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Re: TFSC: Willis/Willingham

Summary:

To the best of my knowledge, there was no uniform "standard of practice" for state or local fire investigators in Texas or elsewhere in the U.S. at the time of the Willingham case. The knowledge base on which existing practices were based was very limited, lacking in support from scientific or engineering knowledge, and extremely variable (and often badly flawed) due to the one-on-one training that dominated. Training at the National Fire Academy and national professional training conferences were similarly flawed until quite recently. Editions of my own textbooks were considered by some to be useful and reliable, and the changes made in them (from 1983 to 1991 to 1997 to 2002) reflect much of the progress made. The NBS *Fire Investigation Handbook* (Brannigan, Bright, and Jason, 1980) was one of the better guides to good practice at the time. Its discussion of indicators, however, is just a few pages in length. Even that guidance is very limited (in a few cases incorrect) and is easily subject to misinterpretation by a reader who wishes to bolster his own interpretation. There was only very limited discussion of flashover and no discussion of flashover-induced

floor burn patterns since the phenomenon had not been studied by researchers at that time. Interestingly, there was a discussion of flashover-induced fire spread from the room of origin into adjacent spaces that would have been relevant to the Willingham investigation as to its conclusions of multiple ignition points. Since the Handbook was written by fire scientists rather than investigators, however, its advice was often ignored by field investigators. The same was true for the editions of Kirk's available at the time.

NFPA 921 was not released until 1992 so it could not be expected to have any impact on the original proceedings. Circulation of "draft" versions was discouraged. It was available to NFPA members for review and comment (as per NFPA practices) but very few investigators then (or even today) are NFPA members. Even after its release, its acceptance by public – sector investigators was very slow. It is only in recent years that it has been suggested (in legal proceedings) that it even be considered as a "standard of care" for the profession. Even the professional organizations (IAAI and NAFI) took years to recommend its general use.

I do not know when the Texas State Fire Marshal may have adopted NFPA 921. I do not know of any public agency that has gone on record as adopting it. Because its language and intent is that of a guide, not a code or standard, it cannot be enforced as a matter of legislation. Most public agencies I have dealt with in the past few years have come to realize that failure to follow NFPA 921 practices can lead to significant challenges to their own investigators in trials. As a result, investigators are strongly urged to follow its guidance so as to demonstrate reliance on a method that will withstand legal adversarial challenge.

<u>Introduction</u>:

I, John D. DeHaan, Ph.D., am currently an independent forensic scientist/fire consultant and have been asked to comment on the standards of practice for fire investigation in 1986 to 1992, in particular to those involved in the Willingham case. A copy of my resume is attached as Exhibit A. In the course of my professional practice, I have been a forensic scientist/criminalist since 1970, having served with the Alameda County Sheriff's Department, California Department of Justice – Bureau of Forensic Services, and the U.S. Treasury Department – Bureau of Alcohol, Tobacco and Firearms. I have served as president of Fire-Ex Forensics, Inc. since its incorporation in January 1999. I have been involved with various aspects of fire and explosion investigation since 1971. In the past 17 years, I have testified as an expert witness in over 50 cases. Information about those cases is listed in Exhibit A, Appendices 4 and 5. In the past 25 years, I have authored several editions of one major textbook, co-authored another textbook, chapters in three textbooks, and over 30 scientific papers; and the titles are listed in my vitae, Exhibit A, Appendix 1.

The various editions of my textbook, *Kirk's Fire Investigation*, reflect the changes in the discipline of fire investigation as it evolved between 1983 (2nd Ed), 1991 (3rd Ed), 1997 (4th Ed), 2002 (5th Ed), and 2006 (6th Ed). When I began as a criminalist with the California Department of Justice in June 1974, my position entailed working with the Arson and Bomb Investigation Unit (ABIU) of the California State Fire Marshal on their training exercises as well as case work (fire and explosion debris analyses). At that time the investigators were strong believers in training themselves and local authorities via live-burn exercises where structures and vehicles were ignited by a variety of methods (both incendiary and re-created accidental). These fires were observed and often recorded (via video and still cameras) and then processed by the participants. Nearly all of the participants had been trained in fire investigation in the classical master-apprentice manner. Under that system, there was reliance on the experienced investigator passing along his knowledge and methods. There were very few published texts or guides that could be used. Prof. Paul Kirk's original text (*Fire Investigation*, 1969) was used by some and it was the first text written by a scientist (who conducted systematic, if limited, testing of hypotheses). Other texts (e.g. Rethoret, 1945; Bates, 1975; Kennedy, 1977) were written by investigators with the offered guidance based on their experience as investigators, not as scientists. It must be recognized that nearly all this 'experience' was gathered from their examination of scenes that had already been burned, (sometimes moderately, often very extensively). Their conclusions were based on what fuels they thought were present, processes they assumed they understood (often from experience as fire <u>fighters</u>) and effects of an often misunderstood sequence of fire events of unknown duration

Investigators assembled a list of indicators that seemed to occur in incendiary fires and seemed to make "common sense". Those were the backbone of the training and knowledge passed along to trainees. There <u>were</u> scientists involved in developing an understanding of fire processes and effects but their information and insights were not common knowledge to fire scene investigators. It was not until the 1980's that scientific knowledge was published and circulated to the general investigative profession. The NBS *Fire Investigation*

Handbook (Brannigan, Bright and Jason, 1980) was among the first. Even their material contained some of the 'indicators' of behavior that have since been shown to be unreliable. My Kirk's second edition was published in 1983. Roy Cooke and Rodger Ide were forensic scientists with tremendous experience in fire investigation. Their book Principles of Fire Investigation was published in the U.K. in 1985. Although dated in many respects, it is still in print. Drysdale's classic Introduction to Fire Dynamics was also published in the U.K. in 1985. While all of these addressed the scientific knowledge underlying fire behavior and effects of concern to fire investigators, none of them enjoyed wide acceptance by the investigative community. They were considered largely to be the writings of "lab" experts with no knowledge of "real" fire scenes and generally ignored.

It was not until ATF (U.S. Dept. of Treasury) investigators started interacting with NIST (formerly NBS) fire scientists in some of their major fires in the late 1980's that the American investigative community started to realize that there was a body of knowledge that could be useful. Fire engineers like Harold 'Bud' Nelson showed how even simple scientific models could provide guidance and often data in fire investigations. Involvement of fire scientists (or even forensic scientists) in most fire investigations by public authorities was rare.

In my own experience, by 1982 I had participated in hundreds of fire tests conducted as training exercises by California authorities. It was evident that many of the widely-held, so-called "indicators" of arson were not only produced by non-incendiary fires but were more frequently produced by them. It was also evident that fire behavior and its effects are considerably more complex and dependent on many more variables then previously thought. (Even today, there are a great many gaps in science's understanding of fire processes). Some of this new knowledge was incorporated into the 1983 edition of Kirk (along with some of the theories later shown to be incorrect). For example, it was clear that flame temperatures involving ordinary combustibles are about the same as those of flammable liquid fires. The highest flame temperatures were observed in fires involving polyurethane foam, polystyrene and some acrylic plastics, not gasoline or kerosene. We also observed time frames of developing fires (especially in upholstered furniture room fires) to be much shorter than "commonly" believed. The average difference between full room involvement of a non-accelerated fire and one accelerated with gasoline was less than 2-3 minutes and the maximum temperatures were the same (and dependent on fuel load). We also observed the role of radiant heat from the hot smoke layer in producing 'low' burns involving floors and floor coverings of a room. These observations gave rise to my paper of 1987 on radiant heat and floor level burns. That paper, published in the *Fire & Arson Investigator* (journal of the International Association of Arson Investigators), tried to draw attention to the radiant heat production of floor-level burns, but did not address flashover. With the exception of a brief mention of flashover in the 1980 NBS Handbook, the concept of 'flashover' was not suggested in fire investigations until about 1989 and it was not widely described in the fire scene literature. When it was described (circa 1990) as the mechanism most likely to produce generalized floor damage including irregular burn patterns resembling 'pools', 'puddles' or trails, it was generally decried by fire investigators as nonsense or an invention of defense experts just to discredit public sector investigators.

The same was true for publication of observed tests that produced spalling of concrete surfaces, V-patterns down to floor levels, melting of aluminum door thresholds, crazed window glass, intense floor level fires in doorways, and melting of copper wires all without flammable liquids. When the tests with flammable liquids failed to produce such indicators, the reaction of many fire investigators was to deny the reliability of the authors. Because few fire investigators actually publish peer-reviewed (or even editorially-reviewed) papers, the published materials did not include many of the tests they actually conducted. Although some papers were published in the *Fire and Arson Investigator*, it is unknown how much was comprehended. Many of the relevant scientific papers were published in *Fire Technology* and *Fire Engineering*, both of which have limited readership among public-sector investigators Even peer-reviewed textbooks like *Kirk* were dismissed as laboratory tomes with no "real fire" results. As the author of *Kirk's*, I was criticized repeatedly when each new edition came out discrediting more of the indicators so widely held, even when the fire science literature demonstrated the unreliability of such 'indicators'.

It was not until NFPA published 921 in 1992 that fire science and fire investigation knowledge really came together in a nationally circulated form. (I was a member of the 921 Technical Committee from 1991-1999.) Published by a national, independent, consensus organization as a thoroughly peer-reviewed document, authored by a wide cross-section of fire experts, it was difficult to ignore. So much of the content, however, challenged the over-simplified 'rules' that dominated most fire investigation 'methods', that it was very slow to be accepted in the discipline.

One of the major problems to its acceptance is the lack of general science knowledge on the part of many fire investigators. Very few fire investigators had any scientific education beyond high school chemistry or physics (and much of that was long-forgotten). (This is changing today with more fire and police personnel having some basic college chemistry, and even a few with bachelor's degrees in chemistry. There are also post-secondary courses on specialist science and engineering being offered by IAAI, National Fire Academy, and others.) Fire is a complex physical and chemical phenomenon and to understand it requires some appreciation for the scientific laws that these processes follow. This is especially critical in pressing the "what if" questions – what if the door were open or closed, what if the bed or sofa was made of polyurethane, what if the walls or ceilings were covered with combustible paneling or tiles (versus non-combustible coverings or plaster)? What effects would one see and how does one predict the effects or evaluate the damage patterns?

These critical decisions are at the heart of the scientific method that is now widely promulgated. The reluctance of many fire investigators to have anything to do with science in any form has been a major issue since the 1980's. Even the basic concepts of what is "data", how is it collected, and how is it used were not widely understood. As an author, I was reluctant to even use the term "scientific method" since I suspected the word "science" would discourage readers. On the 921 committee, there were considerable discussions about it even when we agreed that it was necessary. We had to introduce concepts like fractional powers (in numerical expressions) gradually but even the addition of simple equations prompted waves of protest from readers.

Even its fire-profession based provenance did not guarantee acceptance of 921 even as a professional guide. When the Daubert v. Merrell Dow decision (and its sequelae) expected all technical witnesses to be able to understand and describe the science behind their conclusions, the International Association of Arson Investigators filed an *amicus curiae* brief claiming that fire investigation was not strictly science based and therefore these experts should be exempt from that judicial expectation. Needless to say, that claim came as a profound shock to those of us fire investigators who had always claimed a scientific background. Ultimately, that argument was rejected, and fire investigators today are expected to be able to describe their methodology, rationale, and scientific understanding, at least in Federal courts and State courts that follow the FRCP. Unfortunately, that leaves a lot of courts free to admit "expert" testimony of questionable validity and reliability.

Many practicing investigators, fearful of the consequences of admitting that they may have reached erroneous or unsustainable conclusions about their fires, rejected the 'scientific method' and, thereby, both 921 and *Kirk's Fire Investigation* (and all their new guidance). Even the National Fire Academy was very slow to accept revised curricula and new reference materials. Acceptance by the general profession has been very slow, advancing primarily only as many of the 'old school' investigators retired. When asked in court about their reliance on NFPA 921, many investigators would point out that it was only a Guide, not a mandatory standard. There were some, however, that considered the new way to be better and more accurate (even if their clearance rate went down with a higher number of 'undetermined' fires). Today, most practicing fire investigators in both public and private employ have been exposed to the scientific method since their careers started and consider it to be the normal course of business.

In response to the questions you posed in your letter of August 2, 2010, I have reviewed the Beyler report of August 17, 2009, the rebuttal by Corsicana Fire Dept. Chief Donald McMullan of September 29, 2009, the *New Yorker* article 'Trial by Fire' of September 7, 2009, the original investigation report by Deputy State Fire Marshal Manuel R. Vasquez of January 24, 1992, the trial transcripts of Dep. State Fire Marshal Vasquez, Asst. Corsicana Fire Chief Douglas Fogg, and Corsicana Fire Marshal James Palos.

The primary indicator that most fire investigators prior to 1992 focused on was the condition of the floor or floor-covering. It was rationalized that fire moves upward (at least the flames and hot gases do) and that carpet and flooring is difficult to ignite, therefore any damage at floor level is nearly proof alone that the fire was started with an ignitable liquid. If one pours an ignitable liquid on a floor and lights it, one observes the carpet burning away in an irregular path similar to the deposits of the liquid. Therefore, the logic follows that whenever such patterns are seen, an ignitable liquid was involved. This rationale was often carried to the extreme that rooms were emptied of their contents and the floors washed clear of all debris just to rely on the floor patterns, ignoring or destroying all other evidence. (Apparently, Fire Marshal Vasquez followed this "logic" by examining the floor burn patterns in great detail and reaching conclusions about the fire's origin without examining the debris previously removed by Fogg.) While this rationale is defensible when the fire damage is limited to an isolated area, surrounded by an expanse of unburned carpet, it does not apply in fires where the damage is nearly total, indicating the fire approached or surpassed flashover conditions. At that point, all of the exposed carpet will be ignited. Synthetic carpets and pads melt or decompose to liquids as they burn, producing highly irregular and unpredictable patterns of damage. The intensity of post-flashover burning is dependent on ventilation conditions, producing more intense damage where airflow (of fresh, oxygen-rich air) is best. This produces more burn damage near open doorways, down the centers of hallways, or along paths connecting open doors and broken windows. It is clear from their testimony that both Vasquez and Fogg relied on the patterns of floor damage to conclude where the fire started (in three separate areas) and how it spread. They focused on irregular floor burns as indicators of "combustible liquid" used in large quantities, to the exclusion of witness descriptions and, more importantly, the absence of any positive lab results inside the house. (The one positive sample was outside the house on the front porch, where there was possible contamination from charcoal starter fluid or even insecticide residues.)

Both investigations failed to consider the fuel loads and ventilation conditions that would have been expected to produce large, intense fires in small rooms where there was excellent ventilation (from open doors and broken windows). They misinterpreted floor burns and partial penetrations as proof of the presence of ignitable liquids even under beds without considering the contributions of falldown of burning synthetic mattresses and bedding. Our testing of the 1980's and 1990's demonstrated that ignitable liquids alone do not burn long enough on wood floors to penetrate them at any depth, but that combustion of clothing and bedding and the radiant heat of a fully-involved room fire can be sustained to penetrate floors.

The investigators failed to consider conflicting information such as concluding the fire was started with a liquid accelerant on the front porch, ignoring eyewitnesses who saw only smoke coming from the house at the initial stages, not flames. They based their conclusions of "origin" in part, relying on the theory that a "V-pattern" on a wall points to the origin of the fire. This indicator, of course, has long been known to simply "point" to where something was burning at some stage of the fire, not just an origin. They held to the widely-held belief that the flames of wood-fueled fires are cooler that those fueled by petroleum products, and therefore, concluded that such a hot fire had to have an accelerant ignition. Lack of data about the speed of development of room fires, led them to conclude that the fire was "too fast" to be of accidental origin. Even in their testimony, they admitted that there were alternative explanations for some of their observations, but that the conclusion that Mr. Willingham deliberately started the fire using large quantities of an unidentified combustible liquid was the only one that could be reached. Apparently, their evaluations were influenced by the conflicts they detected in interview statements given by Mr. Willingham and neighbors.

Conclusions:

Based on my review of the available materials, it is my opinion that the original investigators in the Willingham case relied on investigative methods and indicators that have been shown to be unreliable. The methods they used, the indicators they relied upon, and the logic employed were typical of investigations carried out at that time. The sources of information and revised methods of investigation that have dramatically improved the quality and reliability of fire investigation since then were limited in scope and circulation at that time.

To the best of my knowledge, there was no uniform "standard of practice" for state or local fire investigators in Texas or elsewhere in the U.S. at the time of the Willingham case. The knowledge base on which existing practices were based was very limited, lacking in support from scientific or engineering knowledge, and extremely variable (and often badly flawed) due to the master-pupil method of training that dominated. Training at the National Fire Academy and national professional training conferences were similarly flawed until quite recently. Editions of my own textbooks were considered by some to be useful and reliable, and the changes made in them (from 1983 to 1991 to 1997 to 2002) reflect much of the progress made. The editions available then still included some information and guidance that have since been found to be misleading. The NBS *Fire Investigation Handbook* (Brannigan, Bright, and Jason, 1980) was one of the better guides to good practice at the time. Its discussion of indicators, however, is just a few pages in length. Even that guidance is very limited (in a few cases incorrect) and is easily subject to misinterpretation by a reader who wishes to bolster his own interpretation. There was only very limited discussion of flashover and no discussion of flashover-induced floor burn patterns since the phenomenon had not been studied by researchers at that time. Interestingly, there was a discussion of flashover-induced fire spread from the room of origin into adjacent spaces that would have been relevant to the Willingham investigation as to its conclusions of multiple ignition points. Since the Handbook was written by fire scientists rather than investigators, however, its advice was often ignored by "field" investigators. The same was true for the editions of Kirk's available at the time.

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These conclusions are based on review of the materials submitted to date and reliable published data, as well as extensive personal knowledge of laboratory analysis, fire dynamics, ignition processes, flame spread, fire growth, smoke production, and fire indicators. They are expressed to a reasonable degree of scientific certainty. If additional information becomes available that has a bearing on these conclusions, these conclusions will be amended or supplemented appropriately.

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Consultant Services in the Investigation and Reconstruction of Fires and Explosions, Case Review, Quality Assurance, and Training

FIRE INVESTIGATION HANDBOOK

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adjacent window shows fire effects, it is likely that the door was closed at the time of the fire. On the other hand, if the fire effects over the doors and windows are similar, it is likely that the door was open during the fire.

Look for evidence that the fire may have started on the outside of the structure (commonly trash and brush fires) and spread into the structure through openings such as windows, vents, and the like. Char patterns on the exterior of the structure leading up and through an opening are definite indications the fire started externally and spread into the structure.

If a large area is involved, such as a lumber yard or a row of buildings, viewing the scene from a higher elevation, such as from a nearby taller building, an aerial platform, or possibly a helicopter, can provide an overall view of the fire scene.

Wind may influence the spread and pattern of external fire damage. This should be taken into consideration when examining the exterior of the structure.

1.1.2.2 Interior of the Structure

As a general rule, one should begin the interior examination by beginning with the areas and rooms with little or no damage and working towards the areas or rooms with the most damage.

1) Start with the lightly smoke-stained areas moving towards the heavily smoke-stained areas.

2) Proceed from areas of light heat damage towards areas of heavy heat damage. As a clue to the buildup of heat look for sagging paint (oil-based paints, primarily) and blistered paint.

3) Move into the most severely burned area or areas.

At this point, the investigator should be in the room or area where the fire originated.

1) Try to establish the lowest point of burning in the room. Look for definite patterns of fire travel upwards and outwards from this lowest point in the shape of a "V" on nearby or adjacent walls. If the fire began in the center of the room or area, there may be no "V" patterns. It will be helpful to look under furnishings, shelving, and window sills for evidence of fire damage as an indicator of low points of burning.

2) Check ceilings over the apparent fire origin for signs of more extensive damage than adjacent areas. If the ceiling over the apparent origin appears relatively undamaged but is lighter in color than adjacent ceiling areas, chances are this lighter area has been subjected to higher heat and/or direct flame impingement which has burned away the smoke deposits. If such a condition is found, this usually indicates that a hot fire occurred directly below and may be an indicator of the point of origin.

3) Look for direction of heat flow as confirmation or indication of the fire origin. As the heat flow will be primarily along the ceiling, examine light fixtures, light bulbs, and other materials at the ceiling level. Light bulbs begin to swell and distort around 900° to 1,000°F (482° to 538°C) when exposed to heat. If the heat continues to rise, the bulb may blow out in the direction of the heat source leaving a point. If the heat continues to rise, however, the glass may soften and begin to flow and this heat flow indicator will be destroyed. Plastics at the ceiling level will soften and melt at temperatures much below those of light bulbs. Temperatures of 200° to 400°F (93° to 204°C) will cause these changes in plastics.

4) Glass objects, including window glass, often will give clues as to a fire's location, as well as its intensity and rate of buildup. Glass further from the fire will have heavier soot and smoke deposits than glass which is closer. Window glass will expand under fire exposure and due to the confinement within the window frame, will break. Part of the glass usually falls out of the frame and part remains within the frame. Window glass fragments in large pieces with heavy smoke deposits usually indicates slowly developing fires. Crazed or irregular pieces with light smoke deposits indicate a rapid buildup of heat. Pieces of glass found with rounded edges indicate exposure to temperatures in excess of 1,400° to 1,600°F (760° to 871°C), the softening point of glass. Glass does not have a well defined melting point, melting anywhere between 2,000° and 2,600°F (1,093° to 1,427°C). While this is so, the presence of melted glass does indicate a hot, intense fire. However, it should be noted that thin glass requires much less time at high temperatures before melting than does thick glass. Thus, melted light bulbs may indicate nothing more than a short burst of high heat.

5) Floors seldom receive damage similar to that of ceilings, even in the case of total burnout, as the heat of the fire will be concentrated at the ceiling. In addition, as ceiling materials are damaged and fall, these materials protect the floor below. If, on the other hand, a large area of the floor is extensively damaged, the use of accelerants may be indicated. Keep in mind, however, that plastics used in furniture, mattresses, drapes, and other interior decorations, can give the appearance of a flammable liquid burn and must be considered to avoid improper conclusions.

6) Look for evidence of multiple fire origins. If the fires appear to be unrelated or discontinuous, the fires may have been deliberately set. However, multiple fires in a room, all originating from one fire are not uncommon. High-heat-producing fuels, such as plastics and interior finishes, can cause a degree of fire damage sufficient to mislead the investigator. Also, when ceiling temperatures reach 932° to 1112°F (500° to 600°C), flashover may occur when literally the entire contents of the room burst into flames simultaneously. The results of flashover which may cause the investigator to conclude there were multiple fires when such was not the case. The questions to be answered on apparent multiple fires are: Were these fires the result of normal fire spread from fuel load to fuel load, either by flashover, burning materials being carried around the room by the effects of the fire, or other mechanisms? Or were the fires independent of each other and, therefore, of suspicious origin?

7) Sometimes it is important for fire investigation purposes to know whether doors were open, partly open, or closed during the fire. Here are some of the things to look for in answering this question:

a) Closed doors - damage on only one side of the door. Hinges and the inside faces of the door frame may be free of smoke and heat effects, but not always;

b) open doors - damage on both sides of the door. Hinges and inside faces of door frames will be heat and smoke stained;

c) partially-open doors - same comments as b). However, there may be relatively undamaged portions of the floor in the doorway opening directly below where the door was positioned. Check for this.

If the positions of the doors were changed during the firefighting operations, observations a-c may not be valid.

8) In determining whether the fire was a slowly developing one or a rapidly developing one, the following indicators may be used:

a) Alligatoring of wood - slow fires produce relatively flat alligatoring. Fast fires produce hump-backed, shiny alligatoring. These observations apply, however, to unfinished lumber. Wood which has been painted or finished exhibits different characteristics depending upon the type of finish and thickness of the finish. Sometimes, taking a cross section of the wood exposed to a fire gives a clue as to the type of fire. A distinct line between the charred and uncharred portions indicates a rapidly developing fire. Lack of a distinct line usually indicates a slow, cooking process, thus, a slowly developing fire.

b) Spalling of concrete - indicates an intense, high heat fire. The spalling is caused by rapid boiling of the moisture trapped in the concrete.

c) Fire patterns - a wide angle or diffuse "V" pattern generally indicates a slowly-developing fire. A narrow sharply defined "V" pattern generally indicates a fast-developing, hot fire.

d) Ceiling damage - if the ceiling exhibits uniform damage, a slowly-developing fire is indicated. Extensive ceiling damage in one place indicates a rapidly-developing fire directly below the damaged location.

1.1.2.3 Summary

A systematic study of the fire scene is usually necessary to determine the origin of the fire, the first step in establishing the cause.

The physical evidence developed during the investigation should be checked against the statements of witnesses. The two may reinforce one another, or the two may conflict. It is important that the investigator try to resolve any conflicts. While it is important that the investigator keep an open mind, do not forget that witnesses' accounts may be less than reliable, particularly if they have had little experience with actual fires.

The quicker the fire department can extinguish the fire, the easier it will be for the investigator to determine the point of origin and establish the cause. On the other hand, if the fire department is relatively unsuccessful in preventing a total loss for one reason or another, finding the origin (and cause) will be extremely difficult. However, even in the extremely difficult situations, intelligent use of all of the available information, including that from witnesses, may permit the investigator to assign a "most probable cause" with reasonable accuracy.

1.1.3 Determining the Cause

1.1.3.1 Introduction

Once the point of origin has been determined, the cause of the fire is next. Causes of fires can be categorized as accidental or incendiary. Accidental causes include heating, cooking, smoking and similar causes. The word "incendiarism" will be used in its broadest sense, that is, the intentional burning of property. Arson, which is a felony or crime, is the deliberate setting of a fire for illegal gain or with malice.

For a larger fire, however, the effect of the enclosure will begin to be felt. There are two primary effects that will now determine the course of the fire; one is ventilation, the other is called reradiation. The fire, beyond the size of a candle, will be consuming oxygen at a much greater rate, such that normal leaks will not be sufficient. For a completely sealed room the fire will go out due to a lack of oxygen.

Doors are not always closed or even present in open-plan homes or offices. Hence, a ready supply of air is generally available to a fire and the fire will grow. Fresh air will be drawn in through the lower part of the door opening at the same time hot gases from the fire will be collecting at the ceiling, filling the upper portion of the room and spilling out under the top of the door frame. (In older buildings, transoms were often installed over doorways for ventilation and light. This permitted the room fire to spread quickly to the corridor. After several hotel fires in which transoms were a factor in fire spread (2,3), many codes were changed to require the permanent closure of the transoms, and they are not installed in modern buildings.)

The second effect of the enclosure will begin to be realized. The trapped hot gases in the upper portion of the room will heat the ceiling and walls. These surfaces, together with the gases themselves, will radiate down onto the unburned fuel in the room raising the fuel to the required temperature necessary for burning. An additional acceleration process (reradiation) now will be operating making the fire spread and grow further (see figure 5.4.4-1).

The larger fire will draw more and more air through the doorway. If the opening is large enough relative to the potential fuel supply, the controlling mechanism for further development is the amount of fuel present, the so-called fuel-controlled or fuel-limited fire. The fire will continue to grow until all of the fuel elements are burning inside the enclosure as long as there is more than an adequate supply of air coming through the door. This fire will continue in a more or less steady manner until the fuel is consumed.

5.5.5 Flashover

Consider the same sized opening, with considerably more fuel than in the previous case. The fire would continue to get larger, drawing more and more air, burning more and more vigorously. Temperatures and corresponding radiation feedback would rise until rather dramatically a phenomenon known as "flashover" occurs. Items in the room not in direct contact with the original flames suddenly burst into flame due to the high radiation levels. The rate of burning for all items in the room becomes so high that the amount of air coming through the door is inadequate. Flame lengths become longer and reach out through the door in search of more air to burn the additional combustibles and the "inferno" inside becomes controlled by the amount of air entering. This is called a ventilation-controlled fire. The fire cannot get any larger in the room because all the air entering is being utilized. The fire will continue in this fashion until all the fuel is burned up.

Flashover can be abrupt, unpredictable and highly dangerous. Firefighters are warned about entering rooms or buildings not knowing the state of things. For a growing or fuel-controlled fire one might be able to crawl into the room for rescue purposes. If the room has "flashed over", the flames coming out the door will prevent entry. It is likely that the fire will extend to the corridor and adjacent parts of the building are now in grave danger. Inspection of the enclosure after a fire often will reveal the telltale signs of flashover--every combustible in the room will exhibit some degree of fire damage, if not totally destroyed, even to charring of the paint and paper on gypsum walls.

5.5.6 References

(1) Fire Protection Handbook, 14th edition. Boston, National Fire Protection Assoc., 1976, p. 6-47.

(2) McElroy, J. K. The Hotel Winecoff Disaster. NFPA Quarterly, Vol. 40, No. 3, pp. 140-159, January 1947.

(3) Clevely, H. Famous Fires. New York, John Day Co., 1958. p. 37.