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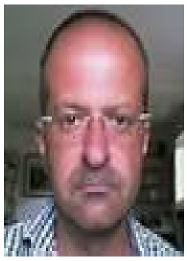
CODED SURVEY IN THE FIRE INVESTIGATION ACTIVITY





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ABSTRACT

A systematic evaluation of the fire scene and survey operations constitutes the core of every fire investigation. The absence of a procedure based on the scientific approach can lead to mistakes and negligence during the data collection stage. This research therefore introduces a standardized procedure, using an IT based methodology divided into phases and investigative operations.
In particular this work aims to define in depth the fire patterns analysis stage which is part of the described procedure. This step involves compiling evaluation schedules called "fire patterns fact sheets" using synoptic table to compare and recognize the fire patterns.
Once the investigator can demonstrate an adequate connection between the analyses of the gathered patterns and numerical simulation results, the causal link can be demonstrated in court, with a reasonable safety margin.

1 INTRODUCTION

This research is about the analyses and methods used in the practice of fire investigation engineering and it is prepared for the use and guidance of those designed with investigating the fire. In particular the chapter "Fire investigation Planning" shows a standardized procedure divided into five phases and investigative operations that has to be done following the scientific approach described in the NFPA 921. The crucial phase of this procedure is the Semiotic fire analysis, because each evidence gathered shall have a scientific value and furthermore a legal value.
First of all this research concerns the forensic aspects of the Semiotic Fire Analysis and, in particular, how to support the conclusion indicated by the fire investigator.
Finally this paper reports a "cascade" procedure to recognize fire patterns through the use of synoptic tables that allow the investigator to compare the fire pattern with a data-base and to plan the further steps of investigation, such as laboratory testing or evidence collecting.

2 FIRE INVESTIGATION PLANNING

Difficulty and complexity in an accurate fire investigation set the special need for every investigator to develop a comprehensive analytical approach to the task. The fire investigator should certainly follow a standardized procedure of data collection on the fire scene and its consecutive analyses.

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The general approach to scene documentation is outlined in the Figure 1 and consists of five different stages

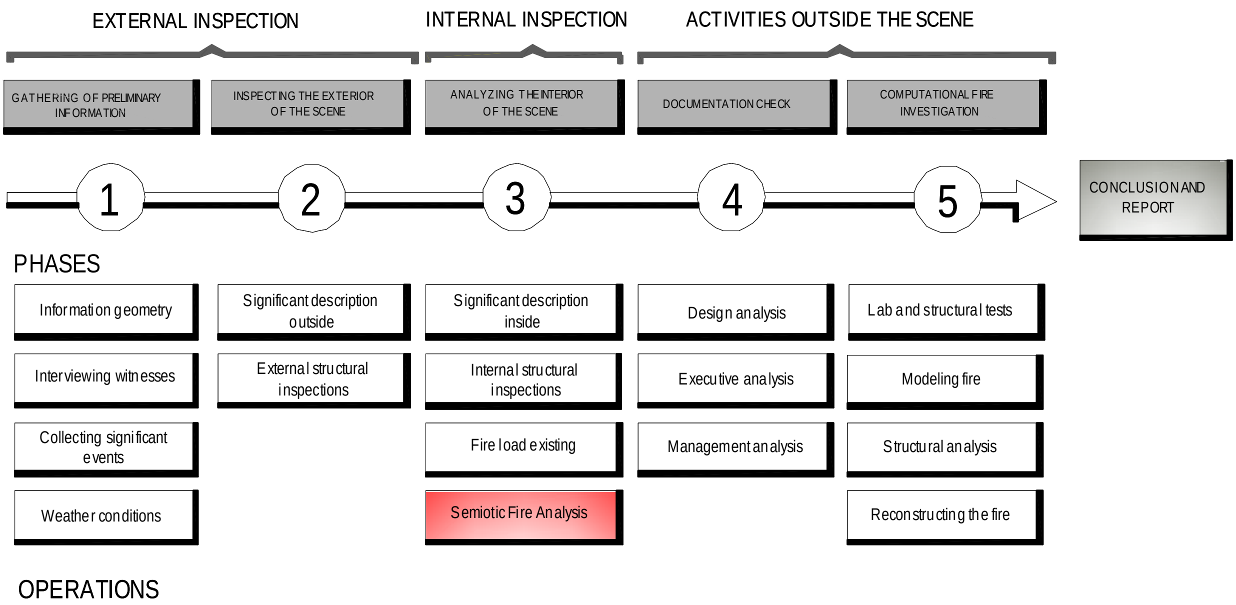


Fig. 1: Organization of a fire investigation process

The first step of the investigative *iter* proposed is the data collection, in terms of gathering the preliminary information. This phase permits to *recognize the need* and *define the problem* in order to start the scientific method steps, as outlined in the NFPA 921. In observing a fire scene for the first time, it is often best not to rush directly into the fire damaged areas in search of the origin. Most fire investigators will first reconnoiter the fire scene to observe which areas did not burn. Often knowing what was not burned by the fire allows the elimination of many theoretical point-of-origin possibilities [1]. Hence the second phase consists in the external examination of the scene, gathering and categorizing pieces of evidence. The third phase consists in the investigation directly inside the fire damaged area. In this phase the investigators will search for the fire patterns applying **a Semiotic Fire Analysis** (highlighted in red in Fig. 1), which is the focus of the following article.

3 SEMIOTIC FIRE ANALYSIS

3.1 Forensic aspects

Today's fire investigators must demonstrate to the court that they have data to support that conclusion, having followed an appropriate protocol in the investigation and decision-making process, and the scientific method of inquiry.
Initially, only the end result is known, i.e. the accident. From this starting point, the fire engineer gathers evidence to "reverse engineer" how the failure occurred. In fact fire investigation in the first phase is similar to a failure analysis: the errors determination permits to find the causes associated.

The semiotic analysis permits to recognize the fire indicators that are visible changes to the surface and materials of a fire scene produced by smoke, heat or flames, i.e. physical evidences. Because they are produced by predictable physical processes, they can be used to re-create the path of the fire's development, the location of fuel packages, the nature of ventilation, and sometimes the height intensity and duration of the flames[1]. The fire patterns determination intrinsically permits to relate causes with effects, as indicated in figure 2. In fact demonstrating to a court and jury the condition and exact location of a fire pattern is as important as the evidence itself[2]. The fire patterns analysis, i.e. the effect analysis, and the scene reconstruction shall be seen as one entity to find the final consequences.

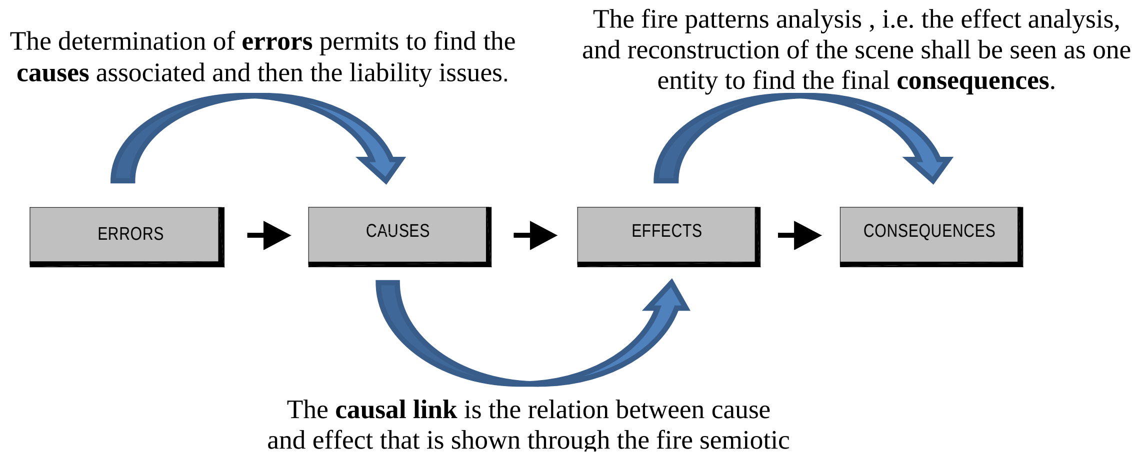


Fig. 2: Forensic Fire step

Finally the investigation must gather adequate and reliable data and apply reliable analyses to test the working hypothesis and to find the conclusions.

3.2 Classification of the signs

The semiotic analysis is a fire investigation branch dealing with the study of the indicators of damage. Since the indicators of damage form patterns, and are created by a combination of smoke, heat and flames, they are called fire patterns and can be divided in six typologies as shown in figure 3 :

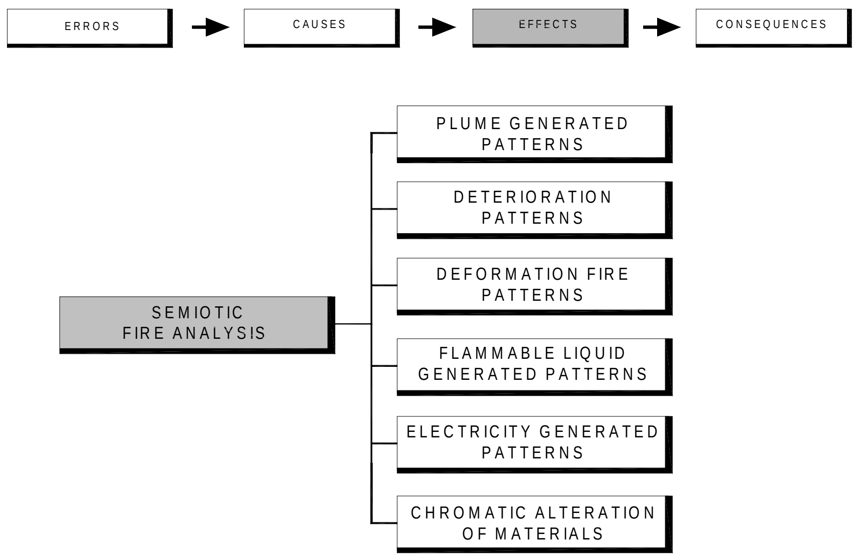
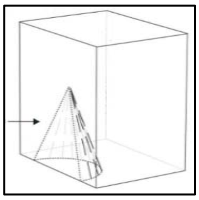
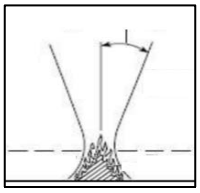
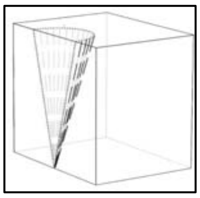
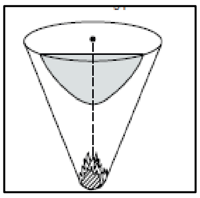
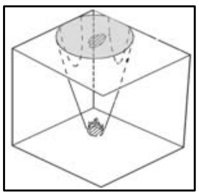
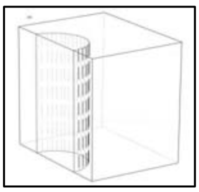
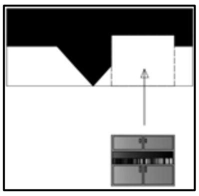
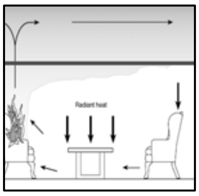


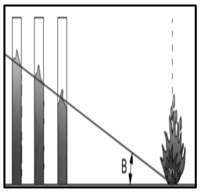
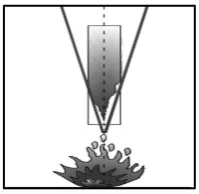
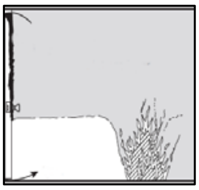
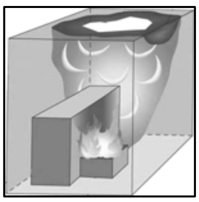
Fig. 3: Semiotic Fire Classification

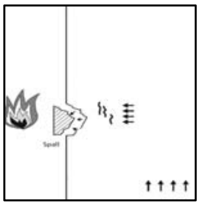
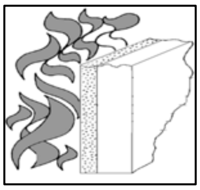
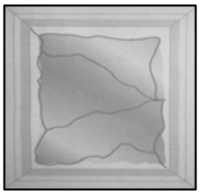
The approach shown in this paper consists in synoptic tables for each one of the above-mentioned categories. This table is just one step of an IT based methodology that allows the investigator to quickly recognize the fire patterns.

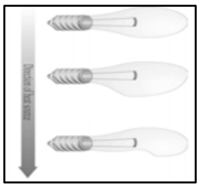
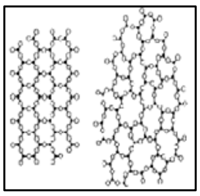
The use of synoptic tables in order to recognize transformation patterns is a technique already used in the restoration field. In Italy, the regulation 1/88 shows a table that permits to describes and identify each typology of deterioration on the surfaces of historical monuments.
The use of these sheets suggests to the fire investigator which material is necessary to collect and which additional technical analyses are needed such as laboratory testing of the evidence collected. [3] The following synoptic tables show the above-mentioned signs classified:

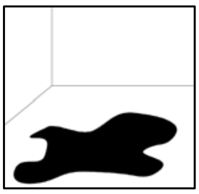
Plume Generated Patterns			
Fire Pattern Name	**Theoretical scheme**	**Photo**	**Description**
Inverted Cone			The inverted triangular, "V" or "A" pattern of damage is typically caused by a small fire of low energy and limited duration. This pattern appears if the wall or its covering is not readily ignitable. (Figures Credit [4][2])
Hourglass			The hourglass pattern represents a middle stage between the inverted cone pattern and the V shape. It is a transition phase between a fire with low energy and a fire with long duration. . (Figures Credit [3])
V Shape			The "V" pattern on a wall is the result of a localized fire. The most important data related to this fire pattern is that the apex of the "V" points toward the origin of the fire. This fire pattern can be found when the fire continues to grow, after having generated the inverted cone pattern, and becomes obstructed by a ceiling. . (Figures Credit [2])
U Shape			The "U" pattern has the same cause of the "V" patterns. It gives further information about the distance of the source from the wall. In fact the U appear if the fire is located some distance away from the wall. (Figures Credit [5])
Circular bull's eye pattern			The circular bull's eye pattern can be seen in the ceiling directly above a large fuel package. The center of the circular pattern reflects the effects of the high temperature of gases, and succeeding rings of less damage. If the fire is located against a wall, the circular pattern is interrupted by the wall to form a semicircle. (Figures Credit [2])
Column shape			Column patterns are short-lived and uncommon indoors. In fact the fire that causes this pattern is usually extinguished before it has much time to interact with the ceiling. The column pattern would have developed into a cone-shaped pattern if the fire is not extinguished. (Figures Credit [2] [5])

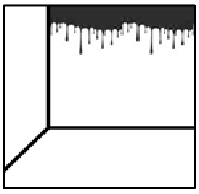
Plume Generated Patterns			
Fire Pattern Name	**Theoretical scheme**	**Photo**	**Description**
Protected Areas			The protection patterns are clean areas that are not covered by soot as the other part of the surfaces (wall or ground) where the fire spreads. This fire pattern is related to the presence of an incombustible element placed on the protection pattern area. This element acts like a shield to protect the surface to the flame plume. (Figures Credit [3])
Smoke lines demarcation			The smoke lines demarcation are the result of surface deposit on the ceiling and on the upper part of the wall. This surface deposit can reveal the height at which smoke has stained the walls and windows of a room (the smoke horizon). (Figures Credit [7])

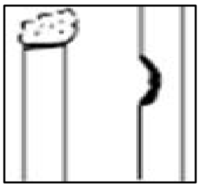
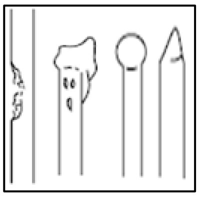
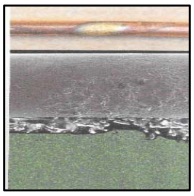
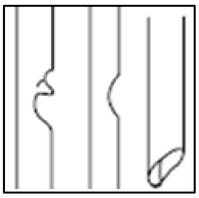
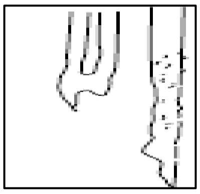
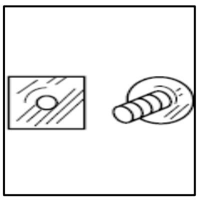
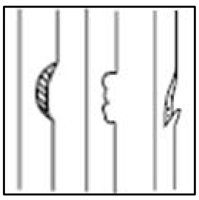
Deterioration patterns			
Fire Pattern Name	**Theoretical scheme**	**Photo**	**Description**
Decreasing charring			The decreasing charring fire patterns are commonly displayed on a series of combustible elements. The progress and direction of fire spread along a wall can often be identified and traced back toward its source by an examination of the relative heights and burned-away shapes of the wall studs left standing after a fire. (Figures Credit [7])
V-pattern chars			The V-pattern chars are fire patterns that are caused by the burning off of the sharp angles of the edges of the studs on the sides toward the heat source that produces them. The shape of the studs' cross section will tend to produce "arrows" pointing back toward the general area of the source of heat. (Figures Credit [7])
Penetration of horizontal surfaces			Penetration of horizontal surfaces, from above or below, can be caused by radiant heat, direct flame impingement, or localized smoldering with or without the effects of ventilation. Whether a hole burned into a horizontal surface was created from above or below may be identified by an examination of the sloping sides of the hole. (Figures Credit [3])
Heat level (Heat horizon)			The heat horizon is a fire pattern caused by flame front that comes into contact with vertical surfaces, it produces a characteristic "front". The area above the level is characterized by the charring, burning, blistering, or discoloration of paint or wall covering. (Figures Credit [3])
Clean Burn			Clean burn is a typical pattern for a non-combustible surface where soot deposits have been burned away by direct flame contact or intense radiant heat, leaving a "clean" area bordered by sooty stains. The surface temperature needed to accomplish this are flame temperature (> 500°C). (Figures Credit [4][5])

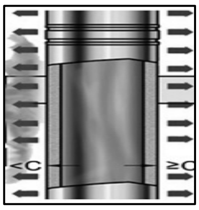
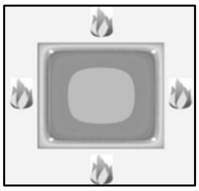
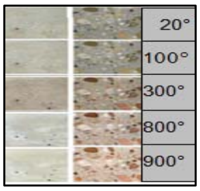
Deterioration patterns			
Fire Pattern Name	**Theoretical scheme**	**Photo**	**Description**
Spalling			Spalling is the breakdown in surface tensile strength of concrete, masonry, or brick caused by exposure to high temperatures and rates of heating resulting in mechanical forces within the material. (Figures Credit [4])
Calcination			The term calcination is used by fire investigators to cover the numerous changes that occur in plaster or gypsum wall surfaces during a fire. Calcination of a true plaster wall involves driving the chemically bound water out of the gypsum. (Figure Credit [4])
Glass Breakage			The glass breakage fire pattern can be caused by the thermal difference. If a pane of glass is mounted in a frame that protects the edges of the glass from radiated heat of fire, a temperature difference occurs between the unprotected portion of the glass and the protected edge. (Figure Credit [4])

Deformation fire patterns			
Fire Pattern Name	**Theoretical scheme**	**Photo**	**Description**
Light bulb softening			Incandescent light bulbs can sometimes show the direction of heat impingement. As the side of the bulb facing the source of heating is heated and softened the gases inside a bulb of greater than 25 watts can begin to expand and bubble out the softened glass. (Figure Credit [3])
Material melting			The melting of a material is a physical change from a reaction caused by heat. The border between the melted and solid portions of a fusible material can produce lines of heat and temperature demarcation that the investigator can use to define fire patterns. (Figure Credit [2])

Flammable liquid generated pattern			
Fire Pattern Name	**Theoretical scheme**	**Photo**	**Description**
Pool fire pattern			The low burn can be caused by the ignition of a pool or a trailer of ignitable liquid on the floor. When localized burn damage extends right down a wall to the floor surface, it may indicate that an ignitable liquid was used, since other sources of intense local combustion, such as trash, usually do not burn right to the floor level. (Figure Credit [2])

Flammable liquid generated pattern			
Fire Pattern Name	**Theoretical scheme**	**Photo**	**Description**
Run down Burn			Run down burn patterns are burned spots caused by a flammable liquid that was sprinkled on a vertical surface. The exeletant poured on the object usually leaves a black burn marks. (Figure Credit [2])

Electricity generated patterns			
Fire Pattern Name	**Theoretical scheme**	**Photo**	**Description**
Alloying			The alloying of a Copper wire (heated) happens if the aluminium has penetrated into the copper as well as on the surface. (Figures Credit [3][4])
Arcing through char			The arcing through char start after an existing fire. In fact the insulation on conductors, when exposed to direct flame or radiant heat, may be charred before being melted. That char, when exposed to fire, is conductive enough to allow sporadic arcing through the char. The ends of individual conductors, when severed, will have beads on the end. (Figures Credit [3][4])
Parting arcing			Parting arc is a brief discharge that occurs as an energized electrical path is opened while current is flowing, such as by turning off a switch or pulling a plug. If the gap does not become too great, the arc will be sustained. The arc quenches immediately but can throw particles of melted metal (i.e., sparks) around. (Figures Credit [4])
Cable exposed to an existing fire			When exposed to fire, copper conductors may melt. At first, there is blistering and distortion of the surface The striations created on the surface of the conductor during manufacture become obliterated. Further melting may allow flow with thin areas (i.e., necking and drops). In that circumstance, the surface of the conductor tends to become smooth. (Figures Credit [4])
Heating connection			Connector screws can show extensive effects of heat, including arc transfers on the edge of the screw. Prolonged heating in a poor connection condition can cause heating of the entire length of the screw. (Figures Credit [3][4])
Scrapes and gauge			This pattern can be found when the wire is scraped or gouged by something. Gouges and dents that are formed in a conductor by mechanical means can usually be distinguished from arcing marks by microscopic examination. Dents or gouges will not show the fused surfaces caused by electrical energy. (Figure Credit [3])

Chromatic alteration of materials			
Fire Pattern Name	**Theoretical scheme**	**Photo**	**Description**
Chimney heating			The chimney heating cause a pattern characterized by different colors. These colours depend on the temperature of the flame and on the flame exposition time. This is a typical pattern for chimney fires in stainless steel chimney liner. This fire pattern can be caused by a soot fire inside the chimney.
Chromatic concrete alteration			Chromatic concrete alteration is a fire pattern caused by the heat on a concrete surface. Each color corresponds to a specific temperature, that can be determined by the colorimetry techniques. (Figures Credit [7])

4 CONCLUSIONS

The categories of fire patterns indicated in this report are the result of a fire phenomena collection, which were given by scientific literature or were observed during professional life

The synoptic tables developed in this paper might not cover all the possible fire patterns and may require some updates and developments as new patterns will be recognized by the scientific community.

The use of synoptic tables can enable the technical staff, involved in the early investigations, to compare the fire pattern with a data-base and to plan the further steps of investigation, such as laboratory testing or evidence collecting. Furthermore the simple structure of the synoptic table, which consists of four column, enables the non-technical staff involved in the judicial process to understand and recognize the fire patterns.

This research could be also a proposal as an update of the NFPA 921, where there is already a simple synoptic table related solely to the electricity generated patterns. Using this methodology the errors can be reduced and a clear causal link can be demonstrated in court.

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