the years 2002/2003- 2007/2008. Note that the year in New Zealand in this context is from 1st July to 30th June. The data is presented in Table 3:10.

Fires during the six-year period cover standard sprinkler and residential sprinkler. Residential sprinkler should not be mistaken for domestic sprinkler as it refers to sprinkler installed in, for example, hotels, retirement homes and nursing facilities. In addition the residential sprinkler complies with a different code than standard sprinkler. Neither deluge nor spray systems are included in the material (N. Challands, personal communication, June 19, 2008).

Since only activated sprinkler systems are included in the data the performance reliability is calculated, which is 96 percent according to:

$$Performance\ reliability = \frac{Number\ of\ effective\ incidents}{Total\ number\ of\ incidents}$$

**Table 3:10 The effect of activated sprinkler systems divided into type of sprinkler for the years 2002/2003-2007/2008 (Incident statistics from New Zealand, 2008).**

| **Effect** | **Standard sprinkler** | | **Residential sprinkler** | | **Total** | |
|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent |
| Effective | 451 | 96 | 14 | 93 | 465 | 96 |
| Not effective | 17 | 4 | 1 | 7 | 18 | 4 |
| Total | 468 | 100 | 15 | 100 | 483 | 100 |
| **Performance reliability [%]** | **96** | | **93** | | **96** | |

### 3.5.1 Cause of Failure

When the effect of the sprinkler system is assessed as not effective the cause of failure is stated for 14 of 18 incidents, which are presented in Table 3:11. All 14 causes are from the group standard sprinkler. The most common cause of failure is that the extinguishing agent did not reach the fire.

**Table 3:11 Cause of failure for standard sprinkler (Incident statistics from New Zealand, 2008).**

| **Cause** | **Standard sprinkler** | |
|---|---|---|
| | Number | Percent |
| Extinguishing agent did not reach fire | 7 | 50 |
| Insufficient extinguishing agent | 5 | 36 |
| System turned off | 1 | 7 |
| Deficient maintenance | 1 | 7 |
| Total | 14 | 100 |

## 3.6 Statistics from Industriförsäkring AB for Finland

Statistics from the insurance company Industriförsäkring AB have been received from Lars-Erik Willberg, engineer in risk management.

The material includes 645 incidents. The effect of the sprinkler system is stated for 594 of these incidents.

After the process, done by the authors, the data consists of fires in industrial buildings insured by Industriförsäkring AB in Finland between 1986 and 1998 and contains a total of 594 incidents. The data is presented in Table 3:12.

The statistics are not divided into type of system, but Willberg (personal communication, 26 June 2008) implies that most of the sprinkler systems are of the type wet pipe system. Furthermore, he believes that the material represents the major part of all industrial fires in Finland. Cause of failure is not specified in the statistics.

When an incident has occurred the policyholder completes a form that describes the performance of the sprinkler system. The terms that describe the performance of the sprinkler are decisive, significant and insignificant. The meaning of the terms is vague. Decisive means that the fire more or less has been extinguished at the arrival of the rescue service, while significant means that the sprinkler system has controlled the fire or that the rescue service has arrived at an early stage and assisted the sprinkler system. Insignificant means that someone has managed to put out the fire before the sprinkler had effect, that the geometry of the room led to the sprinkler being unable to reach the fire or that the fire started in an area where no sprinkler was present (L-E. Willberg, personal communication, 26 June 2008).

The statistics consist of fires where sprinklers have activated, thus a performance reliability is calculated. Incidents where it is stated that the effect of the automatic sprinkler system was decisive or significant have been assessed as successful by the authors.

The performance reliability of automatic sprinkler systems is calculated to 91 percent according to:

$$Performance\ reliability = \frac{Number\ of\ decisive\ and\ significant\ incidents}{Total\ number\ of\ incidents}$$

**Table 3:12 The effect of automatic sprinkler system for the years 1986-1998 (Statistics from Industriförsäkring AB, 2008).**

| **Effect** | **Industry** | |
|---|---|---|
| | Number | Percent |
| Decisive | 224 | 38 |
| Significant | 319 | 54 |
| Insignificant | 51 | 9 |
| Total | 594 | 100 |
| **Performance reliability [%]** | **91** | |

## 3.7 Statistics from AFPA for Australia och New Zealand

The material in this subsection is entirely based on the book "Fire: A century of automatic sprinkler protection in Australia and New Zealand 1886-1986", written by Harry Marryatt.

The book describes 9022 fires in buildings with installed sprinkler that occurred between 21st December 1886 and 21st December 1986 in Australia and New Zealand. No distinction between wet and dry pipe system is made in the book. Marryatt makes a classification into types of occupancy which is the basis for the authors-based division into industrial and general building in this subsection. The data is presented in Table 3:13.

The basis for the book is reports provided by Australia Fire Protection Association (AFPA) and it is estimated that the available reports cover 98 percent of all fires until 1968. For the period from then until 1986, the corresponding value is 94 percent due to the decreased interest in making detailed reports available. Facts and figures in the book are verified by a thorough investigation assisted by persons controlling a number of large fires reported. Furthermore, the data in the book is considered to be sufficiently large and wide to enable valid conclusions regarding the reliability of automatic sprinkler systems to be drawn (Marryatt, 1988).

Fires are divided into two groups only regarding the effect of the sprinkler system. In the group of fires not controlled by automatic sprinkler system 49 of the 9022 fires can be found, whereas the rest is registered as fires controlled by the automatic sprinkler system. The definitions of the two groups according to the book are:

> "**Fires Not Controlled:** Fires in which automatic sprinkler systems have been unable to prevent major damage to the building and contents.
> **Fires Controlled:** Fires which have either been completely extinguished, or controlled by automatic sprinkler systems to the point that they would be extinguished even if supplementary action had not been taken by fire brigades or others." (Marryatt, 1988, p.18.).

The reliability of automatic sprinkler systems is 99.5 percent according to:

$$Reliability = \frac{Number\ of\ Fires\ Controlled}{Total\ number\ of\ fires}$$

**Table 3:13 The effect of automatic sprinkler systems divided into type of building for the years 1886-1986 (Marryatt, 1988).**

| **Effect** | **Industry** | | **General building** | | **Total** | |
|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent |
| Fires Controlled | 6828 | 99.4 | 2145 | 99.5 | 8973 | 99.5 |
| Fires Not Controlled | 38 | 0.6 | 11 | 0.5 | 49 | 0.5 |
| Total | 6866 | 100 | 2156 | 100 | 9022 | 100 |
| **Reliability** | **99.4** | | **99.5** | | **99.5** | |

### 3.7.1 Cause of Failure

Causes for why the sprinkler system has not performed as expected in the 49 cases where the fire has been specified as not controlled are presented in Table 3:14. It should be mentioned that different causes often are present in the same incident. In those cases the cause that the authors assess as the most significant for the failure is represented. The most common cause of failure is that the building has been partially sprinklered with deficient fire compartmentation. The classification in the table is done by the authors with respect to both the name of the group and to the attribution of each incident.

**Table 3:14 Cause of failure divided into type of building (Marryatt, 1988).**

| Cause | Industry | | General building | | Total | |
|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent |
| Insufficient amount of water | 7 | 18 | 1 | 9 | 8 | 16 |
| Inadequate designed system for present occupancy | 9 | 24 | 0 | 0 | 9 | 18 |
| Building partially sprinklered with deficient fire compartmentation | 8 | 21 | 7 | 64 | 15 | 31 |
| Valve shut off | 2 | 5 | 2 | 18 | 4 | 8 |
| Valve shut off during fire | 3 | 8 | 1 | 9 | 4 | 8 |
| Rapid spread of fire /Explosion | 5 | 13 | 0 | 0 | 5 | 10 |
| Other/difficult to determine | 4 | 11 | 0 | 0 | 4 | 8 |
| Total | 38 | 100 | 11 | 100 | 49 | 100 |

In two of the four incidents where the valve had been shut off, this has been done intentionally by an arsonist. In three of the eight incidents where the amount of water had been insufficient it was because of the fire brigade connecting to the main water supply which already provided the sprinkler system. Only once the system had originally been inadequatly designed, in the other incidents the design was inadequate due to a change of occupancy in the building (Marryatt, 1998).

## 3.8 Statistics from NFPA for the U.S.

This subsection is based on the 2007 report from the National Fire Protection Association (NFPA) written by John R Hall, Jr. NFPA has issued a statistical report on the effect of sprinkler systems almost every year for the last 20 years. The report is the most recent and the first in their collection with data from a new system which is used to collect more detailed statistics (J.R. Hall, Jr, personal communication, 11 July 2008).

The data in the report is a compilation of information from the years 2002 to 2004. Data are derived using two different databases in order to avoid biases that can occur as the reporting is voluntary. Due to this method an estimated figure of all incidents is used. The national estimated data for the three-year period is 10 100 fires. Of these incidents 8 800 are wet pipe systems and 1 000 are dry pipe systems. Fires that were too small to activate a sprinkler system and fires in an unprotected area are not included in these data. Furthermore, not all incidents are reported in the U.S. since other fire departments than the U.S municipal fire department sometimes are called. If multiple sprinkler systems have been installed the system that is designed to protect the area where the fire started is chosen (Hall, 2007).

In Hall´s report operational reliability, performance reliability and reliability are stated for automatic sprinkler systems. There is no division into industries and general buildings in this subsection as it is not allowed by the material.

In Table 3.15 operational reliability, performance reliability and reliability are presented. The figures in the table are directly reproduced from Hall´s report. It should be noted that wet pipe and dry pipe systems do not sum up to the total number of sprinkler systems as that group also includes systems with other extinguishing agents.

The operational reliability is 93 percent for all sprinkler systems. For wet pipe and dry pipe sprinkler it is 93 and 87 percent, respectively. The operational reliability is calculated according to:

$$Operational\ reliability = \frac{Number\ of\ sprinkler\ systems\ that\ activated}{Total\ number\ of\ sprinklered\ fires}$$

The performance reliability is 97 percent for all sprinkler system. This means that when a sprinkler operates it is effective 97 percent of the times. For wet pipe and dry pipe systems the performance reliability is 97 and 95 percent, respectively, and is calculated according to:

$$Performance\ reliability = \frac{Percentage\ that\ activated\ and\ were\ effective}{Percentage\ that\ activate}$$

To declare a sprinkler system as effective it has to control and contain the fire until the fire department arrives (Hall 2007). To control a fire Hall explains as a prevention of fire spreading to another room. In large premises the sprinkler system should be designed to stop fire spread at an earlier stage (J.R. Hall, Jr, personal communication, 11 July, 2008).

The product of the operational reliability and the performance reliability gives reliability. The reliability of automatic sprinkler systems is 90 percent. For wet pipe and dry pipe systems the reliability are 91 and 83 percent, respectively. The reliability is calculated according to:

$$Reliability = Operational\ reliability \times Performance\ reliability$$

**Table 3:15 The effect of automatic sprinkler systems divided into type of system for the years 2002-2004 (Hall, 2007).**

| | Wet pipe | Dry pipe | Total |
|---|---|---|---|
| Operational reliability [%] | 93 | 87 | 93 |
| Performance reliability [%] | 97 | 95 | 97 |
| **Reliability [%]** | 91 | 83 | 90 |

### 3.8.1 Cause of Failure

The most frequent reason that a sprinkler system does not activate is that the system has been shut off (Hall, 2007). When a sprinkler system has been activated but has not been effective the cause of failure is stated, see Table 3:16. The categories of the causes and the values are reproduced from Hall´s report. Note again that fires too small to activate a sprinkler system and fires in an unprotected area are not included in the data.

The most frequent reason that a sprinkler system has not performed as expected is that the agent did not reach the fire. Same cause applies for wet pipe systems. For dry pipe systems the most frequent cause of failure is insufficient amount of water.

**Table 3:16 Cause of failure divided into type of system for the years 2002-2004 (Hall, 2007).**

| Cause | Wet pipe [%] | Dry pipe [%] | Total [%] |
|---|---|---|---|
| Agent did not reach fire | 51 | 0 | 41 |
| Not enough agent released | 17 | 86 | 29 |
| Inappropriate system for type of fire | 18 | 0 | 14 |
| Lack of maintenance | 5 | 14 | 6 |
| Manual intervention | 5 | 0 | 6 |
| System component damaged | 5 | 0 | 4 |
| Total | **100** | **100** | **100** |

## 3.9 Statistics from Six Articles and Papers

This section presents an overview of values of the reliability of automatic sprinkler installations together with their respective source, see Table 3:17. The sources consist of a number of articles and scientific paper, published between 1988 and 2007, which are briefly described here.

**Table 3:17 An overview of reliability of automatic sprinkler systems from articles and scientific papers. The publishing year is indicated in parenthesis.**

| Source | Reliability [%] |
|---|---|
| FM Global (2007) | 94-98 |
| Koffel (2005) | 90 |
| Arup Fire (2006) | > 90 |
| Budnick (2001) | 92,2/94,6/97,1 |
| Linder (1993) | 97 |
| Maybee (1988) | 99,5 |

**FM Global, 2007**

FM Global has conducted a probabilistic reliability analysis which shows that the reliability is between 94 and 98 percent for wet pipe systems. They specify that the result assumes that the systems are adequatly designed and well maintained (FM Global, 2007).

**Koffel, 2005**

The report by Koffel is a compilation of previous studies. In his paper he refers to Budnick (2001), Marryatt (1988), Linder (1993) and Maybee (1988). He proposes a reliability of 90 percent and believes that the value can be increased if the data would include the fires that are not reported as the sprinkler has extinguished the fire quickly (Koffel, 2005).

**Arup Fire, 2006**

This paper presents values of reliability from the NFPA and the British Standard Institution (BSI). Arup Fire believes that the reliability of sprinkler systems is higher than 90 percent (Arup Fire, 2006).

**Budnick, 2001**

The article by Budnick is a compilation of previous studies. He refers, among others, to Marryatt (1988), Linder (1993) and Maybee (1988). Budnick takes the uncertainties of the stated reliabilities into consideration using a confidence interval and a normal distribution. The reliability is presented as a range between 92.2 and 97.1 percent, with an average of 94.6 percent (Budnick, 2001).

**Linder, 1993**

The report, published by the National Institute of Standards and Technology (NIST), is based on 3446 fires between the years 1988 and 1993. Fires with minor losses are not included in the data since they are not reported. The data represents primarily larger industries. Linder´s conclusion is that sprinkler systems can control 97 percent of all fires (Linder, 1993).

**Maybee, 1988**

The report is published by the Department of Energy in the U.S. The data consists of 184 incidents between the years 1952 and 1987 and includes all fires, regardless of the costs of loss. The reliability that Maybee specifies in his report is 99.5 percent and is valid for wet pipe systems (Maybee, 1988).

# 4 Analysis of Available Statistics

In this section the available statistics presented in Section 3 are analysed and put together. The section is divided into two parts: reliability and cause of failure. The subsections are united with the objective of the report.

## 4.1 Reliability

The reliabilities and performance reliabilities presented in section 3 are arranged in Table 4:1.

The values of reliability in the table vary between 38 and 99.5 percent. Possible reasons for this are that the quality of statistics (for example the design of the incident report) and management of sprinkler systems (installation, inspection and maintenance) differ between countries, (G. Holmstedt, personal communication, 9 June 2008).

**Table 4:1 An overview of reliabilities of automatic sprinkler systems divided into sources.**

| Source | Reliability [%] |
|---|---|
| Incident statistics from Sweden | 69 |
| Incident statistics from Finland | 38 |
| Incident statistics from Norway | 74 |
| Incident statistics from London | 85 |
| Incident statistics from New Zealand* | 96 |
| Statistics from Industriförsäkring AB for Finland* | 91 |
| Statistics from AFPA for Australia and New Zealand | 99,5 |
| Statistics from NFPA for the U.S. | 90 |
| Statistics from six reports and articles | 90-99,5 |

*for these sources performance reliability is stated.

In section 3 the reliability of automatic sprinkler systems is presented. It is divided into type of building and type of system and is arranged in Table 4:2 and Table 4:3, respectively. The reliability is higher for industry than for general building in three of four sources.

**Table 4:2 The reliability of automatic sprinkler systems divided into sources and type of building.**

| Source | Reliability [%] | |
|---|---|---|
| | Industry | General building |
| Incident statistics from Sweden | 77 | 51 |
| Incident statistics from Finland | 44 | 24 |
| Incident statistics from London | 86 | 85 |
| Statistics from AFPA for Australia and New Zealand | 99,4 | 99,5 |

Dry pipe systems have a higher reliability than wet pipe systems in statistics from London, to the contrary in statistics from NFPA.

**Table 4:3 The reliability of automatic sprinkler systems divided into source and type of system.**

| Source | Reliability [%] | |
|---|---|---|
| | Wet pipe | Dry pipe |
| Incident statistics from London | 86 | 92 |
| Statistics from NFPA for the U.S. | 91 | 83 |

### 4.1.1 Analysis of Swedish Incident Statistics

The level of detail in the Swedish statistics is low and to generate data with higher quality the statistics is further processed by the authors in this analysis. The guideline for the analysis is to provide data which will only include a complete protection of automatic water sprinkler system.

The new data is provided using a selection process. The selection process begins with the information received in the Swedish incident statistics being revised. Based on the quality of information three criterions are provided in consultation with Mattias Skjöldebrand, Brandkonsulten AB. The criterions act as a support for the authors in the assessment of which incidents that should be included in the new data. The selection process starts from the original 690 incidents which constitute the data in subsection 3.1.

For each incident the following information is given in the incident report (Home page for the Swedish Rescue Services Agency, 2008):

- Type of building
- Cause description, given as free text
- Incident description , given as free text
- Evaluation description, given as free text
- Area where fire started
- Object where fire started
- Cause of fire
- Coverage of fire on arrival
- Function text that describes the effect of the automatic extinguishing system
- Type of detector that was activated

With the presentation of each criterion it is described how the selection process advances.

**Criterion 1**

The first criterion intends to isolate incidents when the installed sprinkler system has another extinguishing agent than water. Incidents are isolated when:

- it is registered that the automatic fire detection system is activated by a water sprinkler system
- water sprinkler system is mentioned in the free text

Together these incidents constitute 155 of the 690 original incidents.

**Criterion 2**

The second criterion intends to remove incidents, from the 155 remaining, when the sprinkler system is a local sprinkler protection. The authors assess that local sprinkler protection is more frequent in the areas mentioned in this criterion. Incidents are removed when it is stated that it has been a fire in:

- storage room or machine that handles sawdust, wood chips or pellet
- silo, tank plane, drying room or stokehold
- other machine that has its own sprinkler

The second criterion removes 34 incidents from the data.

**Criterion 3**
The third criterion intends to remove incidents, from the 121 remaining, which of self-explanatory reason should not be included in the data. Incidents are removed when:

- it is registered that no fire where located
- it is registered in free text that the extinguishing agent was of other type than water

The third criterion removes five incidents from the data.

**Final data**
The final data consists of 116 incidents and is assessed, with support of the criterions, to consist of automatic water sprinkler systems which constitute a complete protection.

The authors assess that the automatic water sprinkler system has performed as expected when it is stated in the function text that it extinguished or contained the fire. The final data is presented in Table 4:4.

The reliability of automatic sprinkler systems is calculated to 92 percent according to:

$$Reliability = \frac{Number\ of\ incidents\ that\ extinguished\ or\ contained}{Total\ number\ of\ incidents}$$

**Table 4:4 The effect of automatic water sprinkler systems divided into type of building for the years 2006-2007 (Incident statistics from Sweden, 2008).**

| **Effect** | **Industry** | | **General building** | | **Other buildings** | | **Total** | |
|---|---|---|---|---|---|---|---|---|
| | Number | Percent [%] | Number | Percent [%] | Number | Percent [%] | Number | Percent [%] |
| Extinguished | 42 | 64 | 24 | 56 | 2 | 29 | 68 | 59 |
| Contained | 21 | 32 | 14 | 33 | 4 | 57 | 39 | 34 |
| Functioned | 2 | 3 | 0 | 0 | 1 | 14 | 3 | 3 |
| Present | 1 | 2 | 5 | 12 | 0 | 0 | 6 | 5 |
| Total | 66 | 100 | 43 | 100 | 7 | 100 | 116 | 100 |
| **Reliability [%]** | **95** | | **88** | | **86** | | **92** | |

For nine incidents it is registered that the water sprinkler system has failed to extinguish or contain the fire. The incident description is discussed in Section 5. The incident description for these nine cases can be found in Appendix 1 and is discussed in Section 5.

## 4.2 Cause of Failure

By analysing and demonstrating the causes of why an automatic sprinkler system fails, it is clearly indicated where measures can make the most impact. If these measures are taken it would mean an increase of the probability that a sprinkler system performs as expected.

In Section 3 the cause of failure divided into type of building and system is presented. The authors assess that it is not possible to see whether a cause depends on the type of object or system. This is because the level of the statistics is too low. For this reason, no overview of this is presented

### 4.2.1 Analysis of Cause of Failure

In the Swedish incident statistics the cause of failure is not indicated. The sources that specify cause of failure are incident statistics from Finland, Norway, London and New Zealand together with statistics from the AFPA and the NFPA.

Through contact with A. Brinson, M. Arvidson, K. Brandsjö and J-E. Holmli (personal communication, 12 August 2008) the authors have examined which country that resembles Sweden the most with regard to the installation, maintenance and experience of sprinkler installations. The joint perception of the asked persons was that Finland, Norway and England resemble to Sweden more than New Zealand, Australia and the U.S. do. The perception is mainly based on that these countries use similar standards that Sweden use.

The authors make the assumption that the causes of failure that are frequent in statistics from Finland, Norway and England also represent the most common causes of failure in Sweden.

The most common causes of failure of these three countries are sorted by similar failures in four extensive categories. From these, suggestions on measures may be prepared, which is discussed in Section 5. The groups are presented without ranking and the included causes are stated under the name of the group:

- No activation of sprinkler system:
  *Did not have time to function*
  *Not activated*
  *Fire too small to activate sprinkler*

- Fire in an non-sprinklered area with deficient fire compartmentation
  *Fire outside the protected area in the building*
  *Fire outside the building*

- Extinguishing agent do not reach the fire:
  *Insufficient amount of water*
  *Inadequate designed system for present occupancy*

- Sprinkler system shut off:
  *Out of order*
  *System shut off*

# 5 Discussion

The discussion together with the analysis, forms the basis for conclusions and suggestions on measures. This part leaves more room for interpretation and for reflections of the authors.

## 5.1 Reliability

This subsection considers possible explanations to why the reliability of automatic sprinkler systems differs between countries. This is followed by a discussion on the analysis of the Swedish incident statistics.

### 5.1.1 Reasons to Why the Reliability Vary Among Sources

The variation in the reliability from different sources may be the result of different things. It can:

- reflect the real situation
- depend on the design of the incident report
- be because the data vary in actuality, validity, size or response frequency

One reason to why the reliability is different may be that countries have different experiences of, and demands on, sprinkler management. For example Arvidson (1995) says that the high reliability of sprinkler systems in Australia and New Zealand is due to a high standard of installation, maintenance, service and testing.

Incident reports differ in design between the countries. The formulation of questions, and thus the answers, for investigating for example the effect of the sprinkler and possible cause of failure is different depending on the country. An example is that incident statistics from both Finland and Sweden have the concepts of function and contain as two different options to describe a sprinkler systems effect. The interpretation is difficult since the conventional perception of a functioning sprinkler in Sweden is the assumption that it should contain a fire.

Regarding actuality, it is remarkable that the book of Marryatt is widely used despite the fact that it handles incidents from 1986 and 100 years back in time. Furthermore, in the literature study it is noted that Marryatt´s book recurs in several reports. For example, Koffel (2005) refers in his report to both Marryatt (1986), and Budnick (2001). At the same time Budnick is also referring to Marryatt, who is thus represented twice. This is worth having in mind when using these sources.

The validity of the data in the report is affected by the lack of definitions of concepts and guidelines for how the effect of a sprinkler system is to be assessed and specified in the incident report. The intention of such definitions and guidelines is that assessment of the incidents should be equal in each case. The validity of the data does also relate to the topic actuality when Hall (personal communication, 11 July 2008) describes that the reports from NFPA from the 1970s century and earlier did not use a statistically valid or representative method to collect information from the incidents. The authors therefore suggest that older reports from the NFPA should not be used.

The data vary in size and in the period of time it covers. The opinion of the authors is that extensive data which covers a long period of time generally provides less room for random errors.

The sources in the report vary in response frequency. As regards statistics from insurance companies Arvidson (1995) declares that policy-holders do not report all fires to their insurance companies since the liquidation costs in some cases are less than the excess and because of the possible influence on the insurance premium. Equally do not all fires get registered in the U.S incident statistics since the alarm sometimes goes to other fire brigades than the municipal.

All these factors have a part in the fact that the value of reliability differs between countries.

### 5.1.2 The Analysis of Swedish Incident Statistics

The criterions used in the more thorough process of Swedish incident statistics were essential for the outcome of the data and it is therefore considered important to discuss its meaning and its source of error.

The rough formulation of the criterions was necessary since the level of detail of the Swedish statistics was low. The criterions were set to remove incidents when the incident description did not give sufficient information to determine if it should be included in the data or not. This resulted in the data becoming smaller, but also that the data probably included a higher percentage of incidents with installed water sprinkler systems as a complete sprinkler protection.

The first criterion intended to isolate incidents with water sprinkler systems from other incidents. This first criterion reduced the size of the data most of the three criterions when incidents with water spray, foam, gaseous extinguishing agents and incidents where the type of agent was not stated were removed. It is assessed that this criterion even led to some incidents with water sprinkler systems being removed. For example it is sometimes mentioned in free text that a sprinkler system had extinguished the fire when the rescue service arrived. Such an incident has been removed since it could not be determined if it was a water sprinkler system that was referred to.

The term reliability is used for the entire data in the analysis. For the incidents isolated because of the automatic fire detection system being activated by a water sprinkler system a performance reliability would have been the adequate term. However, in some incident descriptions from this group it is stated that the automatic fire detection has not activated. Furthermore, the term reliability is adequate for the incidents isolated because of water sprinkler system being mentioned in the free text.

The second criterion intended to remove incidents when the sprinkler system was a local sprinkler protection. The incidents that were removed by this criterion were mostly from the wood industry. Although local protection is common in the wood industry it is considered probable that local protection in many cases are supplemented with a complete sprinkler protection. Therefore it is probable that incidents that should have been included instead have been removed from the data since it was not known if it was a local or a complete protection that was referred to.

In the received incident statistics the incidents are anonymous because of reasons of secrecy. This gives small opportunities to control the strength of the criterions and therefore also the validity of the selection process.

The nine incidents that in the analysis of the Swedish incident statistics are stated as failed can be found in Appendix 1. The authors assess that it is not a matter of course that all these nine incidents have failed. In the incident descriptions it is registered that several of the fires are extinguished in another way than by the sprinkler system.

For example they have died out or been put out by staff. The authors mean that such incidents should not be regarded as cases where the sprinkler system has failed.

The analysis of the Swedish statistics between the years 2006 and 2007 did result in data consisting of 116 incidents, of which 107 was stated as successful. This gives a reliability of 92 percent. Further the analysis showed that, according to the statistics, sprinkler systems in Sweden function more often in industry compared to general buildings. The level of detail in Swedish statistics does not allow a division of the incidents into type of system.

It is difficult to assess the strength of the results since the data has deficiencies and since the validity in the selection process cannot be controlled. However, it should be noted that statistics from other sources reinforces the results from the analysis of the Swedish incident statistics.

## 5.2 Cause of Failure

At first this subsection discusses possible explanations to why the cause of failure differs between countries. This is followed by suggestions on measures that can increase the reliability of automatic sprinkler systems.

### 5.2.1 Reasons to Why Cause of Failure Vary Among Sources

The data for the section about cause of failure is part of the data used for the section about reliability, thus the discussion in Subsection 5.1.1 also applies to this section. Two further differences are described briefly here.

The questionnaires in the incident reports differ in design and have different options for what the cause of failure for an automatic sprinkler system might be. This results in the categories for cause of failure being both many and various. For example, statistics from the U.S. specify causes of failure for activated sprinkler systems, while Finland has did not activate as an option to cause of failure.

The response frequency regarding cause of failure is low. The incidents where the cause of failure is indicated are usually few to the number. For example, in Norway the cause of failure is indicated for 17 of the 119 incidents in which it is stated that the sprinkler system did not work. The opinion of the authors is that a small number of responses imply a greater risk that the result can be affected by coincidences.

### 5.2.2 Causes of Failure and Remedies for Sweden

The assumption done by the authors in Section 4.2.1 means not only that the causes of failure from other countries are applied to Sweden, but also that the countries most suitable for this are Finland, Norway and England.

The accuracy in the first part of the assumption is difficult to comment. The other part turns out to be of less importance realizing the most common causes for Australia, New Zealand and the United States had resulted in the same four groups as those listed in Section 4.2.1. Accordingly, all countries can represent Sweden.

The differences in design of the incident reports mentioned above lead to that it is complicated to organize the causes of failure. The classification after failure in Section 4.2.1 is the one that the author assess to be best suited for the data presented in Section 3. Each group may have different causes for their failure. The classification is used to provide suggestions on measures to remedy these causes.

In the group *No activation of sprinkler system* causes are found that are difficult to interpret, such as did not have time to function and fire too small to activate a sprinkler system. The authors assess that failures with these causes in many cases should not be ascribed to sprinkler systems and therefore not included in data for calculation of reliability. In some cases, however, causes can be component failure, inadequate design or lack of maintenance.

The group *Fire in non-sprinklered space with inadequate fire compartmentation* shows the importance of a satisfactory fire compartmentation in a partially sprinklered building. In new buildings the sprinkler system should give complete protection. Marryatt (1988) argues that it has been known for long that it is unreasonable to partially sprinkler buildings. He argues that an automatic sprinkler system is designed to contain a fire where it starts, and the idea of only install sprinkler in the part where a fire is most likely to occur is unwise.

There are several possible causes for the group *Extinguishing agent did not reach fire*. The sprinkler system can be inadequate designed for the occupancy of the building, either from the start or as a result of a change of occupancy. Furthermore, the cause may be that the sprinkler head is shielded from the fire or that the amount of water provided by the sprinkler is insufficient.

It is important that the sprinkler system is designed correctly from the beginning. Furthermore, the importance of routines and of having a well functioning fire-protection management system must be comprehended. This to avoid that the sprinkler is shielded from the fire, that the design no longer is correct and to ensure a sufficient water supply.

The last group *Sprinkler system turned off* often occurs due to the lack of routines for temporarily turned off sprinkler systems because of a fire in a new building where the installed sprinkler system not yet has been taken into operation. Again, it is important that the fire-protection management system is satisfactory.

The suggestions on measures can be summarized as the need for a higher level of fire-protection management system, particularly with respect to maintenance and routines. In Sweden the owner of the building and the tenant has the responsibility for this. Further, a higher standard on design, installation and inspection of the sprinkler system is required. It is important that remarks on the sprinkler system are clearly indicated in the inspection protocol and that the person with the responsibility is aware of the remarks and takes measures to remedy them.

Often the remarks remain year after year and the inspections companies cannot put demands for measures being taken. For insured buildings it is the insurance companies that have to take action and put demands on the policy holders (G. Holmstedt, personal communication, 27 August, 2008). The role of the insurance companies is further discussed in section 5.4.

## 5.3 Problems from the Swedish Incident Statistics

As the work progressed, it was noted that the incident statistics from Sweden has many deficiencies. Other countries also have deficiencies, often the same as Sweden. The problems that are presented here are the secrecy, which makes the use of and the access to the statistics more difficult, and the lack of quality of the incident statistics.

National centre for learning from accidents (NCO) has as their mission to collect statistics in order to learn from past incidents and also to meet national needs in respect of facts about safety work in Sweden. NCO collect incident reports from almost all rescue services´ local database and assembles them in their central database. From this database information can be given to third person, arranged by request. However there is a requirement that the information has to be anonymous, since some information has reasons of secrecy. This leads to that the information in the statistics cannot be traced to a specific incident (C. McIntyre, personal communication, 7 July 2008).

If data instead is asked for directly from the rescue services it is not committed with the same secrecy. Instead the problem lies in that the local databases are complex and that the rescue services in many cases cannot retrieve the requested information. In conclusion NCO has the information but is not allowed to hand it out, while the rescue services are allowed to hand it out, but they do not know how to retrieve it (C. McIntyre, personal communication, 7 July 2008).

The authors mean that the secrecy has complicated further investigation of incidents which have had to be clarified, and that this is a hindrance to learning from these accidents. Without the secrecy the selection process probably would have been different and, above all, the number of incidents removed by the first criterion would have been lower. Many of the incidents that were removed by the first criterion had a too vague incident description to determine whether they would be included in the data or not. If a further investigation of the incident, through contact with the rescue services for example, had been possible the effect of the sprinkler system could have been clarified in several of these incidents and the data would have been larger. The design and outcome of the other criterions had also been different if information from the incident report had been better. The secrecy of the data becomes a problem when the information must be clarified. This is discussed further below.

Regarding the quality of incident statistics, problem often can be related to the incident report. The design of the incident report is such that it collects information about all automatic extinguishing systems in the same category. It is questioned how information, that does not differ between extinguishing systems with water gas or foam as agent, or sprinklers with complete or local protection, can be used for learning purposes.

Thomas Gell (2008), head of NCO summarizes the problem: "Those that are especially interested in a particular subject normally wants considerable many and more detailed information on this. Those who fill out the reports want to have as few lines as possible" (page 32, authors´ translation).

As mentioned in subsection 5.1.1 the concept of function, considering the effect of a sprinkler system, is difficult to interpret. There are no guidelines or definitions how words describing the effect of a sprinkler system should be interpreted. The meaning of the word function varies depending on person, and the authors believe that the incident report is too dependent of what each person puts for interpretation in these words. Based on the order that the function texts for the automatic extinguishing system has in the incident report, together with a comprehensive picture of the statistical data, the authors believes that the word function actually refer to activate.

As mentioned in subsection 4.2.1 cause of failure is not registered in Swedish statistics. This should be basic information in order to learn from accidents. The authors mean that a review of the incident report is to be in consultation with other countries. A joint design of the incident report would benefit all countries.

## 5.4 Reflections

Below are further subjects discussed, which are considered as interesting for the project.

#### Passive systems

Reliability is usually associated with active systems and is not often discussed with respect to passive systems. Although a passive system requires little or no maintenance and is long-lasting, there is reason to doubt its reliability. There are documented examples of incomplete cavity barriers and wedged-open doors, and the latter is easier to do than, for example, to turn off a sprinkler system. In contrast, the wedged-open door is more likely to have milder consequences than the absence of activation of the sprinkler at a fire.

There are fire incidents in which the undesirable outcome is partially due to poor performance of passive systems (Arup Fire, 2006).

#### Failures that should be attributed to the sprinkler system

Several of the causes of failure described in the analysis section are attributable to the human factor. This leads to a discussion about which causes of failure that really should be attributed to the sprinkler system. Component failure, although it can be deduced to man, is assessed to be a failure that should be attributed to the sprinkler system. Besides that can just about any cause of failure be attributed to human handling of the sprinkler systems, and therefore it is primarily this that needs to be taken care of in order to increase the reliability.

#### Interests from the insurance companies

As mentioned in section 5.2.2 remarks on a sprinkler system often remain year after year without taking measures to remedy them. Insurance companies have a great possibility to put demands and to take actions. When the deficiency of a sprinkler system is not remedied they can, for example, raise the premium of the policyholder. If the deficiencies are remedied, the risk is smaller for major damage from a fire. Thus, the insurance companies have much to win in the situation.

It is important that inspection companies, insurance companies and the tenant cooperate in order to take measures to remedy the defects quickly, especially at severe remarks such as: change of risk classification and deficient water supplies. This cooperation does not work today and the involvement of the insurance companies in these issues must be improved. A group with representatives from the insurance companies and inspection companies will be put together to discuss these problems and to formulate methods to solve them (G. Holmstedt, personal communication 27 August 2008).

# 6 Conclusions and Suggestions on Measures

The conclusions and suggestions on measures presented in this section are based entirely on the analysis and discussion of the report.

## 6.1 Conclusions

The analysis of the Swedish incident statistics for the years 2006-2007 shows that:

- The reliability of automatic sprinkler systems in Sweden is 92 percent.
- The reliability is higher for industries compared to general buildings in Sweden.
- The level of detail in the statistics from the Swedish rescue services does not permit a division of the incidents into type of system.

These conclusions are based on data that has been processed by the authors. It is difficult to assess the validity of the conclusion since the data is deficient. It should however be noted that:

- The reliability of automatic sprinkler systems from most sources is around 90 percent and that this indicates that the value above is reasonable.
- Several sources with a relatively large data also show that the reliability is higher for industries than for general buildings.
- Two sources present reliability divided into system. Statistics from London show that dry pipe systems have a higher reliability than wet pipe systems while statistics from the U.S. show the opposite.

Further conclusions answering the questions at issue are:

- It is assessed that international statistics can serve as an alternative to Swedish statistics regarding cause of failure under the circumstances given in this report. In other cases, statistics from other countries can serve as support for assessments in the report.
- The data in its entirety is assessed to be too small to determine whether the cause of failure depends on the type of system.

## 6.2 Suggestions on measures

Measures are divided into suggestions that increase the reliability of automatic sprinkler systems and suggestions that enhance the quality of statistics.

- A higher level on fire-protection management system, including maintenance and routines is required.
- A higher standard on design, installation and inspection of sprinkler systems is required.
- Insurance companies have to make demands on policyholders and improve their interaction with inspection companies to ensure a reliable function of sprinkler systems.

- The Swedish incident report has to be revised, especially on three matters:
    - The type of automatic extinguishing system shall be indicated.
    - The function text that describes the effect of the automatic extinguishing system shall be clarified and guidelines for the assessment of the effect of sprinkler shall be established.
    - The incident report shall ask more clearly for the cause of failure in those cases where the sprinkler system is assessed to have failed.

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# Appendix 1– Failed Incidents from the Swedish Incident Statistics

The nine incidents which had failed according to the analysis of Swedish incident statistics (2008) are reproduced below. The translation is done by the authors.

| Function text | Object | Incident description | Cause description | Measures | Type of detector |
|---|---|---|---|---|---|
| Present | 110 Commer cial | The fire had died out so we just checked the building with IR-camera for possible heat spreading, but everything was OK. | Fire in a fuse box which had died out when we came. | | Water sprinkler |
| Present | 110 Commer cial | Could enter the mall with helpl too see that there no longer was a fire. Waited until the owner arrived. Insignificant smoke spread in the building. Wait until owner shows up to check cause of failure. Cancelled after clarified cause! | Probably have water from earlier water leak caused a short circuit with a minor fire in a freezer as a result. The fire had died out. | Everything OK | Water sprinkler |
| Present | 110 Commer cial | | The store owner discovers a fire in the ceiling spot-light, takes a ladder, gets the lamp and puts it outside the store. There was smoke in the store but it was gone when we came. There are no smoke detectors in the mall during the re-construction so watchmen control the building. | | Water sprinkler |
| Present | 110 Commer cial | Watchman discovers a fire in a paper bin. Puts the fire out with a fire hydrant for indoor use. Smells of smoke in the building. The watchman meets us and informs us and we determine that the fire is out. Relatively much water on the floor and we are helping them to get rid of it. Take contact with owner and recommend him to ventilate since many stores are affected by the smoke. He choses not to since he is in Dalarna. The watchman´s shift is over and he doesn’t want to stay | Fire in a paper bin. Arsonist?Somebody has seen persons run from the scene. The police gathered information. | Everything OK from us.. | Water sprinkler |

| Function text | Object | Incident description | Cause description | Measures | Type of detector |
|---|---|---|---|---|---|
| Functioned | 360 Wood industry | Five men tried to stop the dire, but couldn't to adjoining builidings | Timber that stops the machine. Dust and dirt | | Smoke detector, water sprinkler |
| Functioned | 380 Other manufacturing industry | Fire and smoke in machine. Went in with fireman and extinguished the fire. Left the rest to the staff of the building. | Fire in machine. Don't know. | | Water sprinkler |
| Present | 380 Other manufacturing industry | Sparks and smoke from the outside of a ventilator. The enginge was shut off and the staff put water where the smoke came from. Extinguished at arrival. The call came from a telephone, the automatic detection system hadn't activated. | | | Water sprinkler, heat detector. |
| Functioned | 517 Garbage/ drainage/ | There has been a fire in garbage and they want us to control it. Smoke from a variety of trash on beams close to the fire. | Fire in garbage. Inverted suction in the stoke with ignition as a result. | We have done a new Pre-planning with them who worked really well. | Water sprinkler |
| Present | 110 Commercial | Smoke on floor 1. Spontaneous egress together with organized egress by the staff of the mall. Calls came to 112(emergency centre). No activation of the automatic fire detection or sprinkler. Egress is completed without any injuries. Fireman and the inspector at the place (!) Finds the fire at the base of a escalator. Extinguishing is started. | Technical error. Lack of maintenance. | | Water sprinkler |