FIRE INVESTIGATION ROAD MAPS AND DECISION TREES TO ASSIST FIRE CAUSATION IDENTIFICATION AND IMPROVE ARSON PROSECUTIONS

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Abstract

One of the lowest prosecuted crimes in western civilisation is arson. Defence 'experts' may be able to discredit a prosecution charge by demonstrating that there are alternative causes for the fire that their defendant was being accused of setting, which were not investigated thoroughly, nor disproved. Unlike many other crimes, a fire may not be detected as arson until the final stages of an investigation, whereas with most other crimes, there is an obvious victim of a crime in the early stages of an investigation. The investigation of fires can be extremely complex. Fire investigators need to ensure that they have conducted their investigation using a systematic and rigorous methodology so that their findings can with-stand any challenges. At the beginning of this project, it was identified that there was a fundamental lack of a systematic methodology to investigate the cause of fires and a need for one to be developed.

To address this need, a series of 23 Fire Investigation Road Maps (FIRMs) have been designed, developed and tested at real fire scenes and also during cold case fire investigation reviews to assist a competent fire investigator conduct a thorough, rigorous and systematic investigation to determine the origin and cause of a fire. It is the cause of the fire that being the ignition source, first combustible material to become ignited and the mechanism that brought the two together which will determine whether the fire was started accidentally or deliberately. The FIRMs are based on the application of the Scientific Method and are divided into groups and categories to ensure a rigorous and thorough process is carried out during an investigation.

Some examples of applications of the FIRMs during fire investigations when working with the police, forensic scientists and insurance investigators are the Bethnal Green Road two fire fighter fatalities; 'Operation Refit', reviewing the murder of Wayne Trotter; the Iron Mountain data storage depot in East London and the fire in the high rise flats, Lakanal, where six occupants lost their lives. The outcomes of these examples, and many other fire investigations, when applying the FIRMs have demonstrated to the relevant authorities, including several Coroners, that a complete and accurate fire investigation has been conducted.

Utilising the FIRMs during a fire investigation will benefit society by enabling existing data to be gathered, documented, analysed and made available for many interested parties, such as Coroners, civil and criminal prosecutors or used to identify any fire safety issues which need addressing. The accurate identification of the cause of a fire, with supporting forensic evidence, will assist the courts in making decisions as to whether the fire was accidental, deliberate or the result of a design or system failure. In the circumstances of deliberate fires, the FIRMs will support any subsequent prosecutions and help increase the low arson prosecution rates that currently exist.

Fire Investigation Road Maps

Guidance for the use of Fire Investigation Road Maps

The following 23 Fire Investigation Road Maps (FIRMs) are to be used collectively and not in isolation, almost in a three dimensional function. They relate to the investigation of the cause of fires and non-terrorist explosions, however 'fire' is used as a standard term, which may relate to either/or. There are 12 FIRMs relating to non-human agency subjects and 11 FIRMs relating to people. Many of the FIRMs will interact with each other, but their rigorous application during the investigation will allow all available hypotheses to be established, tested and either confirmed as possible or dismissed.

When addressing any human agency involvement with fires, it is the role of the person associated with that fire that should be considered. Much of the data to be obtained from a person associated with a fire is generic, such as 'do they know how the fire started?' however, there are decision points within each of the 'person' FIRMs that are specific to that category of person, such as 'would this person have benefitted from the fire?'

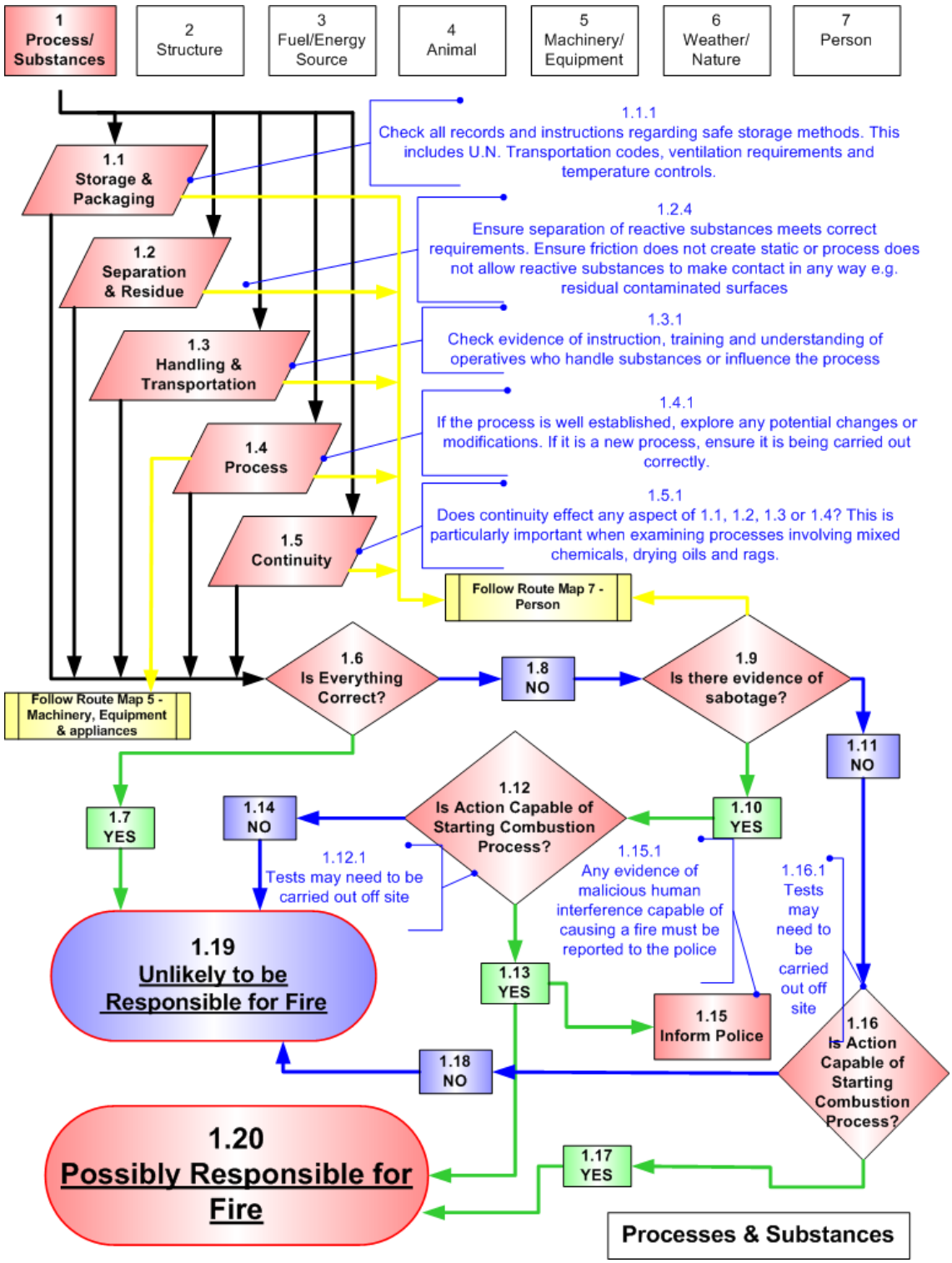
Every FIRM should be referred to at least once whilst the investigator is still at the scene as any evidence 'left at the scene' may be lost at the scene. The FIRMs have been developed to guide and assist the investigator through the complex thought process of what can the most difficult of investigations. Demonstrating what was not a possible potential causation of a fire may prove to be as important as what was possible. It may be risk critical to an investigation if the FIRMs are not completely followed through to their final decision 'boxes'; their superficial application would not be suitable, sufficient or acceptable given the methodology that they are promoting. As with any road map, an investigator may choose which route is to be followed, based on facts uncovered along that route.

Each decision box within the FIRMs is numbered and has supporting textual guidance, which is not finite, to explain some of the issues that the investigator should be addressing.

These FIRMs are not designed to replace or detract from the active use of other published documents and guides, such as NFPA 921 or Kirk's Fire Investigation as examples, but to support the structure and application of a competent fire investigators' methodology. They are also not designed to be a 'tick box' approach to fire investigation but will certainly give the investigation credence due to their scientific methodology.

FIRE INVESTIGATION ROAD MAP #1

PROCESS(ES) AND SUBSTANCE(S)



1 Process(es) and Substance(s)

The term 'substance' is taken to mean chemical substances (also sometimes referred to as pure substances) and may be defined as *any material with a definite chemical composition* (Upshall, 1993). This Fire Investigation Road Map #1 deals with any process(es) which may require the need for strict control measures with regard to the way substances are used or handled and the order in which they are applied.

1.1 Storage & packaging

(a) It is important that all manufacturers' instructions with regard to the correct storage and ventilation methods have been followed. If the ventilation is mechanical then checks must be carried out to ensure that it was working at the time of the fire. The physical form of the substances and their inherent properties, such as self-heating, reactive qualities and oxidisers, should be established and viewed in relation to the method of storage and packaging; this may be done by referring to the material's data sheet.

(b) The investigator should obtain an inventory of substances stored on the premise(s) and ensure that they have full access to all the manufacturers' instructions and COSHH (Control of Substances Hazardous to Health) data. Establish whether any new materials have been stored within the premises.

(c) Personnel involved with the responsibility for accepting deliveries and storing any substances must have adequate instruction, training and understanding and this should be recorded on the premise in accordance with the Work Place Regulations.

(d) The importance of temperature controls and interaction between different substances must be explored. Standard Operating Procedures should be obtained with regard to any process(es) that occur at the scene of the fire to check that these have been followed. Moisture content, out-of-date stock and contamination may play a part in starting a reaction within a substance.

1.2 Separation

(a) Again, manufacturer's instructions as to the separation of substances must be examined and ensured that they have been strictly followed and that correct containers are used. Spacing requirements between substances, even if they are in the correct containers, must be adhered to and it should be explored as to whether

those requirements were followed or not. Zoning criteria on larger industrial sites must also be considered.

(b) As with [1.1 (c)], all personnel should be trained and their training records kept. During any process, it may be necessary to ensure that residual substances have been removed effectively so as not to become contaminated with other substances. Substances may react with each other to create either an ignition source for an adjacent fuel package or start the combustion process within itself, e.g. potassium permanganate and glycerol and linseed oil-soaked rags can spontaneously ignite.

(c) Oxidising agents must be separated from fuel packages.

(d) Such practices as 'decanting' substances into other containers must be explored as to the suitability and safety of the practice. See FIRM #3.8: Electricity (Static)

1.3 Handling & transportation

(a) [1.1 (c)] and [1.2 (b)] apply with regard to manufacturer's instructions of handling substances and correct personnel training.

(b) UN Transportation Codes (United Nations, 2007) should be referred to in order to establish whether the correct method of transporting the substance(s) has been adhered to.

(c) Disturbance of fine particulate substances can create explosive atmospheres.

(d) Static may be created when transporting liquids or fine particulate substances through pipe-work.

(e) Shock or friction exerted upon a substance or its container could start a chain reaction or self-heating.

(f) The fabric of gloves and protective clothing may be inappropriate with certain substances, for instance, cottons and drying oils that are prone to self-heating.

1.4 Process

(a) A full understanding of the process that is being examined must be obtained by the investigator. If it is established that the process is new, the investigator must establish whether or not the correct procedures have been adopted in accordance with the design specification.

(b) If the process is well established, investigations must be made to establish whether any changes or modifications to the process have been made within the recent past, and what those changes were.

(c) The disposal of waste products forms part of any process. Examination of the methods used to dispose of waste or excess products must be explored to establish whether a potential ignition or heat source could exist at that stage of the process.

1.5 Continuity

(a) Does continuity affect any aspect of [1.1], [1.2], [1.3] or [1.4]?

(b) Processes involving the mixing of any substances, drying oils and the use of rags must be closely scrutinised. See [1.2 (b)]

1.6 Is everything correct?

(a) Following extensive investigations covering [1.1] to [1.5] inclusive, the investigator must be satisfied that all procedures have been carried out correctly and no potential existed for the process(es) or substance(s) to generate an ignition source or develop thermal runaway thereby starting the combustion process with an appropriate fuel.

1.7 Yes

(a) The investigator is satisfied that all procedures have been carried out correctly and no potential existed for the process(es) or substance(s) to generate an ignition source or develop thermal runaway thereby starting the combustion process with an appropriate fuel. Proceed to [1.19]

1.8 No

(a) The investigator is satisfied that one or more procedures have not been carried out correctly and that something in [1.1], [1.2], [1.3], [1.4] and/or [1.5] is not correct. Now proceed to [1.9].

1.9 Is there evidence of sabotage?

(a) The possibility that sabotage has occurred must be explored by the investigator. See FIRM #7: Person.

(b) Containers, including lids and securing devices, should be examined to ascertain whether deliberate removal or breaching has occurred. It may be useful to look at other containers remote from the area of origin as a saboteur may have attempted to cause damage in other locations within the premises.

(c) The deliberate act of combining two or more substances that are known to be reactive must be viewed as a possibility if all other indicators suggest that separation, handling and transportation were carried out correctly.

(d) The process and the continuity of that process should be closely examined for sabotage if all other indicators suggest that the process was being adhered to correctly.

1.10 Yes

(a) Physical indicators and/or circumstantial information show that sabotage is a possibility. Proceed to [1.12]

1.11 No

(a) Physical indicators and/or circumstantial information show that sabotage is not a possibility. Proceed to [1.16]

1.12 Is action capable of starting combustion process?

(a) Although there may be evidence of sabotage or vandalism, it is important to establish whether the action, or actions, could have created an ignition source for an adjacent fuel package or started the combustion process within the substance(s).

(b) The investigator is now able to consider any ignition source that may have been available to start the combustion or smouldering process. FIRMs 2, 3, 4, 5, 6 and 7 must all be followed to ascertain the potential for an ignition source to have been initiated from these routes.

1.13 Yes

(a) It has been established that the action, or actions, could have created an ignition source for an adjacent fuel package or started the combustion process. Proceed to [1.15] and [1.20].

1.14 No

(a) It has been established that the action, or actions, could not have created an ignition source for an adjacent fuel package or started the combustion process. Proceed to [1.19]

1.15 Inform the police

(a) The evidence exists of the possibility that human interference has created a fire situation. The intention may not have been to set a fire, but a fire has resulted due to those human actions. The police must be informed by the investigator as to the possibility of an arson fire.

1.16 Is action capable of starting combustion process?

(a) The investigator has determined that there is no evidence of sabotage or vandalism. It is important to establish whether the issues identified in [1.8 (a)] could have created an ignition source for an adjacent fuel package or started the combustion process.

1.17 Yes

(a) The investigator has established that the issues identified in [1.8 (a)] demonstrate that there is physical evidence or witness testimony that indicates a substance(s) or process(es) that could either be an ignition source for an adjacent fuel package, or be responsible for starting the combustion process itself. By following this route it is now possible to proceed to [1.20].

1.18 No

(a) The investigator has established that the issues identified in [1.8 (a)] demonstrate that there is no physical evidence or witness testimony that indicates any substance(s) or process(es) that could either be an ignition source for an adjacent fuel package, or be responsible for starting the combustion process itself. By following this route it is now possible to proceed to [1.19].

1.19 Unlikely to be responsible for fire

(a) All routes have now been explored so as to eliminate this category as a cause of the fire with the data that is available.

1.20 Possibly responsible for fire

(a) By arriving at this point in the FIRM, a hypothesis has been created that needs to be tested and compared to any other hypotheses that may be developed during the investigation. If more than one hypothesis can be proved as possibly being the cause of the fire, then ‘undetermined’ must be recorded.

FIRE INVESTIGATION ROAD MAP #2

STRUCTURES

2 Structures

This Chapter has categorised 'Structures' to cover buildings, frameworks, gantries, chassis, foundations, superstructures and any relationship or inter-relationship of parts in a construction. Structures also provide passages for all building services.

2.1 Does any part of the structure or framework move against energy supply pipes or conductors; do pipes or conductors move against any part of the structure or framework or does any movement of the structure create friction?

(a) A fire may have occurred when either an ignition source or a fuel load, or both, has been created due to the supply system of an energy source suffering either structural failure or becoming damaged due to abrasion, impact or crushing.

(b) This may range from an electrical conductor slowly being chaffed on the sharp edges of an un-grometted metal sandwich panel where the structure moves very slightly because of wind effect, to a fractured gas pipe due to the movement of a building. (See FIRM 6: Weather/Nature to ascertain conditions at the time of the fire)

(c) It must be established whether the structure is permanent or temporary as temporary structures are not usually as secure and sturdy as permanent structures. The use of the structure, its designed fire resistance and compartmentation methods must all be established very early in the investigation. For instance, temporary structures are often made of lighter materials so that deconstruction and relocation can be completed without the use of heavy machinery. These lighter materials may not offer the same fire resistance as more robust materials, such as concrete, bricks and mortar. There may also be more opportunity for fire spread due to gaps in joints where the structural, or other, elements come together.

(d) If the investigator finds evidence that electrical activity has taken place or arc damage has been identified, it must be clearly established whether the arc carried sufficient heat energy for the necessary duration to ignite an adjacent fuel package, such as a rodent nest or polystyrene sandwich panel. (See FIRM 3.15: Electricity).

(e) Timber members such as floor joists, ceiling joists and door frames can 'bounce' when weight or force is applied to them. If electrical conductors are abutting a timber member they may become subjected to mechanical damage which could lead to in-line arcing and localised heating. It is important that the investigator

refers to FIRM 3.15: Electricity, if any electrical activity is suspected within the area of origin.

(f) If conductors or pipe work are not secured in the correct manner, their movement within the structure can cause mechanical damage releasing the source within, which could become a fuel package or an ignition source. It is therefore important to consider the method and effectiveness of the fixing of these items during the investigation. Building Regulation Approval and Fire Prevention Systems should be explored by the investigator .See [2.2].

(g) The investigator must acquire a complete understanding of the basis of the structure, especially its originally designed usage, the design of the structure by reference to approved plans and the types of materials used in its construction.

2.2 Is there evidence of structural damage, failures of fire protection, fire resistance or failure to supply cooling or ventilation and are plans, building regulation approvals, schematics, etc. available for inspection?

(a) Building Regulation Approval and/or Fire Prevention Approval should be explored by the investigator. Often buildings are altered, modernised or the usage of the structure is changed without notification to the enforcing authorities. By checking approved structural and installation drawings with the existing buildings, it may be determined that unauthorised changes have been made.

(b) Structural damage caused by any source can mean loss of fire protection, compartmentation or fire resistance. The investigator will need to establish whether the cause of any structural damage is a result of, or cause of the fire.

(c) Damaged sprinkler systems, for instance by fork-lift trucks, may result in the system, or part of the system, being isolated and therefore not working when a fire develops. Although this would not lead to the cause of a fire, it would be a direct cause of allowing the fire to develop.

(d) Fire engineering design principles may have been ignored or breached. Again, by checking approved plans, the investigator will be able to record the details of what should have been in place at the time of the fire. This is of particular important when dealing with heating, ventilation and air conditioning systems, also known as HVAC systems. The position of fire dampers and their operating methods should be explored to ensure that they were capable of operating correctly.

(e) Many compartments, such as switch gear rooms, lift motor rooms and plant rooms are designed to have adequate ventilation or cool air circulation. If this becomes inadequate and equipment is not protected by thermal safety devices, overheating could occur which could lead to a fire developing. (See FIRM 5: Machinery, Equipment & Appliances to explore all possibilities of these being the cause of a fire.).

2.3 YES

(a) There is evidence that one or more of the conditions in [2.1] existed at the time of the fire. Proceed to [2.5]

2.5 NO

(a) There is no evidence that any of the conditions in [2.1] could have occurred. Proceed to [2.8]

2.5 Is there evidence of this action damaging supply pipes or conductors so as to release a heat source, or creating friction resulting in the generation of a heat source?

(a) Although the findings at [2.1] confirm that damage has been sustained, it must be determined that the energy source was released to create either a fuel or ignition source due to this damage.

(b) It must also be established as to whether the movement of structural components moving against each other are capable of creating a heat source. The types of materials involved must be recorded and structural component samples taken, if possible, to carry out further testing to see if a heat source can be generated by friction.

(c) Failure of service lines and fittings may have nothing to do with the structure but may give the appearance of having been damaged due to structural damage or movement. (See FIRM 3: Energy Supply to differentiate between structural involvement and other defects or acts that may have been the cause of a fire).

2.6 Yes

(a) There is evidence that an energy source has been released due to the damage sustained in [2.5], friction has allowed a heat source to develop, there is structural

damage, failures in fire protection, e.g. failures in fire resistance or a failure in supplying cool air or ventilation. Proceed to [2.11]

2.7 No

(a) There is no evidence as detailed in [2.6] above. Proceed to [2.18].

2.8 Has the structure promoted convection, conduction or radiation of heat onto a fuel source?

(a) A controlled fire or heat process may be running adjacent to, or within a structure, but due to the location, geometry, design or the construction materials of that structure, one or more undesirable situations may have occurred.

(b) Timber is a very viable fuel source with an auto-ignition temperature of 250^0C+ (depending upon the species) and the pyrolysis of timber has been the subject of many studies. The issue that creates much debate is at what temperatures will timber, depending upon the species, ignite following long periods of exposure to heat, sometimes years? Tests have been conducted that demonstrate certain timber will auto-ignite at temperatures considerably lower than their normal ignition temperatures (Babrauskas, 2001). This is referred to as 'pyrophoric carbon'.

(c) Pyrophoric carbon is reported to be much more readily ignitable than virgin wood (Babrauskas, 2001). The phenomenon associated with pyrophoric carbon is long-term, low-temperature ignition of wood without the presence of a pilot flame. (Babrauskas, 2003n) The theory is that as the wood pyrolyses into char and further drying creates cracks in the carbon, it allows air into the cracks. If the carbon (fuel), temperature (heat) and air (oxygen) availability are in correct proportions, flaming will occur.

(d) The removal of moisture and commencement of the pyrophoric action of timber can be initiated by superheated low and high pressure steam pipes, or flues carrying hot gases and either being in contact or extremely close to the timber. Tests and reports show that pyrophoric action is *more likely* to occur where air (oxygen) is restricted and the heat application to the timber is cyclic. Much more research needs to be conducted, but the investigator must consider the possibility of pyrophoric carbon when hot surfaces, (common reported figures of 373K (100^0C)+, but have been reported as low as 350K (77^0C) + (Babrauskas, 2003m)) and depending upon the species, are in contact with timber, especially if there is a restriction of air. There

are theories suggesting that as steam pipes are going through the cyclic heat process, ambient moisture may form condensation on the un-insulated sections of pipe work during periods of non-use and contributing to the exothermic heat of wetting to the self-heating process. During the heating of the pipes, there would then be a drying process of the wood which would allow an endothermic contribution from drying moisture, and an exothermic contribution from oxygen being made available to char pores which were previously moisture laden. (Babrauskas, 2003m) (Tsuchiya and Sumi, 1977).

(e) A rolled steel joist that does not have sufficient thermal protection may form part of a commercial pizza oven or kiln but may also be abutting timber structures some distance from the heat source. Conduction will allow the heat to be transferred through the steel and into the timber.. A similar effect can be created during hot cutting or welding of metal structural members whereby the heat generated may be transferred to combustible materials remote from the cutting or welding area by conduction as well as by welding sparks.

(f) Timber members may be abutting a brick wall whereby a heat source on the opposite side can be transmitted through the bricks onto the timber. This has occurred where chimney stacks have developed cracks within the bricks or where mortar is not stopping the hot gases or flames from impinging upon adjacent timber members.

(g) A more common problem is where plaster board is fixed to stud walls and a boiler or other device, which gives a large heat output, allows heat to transfer through the plasterboard, drying out the timbers and causing them to ignite, sometimes after very long periods of time.

(h) Combustible structural and decorative materials, such as plastics and timbers, may be too close to a heat source, and through thermal radiation may reach their auto-ignition temperature. Study approved design layouts of floor plans to ascertain the geometry and location of combustible items.

(j) It is important to identify the first fuel package that was ignited within a structure so as to clarify if the problem is due to the construction materials, methods employed, the construction geometry, the materials used or the heat source location.

(k) The investigator is now able to consider any ignition source that may have been available to start the combustion or smouldering process. FIRMs #1, #3, #4, #5, #6

and #7 must all be followed to ascertain the potential for an ignition source to have been initiated from these routes.

2.9 Yes

(a) The structure has been either responsible for, or instrumental in, allowing a heat source to come into contact with a fuel package. Go to [2.11]

2.10 No

(a) There is no evidence that the structure has been either responsible for, or instrumental in, allowing a heat source to come into contact with a fuel package. Go to [2.14]

2.11 Can the actions identified in [2.2], [2.5] or [2.8] promote the combustion process?

(a) It must be ascertained if one or more failures identified in [2.2], [2.5] or [2.8] can or cannot lead to the combustion process occurring.

(b) A viable fuel package and ignition source emanating from the investigations made in the stated sections must have been clearly identified to be able to proceed onto [2.12]

2.12 Yes

(a) It has been identified that one or more of the actions identified in [2.11] can lead to combustion. Proceed to [2.19].

2.13 No

(a) None of the actions identified in 2.2, 2.5 or 2.8 were capable of starting the combustion process. Proceed to [2.18]

2.14 Is housekeeping undesirable or is there evidence of hoarding?

(a) It needs to be ascertained whether the general storage and separation arrangements of combustible materials and ignition sources are acceptable to prevent them

coming together to start a fire. Most equipment and products that are stored within structures have clear instructions on how they should be stored and handled.

(b) A build up of flammable contaminants, such as grease residues, within ductwork and extraction systems can be a hazard. Consider looking at other undamaged parts of the structure to compare the overall standard of house keeping.

(c) Hoarders of combustible items such as newspapers and cardboard boxes, especially if they are smokers, increase the potential of an accidental fire.

(d) The 'housekeeping' within a structure can also encompass management procedures that if not adhered to may create a hazardous fire situation. For example the lack of regular cleaning of filters within a tumble drier and any associated ductwork may enable highly combustible lint to accumulate within the drum and extraction system whereby the smallest spark, which could be from the heating device, a control switch, friction or static, could potentially ignite the lint.

(e) Lack of cleaning of wood-shavings, metal particles or dust in a workshop area or store room can have the same effect as [2.14.d]

2.15 Yes

(a) Housekeeping within the structure is in good order and would assist in preventing a fire from occurring and spreading. Proceed to [2.17]

2.16 No

(a) Housekeeping within the structure is in good order and would assist in preventing a fire from occurring and spreading. Proceed to [2.18]

2.17 See FIRMs #1, #3, #4, #5, #6 and #7.

(a) The investigator is now able to consider any ignition source that may have been available to start the combustion or smouldering process. FIRMs #1, #3, #4, #5, #6 and #7 must all be followed to ascertain the potential for an ignition source to have been initiated from these routes.

(b) It has been identified that bad house-keeping presents a viable fuel supply, however by following all other Fire Investigation Road Maps, the investigator will be able to identify any potential ignition sources that could have enabled a fire to start with that fuel source.

2.18 Unlikely to be responsible for fire

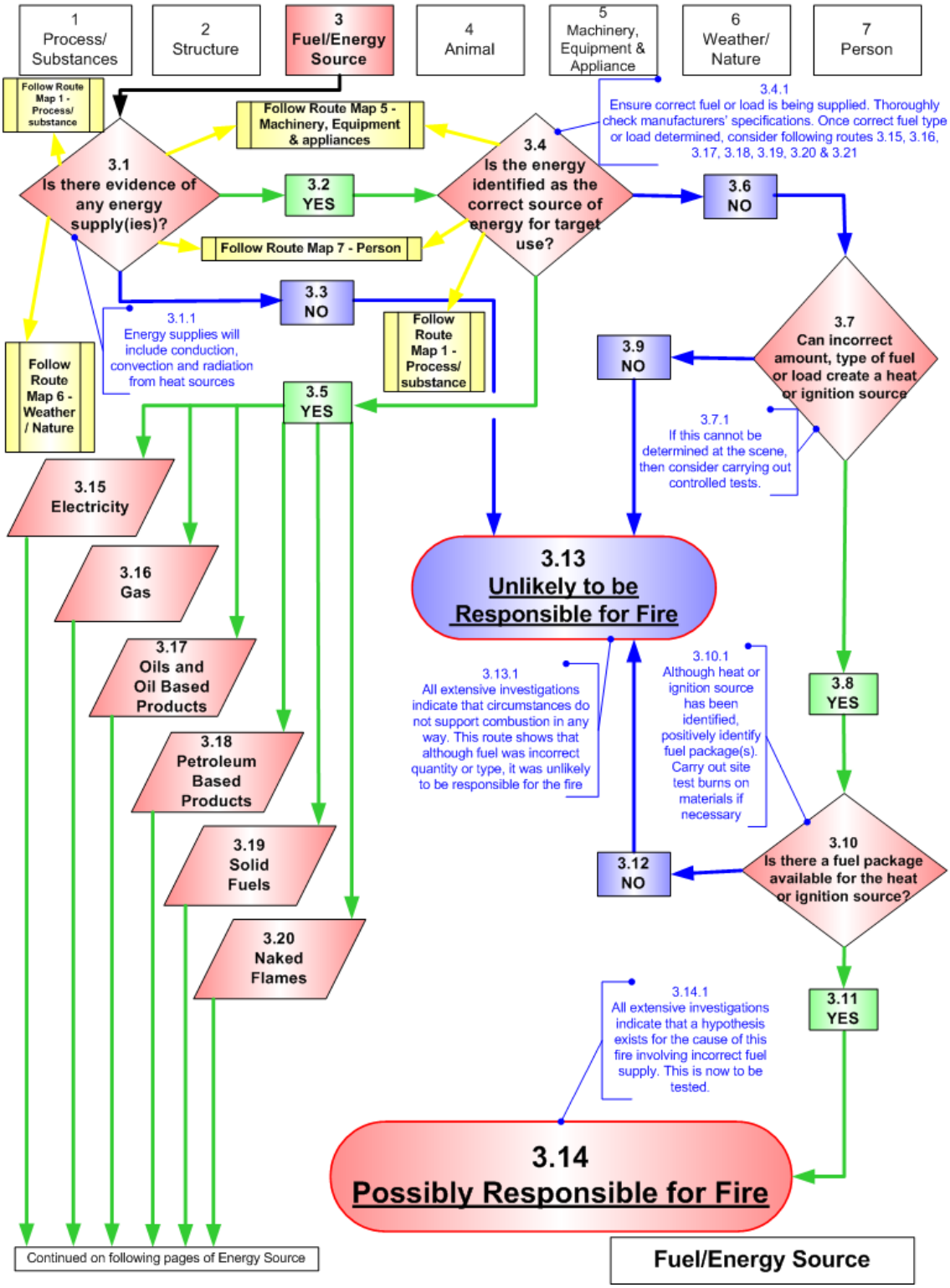
(a) All routes have now been explored so as to eliminate this category as a cause of the fire with the data that is available.

2.19 Possibly responsible for fire

(a) By arriving at this point in the road map a hypothesis has been created that needs to be tested and compared to any other hypotheses that may be developed during the investigation. If more than one hypothesis can be proved as possibly being the cause of the fire, then ‘undetermined’ must be recorded.

FIRE INVESTIGATION ROAD MAP #3

FUEL/ENERGY SOURCE



3 Fuel/energy source

'Without some source of energy, there will be no fire'(DeHaan, 2007g). All of the other FIRMs #1, #2, #4, #5, #6 and #7 are cross-linked to this FIRM #3, as they will all require an energy source to initiate a fire. It is therefore most probable that when using the other FIRMs, the investigator will be referring to this section at some point during the investigation.

This FIRM is subdivided into six categories of energy:

- #3.15 Electricity
- #3.16 Gases
- #3.17 Oils
- #3.18 Petroleum based products
- #3.19 Solid fuels
- #3.20 Naked flames

It encompasses sources of fuel/energy that may be used as or become an ignition or a fuel source, accidentally or non-accidentally, (deliberately).

IMPORTANT NOTE:
In the absence of any other possible energy supply, then by exploring FIRM #3.20 – Naked Flames, the investigator must be aware that this does not encompass the *deliberate* application of a naked flame by the use of a match, lighter, pyrotechnic or any other device that produces or sustains a naked flame, and is intentionally introduced to a fuel package. This is covered in depth within FIRM #7 – Person.

This FIRM does not include mechanical or frictional sparks as these are included in FIRM #5 - 'Machinery, Equipment and Appliances' nor lightning or solar radiation, as these are covered in FIRM #6 - 'Weather & Nature'.

3.1 Is there evidence of any energy source(s)?

(a) As stated in the first paragraph of this Chapter, 'without some source of energy, there will be no fire'. Once the origin of a fire has been established, the most

critical point in any investigation into its cause is to identify the energy source that led to the ignition of a fuel package.

(b) Although it may appear obvious that some form of energy was present within, or close to the area of origin, for example there may be the remains of electrical conductors with evidence of arcing (see [3.15]), the investigator must attempt to identify all forms of energy that could have been present at the time of the fire.

(c) It may seem contradictory to suggest that if the investigator cannot find any possible energy sources within, or close to the area of origin, then the road map will lead to [3.13] – 'Unlikely to be Responsible for the Fire', indicating that there could not have possibly been a fire without an energy source. A hypothesis will be developing that an energy source could have been introduced and then either withdrawn or destroyed. The investigator must therefore proceed to and follow FIRM #6: Weather and Nature, to ascertain conditions at the time of the fire, for instance, bright sunshine or lightning strikes may have occurred and also FIRM #7 – Person, to see if a deliberate act, such as the application of a naked flame, has been committed.

(d) It is important to study FIRMs #1 – Process & Substance, #4 – Animal, and also #5 – Machinery, Equipment and Appliances, to enable the investigator in identifying all possible forms of energy that may have since been removed from the area of origin, or close to the area of origin.

3.2 Yes

(a) One or more energy supplies have been identified as being within, or close to the area of origin. Proceed to [3.4].

3.3 No

(a) No energy supplies have been identified as being within, or close to the area of origin. Proceed to [3.13].

3.4 Is the energy identified the correct source of energy for the designed use?

(a) The term 'Designed Use' in this section refers to the receiver of the energy supply. An example of the source energy being incorrect for the designed use is when a visitor from the USA travels to the UK and uses a charger for an electric toothbrush. The power being delivered to the charger is excessive for the design

and turns the charger into a small heating element with the potential to initiate a fire.

(b) Ensure that the correct fuel or load is being supplied for the designed use. Also check that the energy is being used in the correct manner. Check with all manufacturers' and suppliers' instructions as to energy requirements for the designed use and any safety precautions that should have been in place. (See FIRM #1 – Process/ Substances, FIRM #5– Machinery, Equipment & Appliances and FIRM #7 - Person)

(c) Some examples include a 110volt appliance being used in a 230volt system and over-heating; the wrong type of petrol or diesel for the type of appliance it is supplying; incorrect gas for the type of burners that are consuming it and too large a flame from an appliance causing high temperature convection or radiation to an adjacent fuel package.

3.5 Yes

(a) The energy supply has been identified as the correct amount or type of energy that was being consumed for the designed use.

(b) Depending on the energy supply, either proceed to FIRM #3.15, #3.16, #3.17, #3.18, #3.19 or #3.20.

3.6 No

(a) The energy supply has been identified as the incorrect quantity or type of energy that was being consumed by the designed use.

3.7 Can incorrect amount, type of fuel or energy load create a heat or ignition source?

(a) Although it may be evident that [3.4] has revealed an undesirable situation, it must be determined as to whether a heat or ignition source can be created by that situation.

(b) If this cannot be determined at the scene, then consider carrying out controlled tests elsewhere.

(c) If it has been identified that heat has been generated so as to become a potential ignition source, it will need to be established if the potential ignition source is above the ignition temperature of any available fuel package, or if the ignition

source could have been in contact with the fuel package for long enough to cause combustion. Proceed to [3.8].

(d) If no heat is generated or potential ignition source created then proceed to [3.9].

3.8 Yes

(a) It has been identified that an incorrect fuel or load has generated a heat source which could become a potential ignition source; proceed to [3.10].

3.9 No

(a) It has been identified that no heat sources have been generated by the incorrect fuel or loading identified in [3.4] then proceed to [3.13]

3.10 Is there a fuel package available for the heat or ignition source?

(a) The investigator needs to establish whether a fuel package was available whereby the heat or ignition source identified would be capable of initiating the combustion process. Not only must a fuel package(s) be identified, but it must be possible for the heat source to come together with that fuel package and transfer enough energy to cause ignition to the package.

(b) If little or no evidence remains, then an inspection of any inventories or stock control records, or details of witness testimony, can indicate the types of fuel packages that were available.

3.11 Yes

(a) A fuel package(s) has been identified, and it has been demonstrated that is was possible for the heat source to come together with that fuel package and transfer enough energy to cause ignition to the package. Proceed to [3.14].

3.12 No

(a) A fuel package(s) has not been identified that would enable the heat source to initiate the combustion process. Proceed to [3.13].

3.13 Unlikely to be responsible for fire

(a) All routes have now been explored so as to eliminate this category as a cause of the fire with the data that is available.

3.14 Possibly responsible for fire

(a) By arriving at this point in the road map, a hypothesis has been created that needs to be tested and compared to any other hypotheses that may be developed during the investigation. If more than one hypothesis can be proved as possibly being the cause of the fire, then 'undetermined' must be recorded.

3.15 Electricity

Now proceed to [3.15.1]

3.16 Gas

Now proceed to [3.16.1]

3.17 Oils

Now proceed to [3.17.1]

3.18 Petroleum Based Products

Now proceed to [3.18.1]

3.19 Solid Fuels

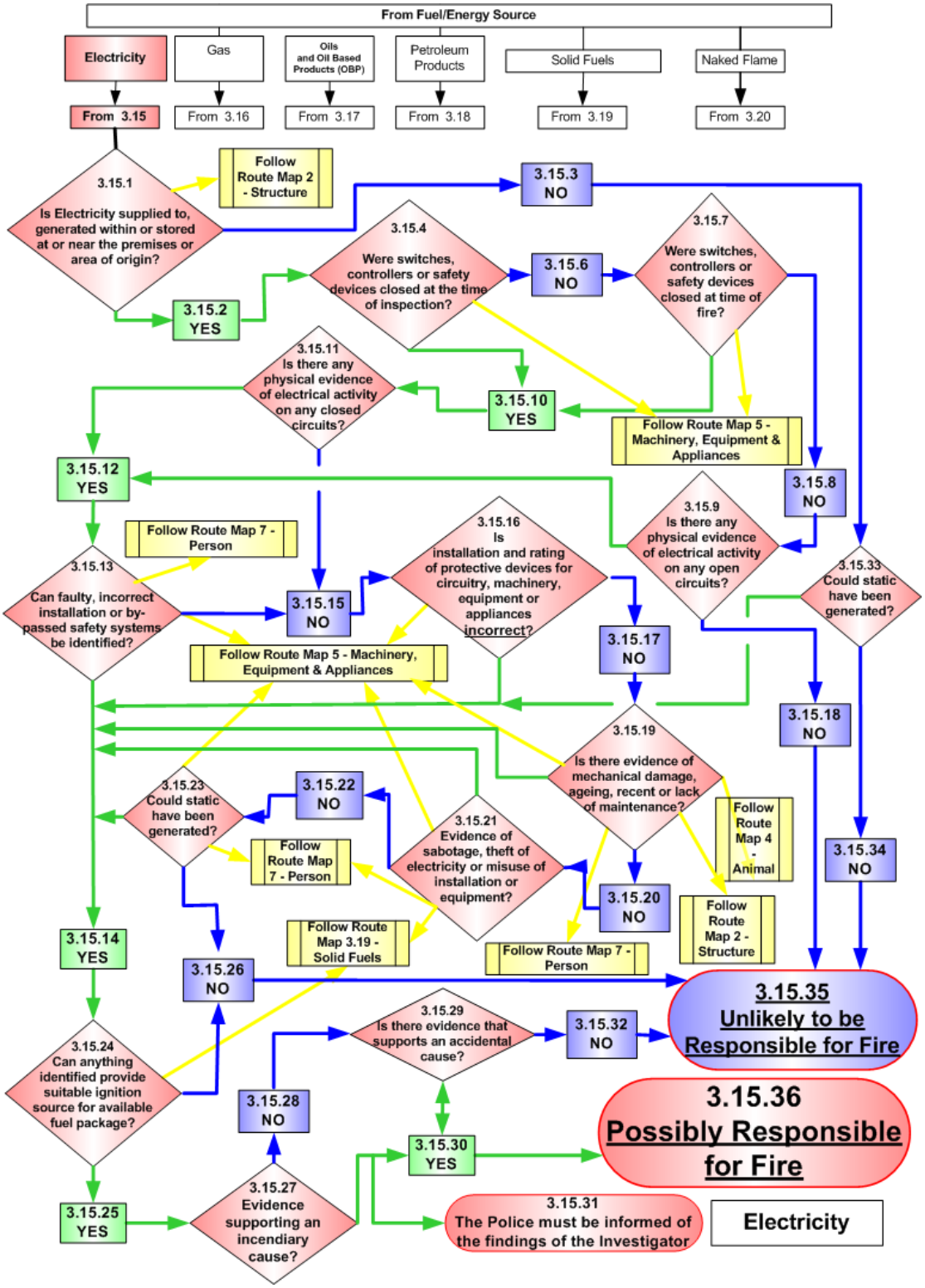
Now proceed to [3.19.1]

3.20 Naked Flames

Now proceed to [3.20.1]

FIRE INVESTIGATION ROAD MAP #3.15

ELECTRICITY



3.15 Electricity

This road map is to be used if the area of origin has an electrical energy supply within it. It should be used to satisfactorily eliminate or to confirm any electrical activity as being the possible cause the fire. It is imperative that nothing is touched, moved or altered prior to recording and photographing any item(s). Careful evaluation of any evidence of electrical involvement must be conducted in conjunction with any other potential ignition sources present. If the electrical knowledge of the investigator is limited then somebody with electrical expertise should be consulted before the road map is followed.

Ensure that the electrical supply has been isolated and 'locked off', preferably with a lock, key and label so that re-activation of the system will not occur.

Electrical examinations can be extremely time consuming and must be done carefully, methodically with all stages being recorded and photographed where necessary. As with any other part of the investigation, all interested parties must be considered as the destruction of any evidence being examined can be seriously detrimental to a third party's investigation.

The investigator must remember that fuses and circuit breakers are safety devices designed to protect against electrical short circuits, over current and overloads. They will not protect against resistive heating, unless the heating subsequently causes a short circuit. A large over current that persists is considered an over load and may cause the conductor to become hot enough to ignite adjacent fuel loads.

3.15.1 Is electricity supplied to, generated within or stored at or near the premises or area of origin?

(a) It is important that the investigator has established whether any electrical source had been supplied to the premises or area of origin. Not only can the source be supplied by an external utility company, but it can also be generated locally or even within the premise by the use of one or more generators. Generators may also be used as a back-up supply should the main supply fail. The generators will activate

with almost no interruption to the electrical supply, thereby maintaining important services, such as smoke extraction plant, and specified equipment.

(b) It must also be considered that an uninterrupted power supply (UPS) may be fitted. This consists of one or more batteries that feed electrical equipment, typically used as a back-up for equipment, such as information technology equipment, when there has been a power failure to the main supply. The mains supply would have kept the batteries charged allowing them to deliver full power if the mains supply is lost.

(c) Another type of stored energy is in the form of fuel cells, which is an electrochemical energy conversion device. Hydrogen atoms enter a cell at the anode where a chemical reaction strips them of their electrons. The hydrogen atoms are now "ionized," and carry a positive electrical charge. The negatively charged electrons provide the current through wires to do work. Oxygen enters the fuel cell at the cathode combining with electrons returning from the electrical circuit and hydrogen ions that have travelled through the electrolyte from the anode. The electrolyte allows ions to pass between the anode and cathode. Whether they combine at anode or cathode, together hydrogen and oxygen form water, which drains from the cell. As long as a fuel cell is supplied with hydrogen and oxygen, it will generate electricity (Smithsonian Institute, 2008).

(d) It may be necessary to check with the local electrical utility company whether any power lines or cables run adjacent to the property or area of origin, either underground or overhead, as any faults within the supply system may have an influence on any item, equipment, appliances or machinery within them due to leakage.

(e) It is important that the investigator establishes what type of electricity supply is being used within the premises or area of origin so that an understanding may be established as to the installation and safety device requirements associated with those supplies. It must be established whether the electrical supply is single-phase, multi-phase or stored energy.

(f) It may be that all three types with various voltages are used; for example, at a shopping centre where three-phase 415V would be supplying the various retail units, single-phase 230V would be fitted within those units, and Direct Current (DC) 12V or 24V would be supplying emergency lighting and other life safety devices in the event of a power failure

(g) The electrical system may need to be fully inspected and must be completely understood by the investigator. If the amount of installation that is involved within the area of origin is relatively small, then localised inspection may suffice.

(h) However, whether it is a full scale or localised inspection, the layout of the conductors, controllers, safety devices, machinery, equipment or appliances all need to be inspected. It is advisable to make detailed sketches and diagrams whilst the inspection progresses. Annotate the sketches and diagrams to include as much information about the system and its components, including conductor sizes and lengths, and take photographs where necessary.

(j) Conductor sizes must be checked to confirm they are the correct size for the load that they are carrying. Below is a simple table that may be used to determine the correct size of conductor in most domestic, commercial and light industrial premises:

Diameter of Conductor Ømm	**Conductor cross-sectional area** mm^2	**Current carrying capacity (free air) amps**	**Solid core or stranded**	**Current carrying capacity (enclosed) amps**
1.14	$1mm^2$	15	Solid	11
1.4	$1.5mm^2$	19.5	Solid	14
1.78	$2.5mm^2$	27	Solid	18.5
7 strands 1.04	$6mm^2$	46	Stranded	32
7 strands 1.35	$10mm^2$	63	Stranded	43

Table 3.1

PVC Covered Copper Twin and Earth Cable Data

(k) The type(s) of electrical supply would have to be identified as each may require safety devices and equipment particular to that supply.

(m) Time should now be spent examining the system(s) and documenting and recording any items moved or relocated during this inspection. The investigator needs to understand the system source type(s) before proceeding with the investigation so that expectations of functions and performances can be assessed against any findings at the scene.

(n) Labelling found on equipment, control and safety devices may give an indication as to the type of voltage and whether it was single-phase, multi-phase or DC supply, as detailed in the example below:

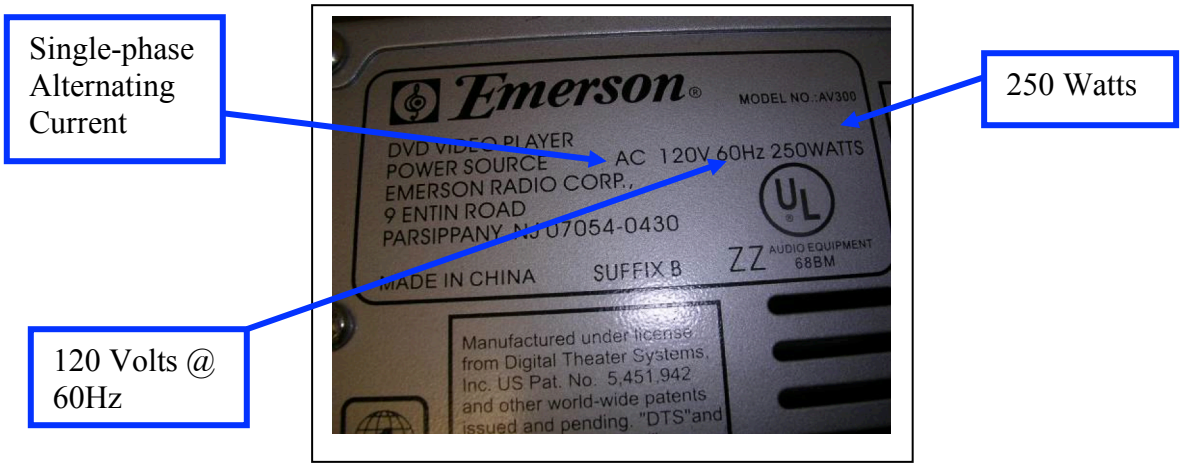


Photo 3.1 Manufacturer's Data Label

3.15.2 Yes

(a) It has been confirmed that electricity is supplied to, generated within or stored at or near the premises or area of origin, or any combination of the latter. The provision and type of supply has also been established. Proceed to [3.15.4]

3.15.3 No

(a) It has been identified that electricity is neither supplied to, nor generated within, nor stored at or near the premises or area of origin. Proceed to [3.15.32].

3.15.4 Were switches, controllers or safety devices closed at the time of inspection?

(a) The investigator needs to establish whether any devices within the wiring systems were closed at the time of inspection. A closed system is when, for example a switch is in the 'ON' position, thereby 'closing' the circuit and making a continuous electrical connection. When the switch is in the 'OFF' position, it is 'open' and the electrical supply cannot get past that part of the system. It may be advisable for the investigator to think of an 'open' circuit as an open bridge; an open bridge cannot be crossed, but a closed bridge makes a path continuous and therefore can be. The investigator should ask the occupier if any switches were opened or closed immediately before the fire or when the fire was discovered (as they may have turned them off).

(b) Apart from checking for mechanical damage and/or any disconnected conductors, devices that will need to be checked include switch gear, fuses, circuit breakers, plugs, sockets, thermostats, timing devices, solenoids, machinery switches, equipment switches, appliance switches and any other fitting that could open an electrical circuit. This can be done by using a continuity tester and tracing the circuit from the electrical distribution panel to its source(s). It is therefore important that the fire investigator has a good quality electrical continuity tester, preferably as part of an electrical multi-meter, and is familiar with its usage and limitations.

(c) All safety devices protecting a circuit must be examined to ascertain their status and to establish whether the distribution panel safety device isolated the system prior to the fire attacking that particular circuit. It is possible that electrical activity on that circuit, which was an effect of the fire and not the cause, has activated that circuit's safety device before activating the distribution panel's device.

(d) The significance of checking for closed circuits at the time of inspection is that the investigator may start to eliminate such circuits as being potentially responsible for the fire as the circuit protection device should have operated had the fire attacked the circuit whilst energised or a Residual Current Device (RCD) may have isolated the distribution board. The investigator should consider that someone may have opened the circuit once they had become aware of a developing fire and that the circuit may have had an appliance connected to it, which may have been responsible for the fire, i.e. an electric heater too close to combustibles.

(e) Depending upon the type of protection to the main distribution board, for instance, if it is fitted with a Residual Circuit Device (RCD) or a cartridge fuse, a short circuit or short-to-earth may operate the RCD and isolate the rest of the system that is distributed from that panel. So, if a well protected circuit is closed following a fire, with no electrical activity evident, then it is unlikely to be a cause of the fire.

(f) If a circuit is open at an isolation device rather than a protection device, such as a switch or a plug, then everything 'downstream' from that isolation device would not have had electricity supplied to it, and therefore is unlikely to have been responsible for the fire. It is important to cross-reference with Road Map [7] – Person, to determine if any person isolated the device *after* the fire had started, and why.

3.15.5 Yes

(a) Circuits have either been identified as being closed at the time of inspection, closed at the time of the fire or electrical activity has been identified on an open circuit. These will now need to be examined further to ascertain whether there was a fault or failure within them.

(b) The importance of finding electrical activity, such as arc damage, on an open circuit is that it may be indicative of that circuit having been closed at the time of the fire. Proceed to [3.15.10]

3.15.6 No

(a) Circuits have been identified as being open at the time of inspection and will need to be examined further to ascertain whether they were closed at the time of the fire. Proceed to [3.15.7]

3.15.7 Were switches, controllers or safety devices closed at the time of fire?

(a) Although devices are found to be open following a fire, the investigator must explore the possibility of the device being closed before the fire and whether the opening of the device was due to the effects of a remote fire or a fault within the circuit or device which may have caused the fire.

(b) Carbon deposits between electrical contacts on safety devices offer little evidential value as contacts often have carbon deposits due to arcing in normal use. However, evidence of corrosion, chronic pitting or welded contacts could indicate a failure in the device. An example is a hairdryer that has been involved in a fire when, upon inspection, it is found that the re-settable thermal cut-out safety device has welded together. This indicates a failure of that device, which may have allowed the hair-drier to overheat and potentially be the cause of the fire.

(c) If it can be determined that any device was closed at the time of the fire, then all wiring and other energised devices downstream on that circuit must be carefully examined for electrical activity in the form of arcing, melting of conductors, welding of contacts, etc.

3.15.8 No

(a) Although it has been established that switches, controllers or safety devices appeared to be open at the time of the fire, the investigator should now proceed to [3.15.9].

3.15.9 Is there any physical evidence of electrical activity on any of the open circuits?

(a) Once it has been established that an open device may have operated during the fire, a check must be made before the investigator can eliminate that circuit as being potentially responsible for the fire. All conductors, equipment, appliances, machinery and safety devices downstream of the open part of the circuit should be examined for electrical activity.

(b) Abnormal electrical activity can produce characteristic damage that may be recognised after the fire. This may be due to the cause of the fire or an effect of it. It can also provide evidence as to the possible area of origin of the fire (NFPA, 2008j).

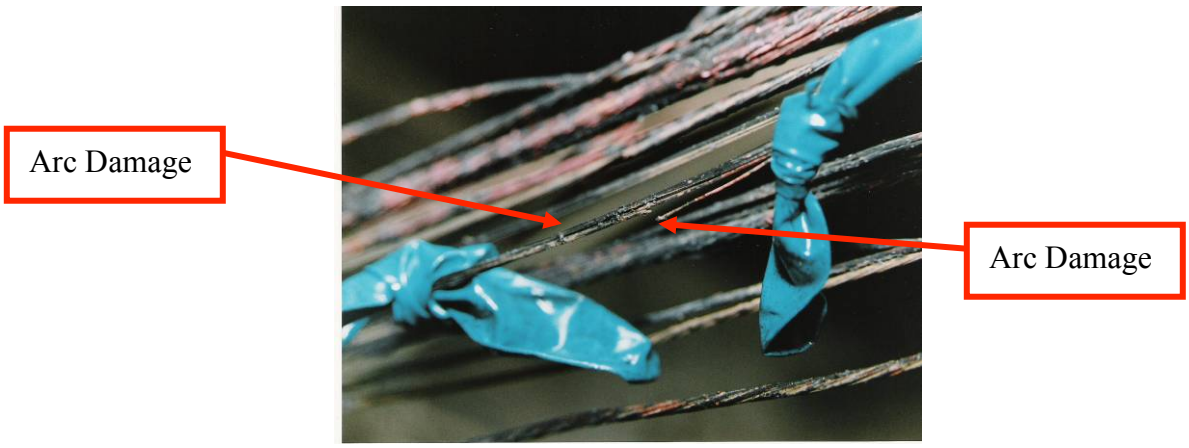


Photo 3.2 Arc damage to conductors

(c) Resistive heating is one of the main causes of electrical fires. The other being misuse of electrical equipment. Resistive heating may take place when there is a loose or contaminated connection, poorly soldered joints (known as dry joints) or breakages in multi-stranded cables. It is common for resistive heating to occur at connection points within a circuit.

(d) Resistive heating will not cause a fuse, circuit breaker or RCD to open as the circuit is not carrying an electrical current higher than the circuit is designed for and there is not an earth fault creating an imbalance in the circuit. It is as if an appliance is acting as a resistance within the circuit, which is normal and the expected condition. It requires a short circuit, overload or earth fault to operate a safety device.

(e) Conductors may have been damaged before or during a fire by other means than electrical causation and the investigator must be able to recognise these effects as not being caused by electrical activity.(See [3.15.13.s] below).

(f) Copper conductors can melt when exposed to high fire temperatures. Globules of melted and re-solidified copper may be seen along the conductor and these will be irregular in shape and size due to the uneven heating effects of a turbulent fire.

(g) Stranded conductors may fuse together to become one solid core of copper. Again, this will be uneven due to the variation in heat application over the length of the conductor.

3.15.10 Yes

(a) It has been established that switches, controllers or safety devices appeared to be closed at the time of the fire. The investigator should now proceed to [3.15.11].

3.15.11 Is there any physical evidence of electrical activity on any of the closed circuits?

(a) Once it has been established that a closed device may have operated during or before the fire, a check must be made of all conductors, equipment, appliances, machinery and safety devices downstream of the closed part of the circuit for any electrical activity.

(b) An arc is a high temperature luminous electric discharge across a gap or through a medium such as charred insulation. Temperatures within the arc are in the range of several thousand degrees but occur so quickly that they may not be competent ignition sources for many fuels (NFPA, 2008i). Fuels with high surface to mass ratio, such as lint or tissue paper, may be ignited by the brief contact with an arc.

(c) Refer to [3.15.9.b] to [3.15.9.g] as these sections also applies to closed circuits.

(d) Another cause of 'electrical fires' is the misuse of electrical equipment. (See FIRM [5] Machinery, Equipment & Appliances). All appliances that are connected to a circuit should be examined so that the correct use of that appliance may be determined; this would include, for example, the positioning of a heater too close to combustibles or the jamming of a fan's blades or other electric motor due to an incorrect mounting causing it to fall and become stalled whilst still being supplied with electricity. Tests have been carried out (Carey and Mansi, 2006) on plastic cased circulating fans where the blades were stalled and the electric motor generates enough heat to eventually ignite the casing.

3.15.12 Yes

(a) It has been determined that there is physical evidence of electrical activity on either a closed or open circuit. Proceed to [3.15.13]

3.15.13 Can a faulty or incorrect installation, a by-passed safety system or device be identified?

(a) The electrical installation may need to be fully inspected and understood to determine whether it has been installed correctly or not and whether any safety systems or devices have been by-passed or over-ridden. Much information would

have been gathered at stage [3.15.1] Once again, ensure that the electrical supply has been isolated and 'locked off' with a lock, key and label so that re-activation of the system will not occur.

(b) It is now very important that the investigator has a fundamental understanding of the complete electrical system and its individual circuits and components within those circuits.

(c) It is advisable for the investigator to obtain any drawings or schematics of the system(s) installed. If none are available, the investigator should start mapping the system as much as possible, creating their own schematic drawing(s).

(d) All conductors and their sizes, switch gear, controllers, safety devices, machinery, equipment and appliances, including their designed operating loads, safety ratings and any other technical information should be recorded.

(e) If the fire occurs within a structure, then it is advisable that the investigator starts at the point where the electricity comes into the property. The service head, meter and distribution board should be examined for arc damage and resistive heating due to a loose connection. In almost all illegal marijuana growing buildings that are converted from domestic dwellings, the electric meter and safety devices are by-passed due to the large electrical requirements for the equipment being used. This means that if the house fuse or main fuse board switch is opened, the complete system could still be live. The investigator must test all electrical circuits, components and appliances prior to examination by using either a multi meter or a voltage test stick, which either lights up, displays the voltage present and/or vibrates when the circuit is still live.

(f) Any equipment that is identified as being involved in the fire must be completely documented. This will include a full prose description of the item and surrounding area and comprehensive photographic documentation. All plugs, cables and connections should be documented including the length of any cables. (See also Road Map [5] – Machinery, Equipment and Appliances to ensure complete examination and determine the designed use of the identified items)

(g) A clean bench-top examination of relevant items with good lighting is advised. It is advisable to correctly package any item that requires further off-site examination. This includes complete documentation and removal to a safe and secure location. Whether on or off-site examinations are to take place, all interested parties must be

informed and given notice to attend any physical examinations, whether it includes destructive testing, dismantling or not.

(h) Consider the use of X-raying any components or items that would otherwise involve destructive examination. Fuses can be successfully X-rayed to confirm whether or not they have operated. The remains of some appliances that are heat generators, such as a coffee maker, can hardly be identified following their destruction (see image below):

Photo 3.3 Fire Damaged Plastic Coffee Maker

However, when an X-ray is taken of the molten remains, the internal components can be easily identified. From an image such as the one below, any safety devices that may have been by-passed will be clearly seen. Also, any defects or loose connections may also be identified without subsequently damaging the item with a physical examination, which may not necessarily yield satisfactory results anyway.

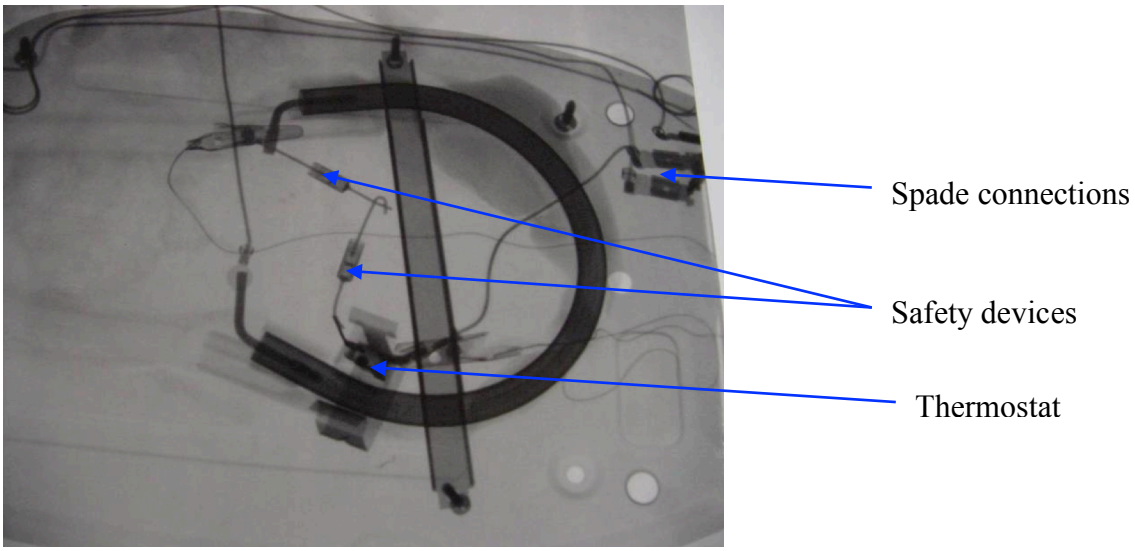


Photo 3.4 X-Ray of Fire Damaged Plastic Coffee Maker

(j) Arc damage found on metal conductors indicates the point at which two conductors have come together or there has been conduction through carbonised wiring insulation creating a fault. The investigator must ascertain whether the fault was created due to mechanical damage, such as an object falling onto the conductors, damaging the outer insulation and allowing the metal conductors to come together, abrasion, or by an external heat source melting the insulation, thereby exposing the metal conductors and allowing them to create a fault.

(k) Any arc damage found must be recorded. A 'map' of all the arc damage found at the scene may be used to locate or confirm the origin of the fire using a process referred to as 'arc-mapping'.

(m) By plotting the location of the arcing damage on a plan the investigator may indicate important information about the location of the origin and the probable sequence of the fire's spread. If the layout of the electrical system can also be put onto the plan then it may be possible to establish the area where the fire and the energised system first coincided.

(n) The methodology described below is suitable for virtually all fires in the UK. This would include for example where cables are surface run (loose, clipped to surface or run in conduit & trunking).

- *Appliance cords/cables and extension leads that are exposed to the fire.*
- *Roof spaces in dwellings, where exposed cables are loose (or clipped to joists) and not entirely covered with insulation.*
- *Retail units and factories where the electrical installations are surface run.*

(p) Where the wiring is buried behind plaster or plasterboard and this does not fail during the fire to expose the wiring, arcing should not occur. To use this methodology in a large building can be extremely time consuming but may produce very positive results.

(q) The electrical system can provide important information following a fire due to its remains being less fragile than that of many combustibles.

(r) The copper wiring used in residential or commercial buildings and appliances will melt at a nominal temperature of 1082^{0}C. This temperature, higher than that often encountered for significant periods of time in the normal fire environment, can

easily be achieved locally by arcing. This arcing is due to electrical current flow between the live & neutral conductors or between these conductors and the earth/ground, called an “arcing fault" (Carey, 2004).

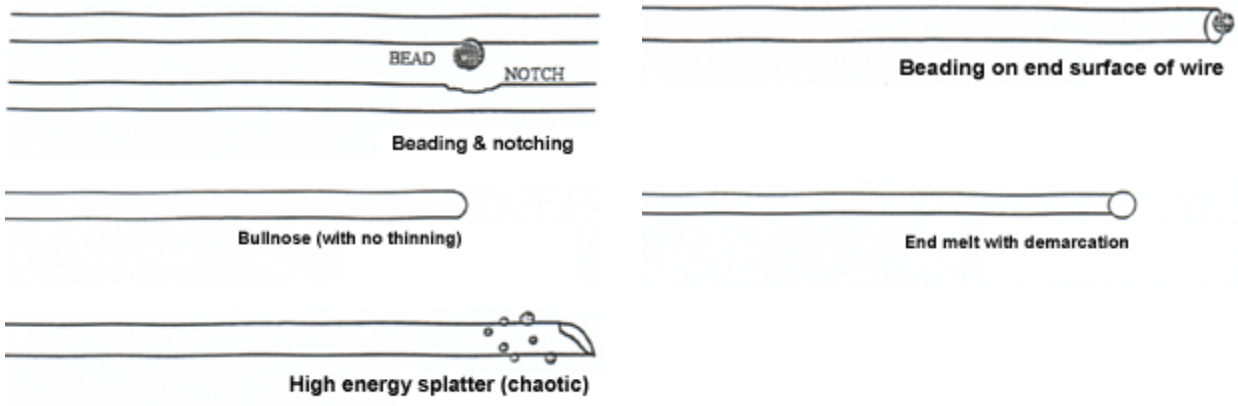
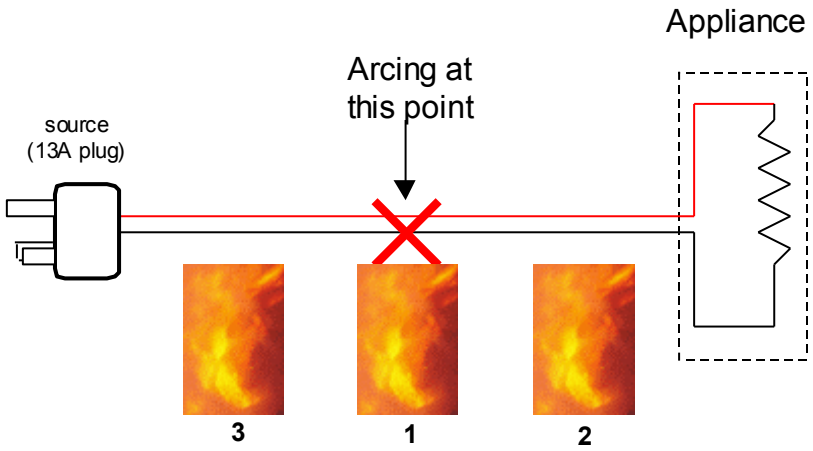


Figure 3.1 Beading examples of copper conductors (Carey, 2004)

(s) True beading (see above diagrams) of the copper conductors due to the electrical arc consists of the spherical beads, notches, lines of demarcation, splattering and other indications of high energy and chaotic activity associated with the electrical arc. Metallurgist with experience in arcing damage to copper may have to be consulted to get more accurate data.



Fire first attacks cable at point 1 and the cable arcs as the wires touch. The protective device (plug fuse etc.) will normally operate now. If the fire continues to attack the cable at points 2 or 3 there should not be arcing at these points.

Figure 3.2 Arcing Sequence Diagram (Carey, 2004)

(t) Figure 3.3 (above) shows fire attacking appliance supply flex/cable's insulation. The source of current (plug) is at the left end of the cable. When fire #1 burns through the insulation, an arcing fault will occur if the wires touch each other or the carbon residue conducts enough electricity. This will cause the wires to bead.

(u) If the fire is slowly developing, this fault will be localised around fire #1 because the over current protection device (fuse, circuit breaker) has time to open. Since the local energy in the arc is sufficient to vaporise copper, the tell tale beads form from the cooling copper as the arc extinguishes during the alternating cycle of current (100 times per second = 50Hz). The formation of the beads results in welding the conductors together, severing the conductors and/or blowing the fuse protecting the wiring (Carey, 2004).

(v) This means that a subsequent fire attack at point #2 on the wire downstream from the original point of arcing produces no further arcing since the electrical supply had been cut off.

(w) Subsequent damage from fire #3 on the wiring upstream of the first fault point may result in arcing if the circuit has not been de-energised (however, this would be very unusual). Therefore, a single wire can indicate where it was first damaged by the fire, by finding the point of fault farthest from the supplying energy source.

(x) To illustrate this, imagine an energised cable/flex feeding a heater in a room. It will have the tendency to fault close to the heater if the heater was at the origin of the fire. However in the unlikely event of the fire starting in the wall socket outlet, we would not expect to find a fault inside the heater or in the appliance cable/flex as the fault in the socket would de-energise the circuit and remove the electricity supply at the plug (Carey, 2004).

(y) Using the example below, it can be seen that if a fire that had started within a waste bin [1] and began to spread within the living room, it may first attack the exposed cable of the light fitting [2] and then the outlet and mains circuit [3]. This would probably trip the circuit breaker or blow a fuse at the consumer unit (fuse board) rendering that electrical circuit [4] dead. Although the television and light [5] may have been switched on, the power to these would have been isolated when the safety devices activated and no arc damage would therefore be found.

In a severely fire damaged room such as this, arc-mapping would be a valuable tool that may add more data to the other investigative tools, such as interpreting fire patterns, estimating fuel loads, excavating debris layers and considering witness testimony and human activity before the fire, for example, if the occupier was smoking on the sofa adjacent to the waste bin at a reasonable time before the fire developed. Follow FIRM #7 – Person to ascertain human agency involvement prior to the fire.

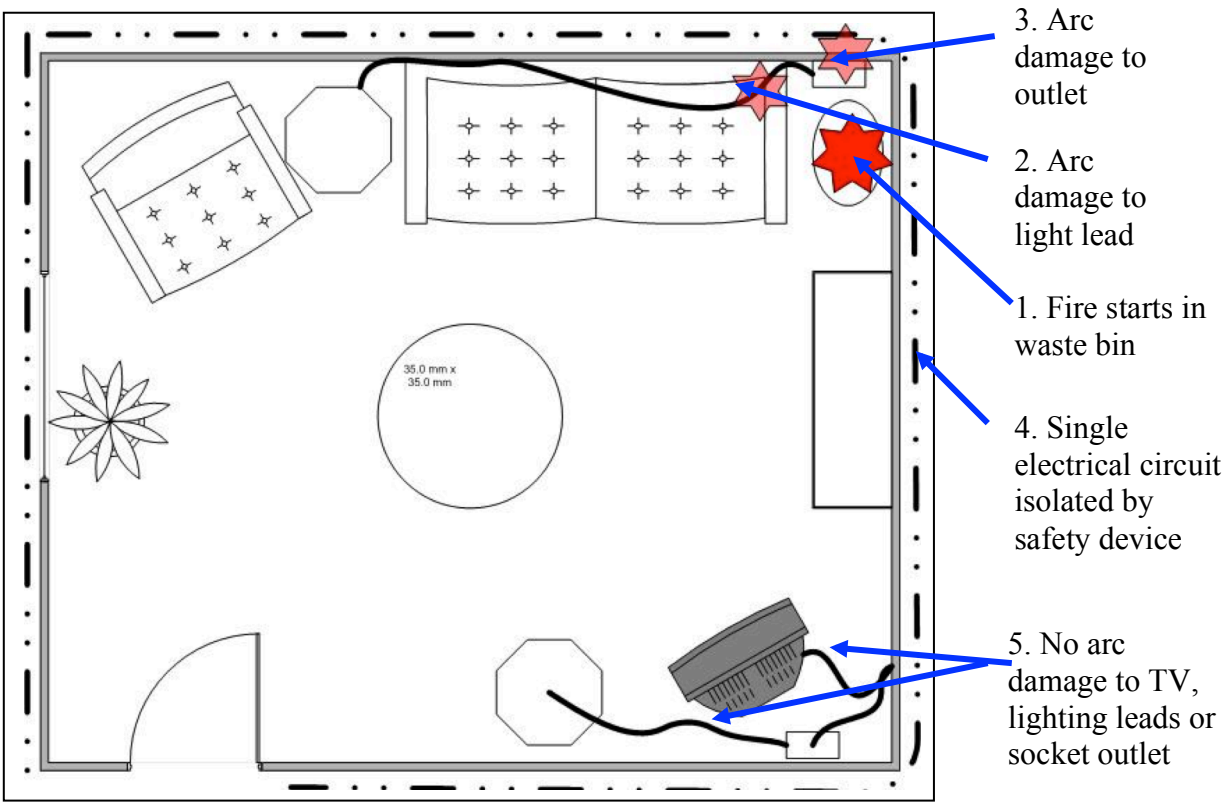


Figure 3.3 - LIVING ROOM FIRE ARC MAPPING

Whilst a close and thorough examination of all electrical conductors and system components needs to be carried out to see if any short-circuiting has occurred, in-line arcing, resistive heating or overloading may have also occurred and been a potential source of ignition. Where there is an increase of resistance at a localised point in an electrical circuit, there will be an increase in heat at that point. Examination of components, as detailed in [3.15.9.d] may have to be done away from the scene in a laboratory and under a microscope to accurately determine and

interpret such damage to ascertain whether the artefact is a cause or effect of the fire.

(z) Two photographs below demonstrate the information that can be obtained by carrying out an examination in a laboratory including using a microscope to determine the damage to conductors involved in fires.

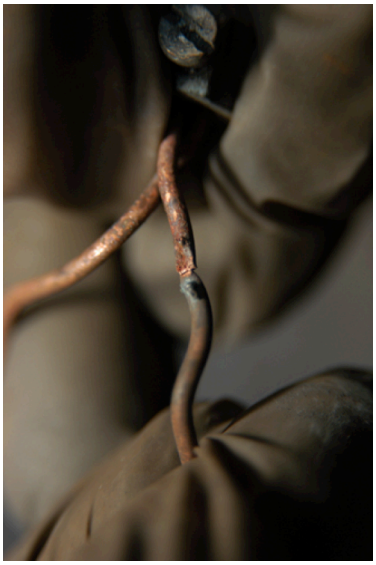


Photo 3.5 Arc Damage
Evidence at the fire scene of electrical activity within an electrical outlet

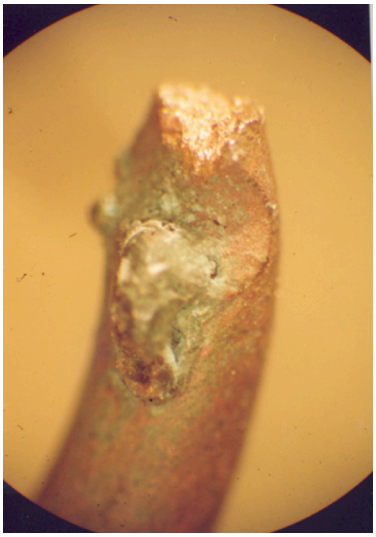


Photo 3.6 Magnified Arc Damage
Arc damage determined to be an effect of the fire, confirming the fire's area of origin using a X10 low power search microscope

(aa) A missing, lost or 'floating' neutral connection in 3-phase electrical systems is a potential cause of fires. The investigator should look at the neutral connections at the source, whilst ensuring that health and safety is of primary importance, as with all electrical inspections. Ensure that power supplies have been isolated by the utility company and ***always*** check yourself with a suitable electrical testing device that the power is off. Take measures to ensure that the power cannot be re-energised whilst any examinations are in progress.

(ab) In the UK, a lost neutral at the supply of a 3-phase intake or sub-station transformer may result in an *over-voltage*. This over-voltage supply can cause some electrical items to overheat and ignite. An example of the effects of a lost neutral is when

occupants of affected premises report that prior to any fire(s) they had witnessed brightening of electric lights and electric fans running faster.

(ac) Other properties supplied by the same sub-station would experience an under-voltage, whereby lights would dim and fans would run slower.

(ad) This event can only occur if there is a fault at the main neutral connection of a three-phase supply/distribution board or the main neutral supply of a sub-station supply transformer (Carey, 2006).

(ae) Safety devices are designed to protect against over-current or earth-leakage devices, not over-voltage.

(af) Loosing the ground or earth connection will not have the same effect. Grounding is a method of creating a constant electrical connection between the exposed metallic components (casings, etc.) of an electrical system and the earth by bonding all metallic objects that should not be electrically charged to a metal pipe or rod which is driven into the soil to a level of permanent moisture. The purpose of grounding is to ensure that any exposed metallic housings or objects within the electrical system cannot become electrically charged, as the resultant ground-fault current will activate the safety devices and isolate the electrical supply.

(ag) Fuses are simple devices that allow a metal conductor to melt at a certain temperature, which is calculated upon the amount of electrical current going through it. Therefore, if too much electrical current passes through the fuse, it will melt and render the circuit de-energised up to the fuse. Fuses protect circuits from short circuit and over-current damage.

(ah) Circuit Breakers differ from fuses in as much as they can be used again following their automatic or manual actuation. They usually function by using a magnetic coil for short circuits. A bi-metallic strip is used for overload faults within the device which will allow a certain amount of calculated over current for a short duration before distorting enough to operate a sprung switch to the ‘off’ position.

(aj) Residual Current Device (RCD) (UK) & Ground Fault Circuit Interrupter (GFCI) (USA) are designed to give increased protection for persons against electric shock. They will normally operate to the safe or ‘Open’ mode with a ground fault as little as 30 milliamps.

(ak) The investigator must be aware that any of these devices will be extremely fragile following a fire. The data that can be obtained from them could be invaluable for many reasons, such as confirming the location of the fire through arc mapping, and

serious consideration should be given to the preserving of any items to be examined. Consider the use of X-rays to ascertain whether a device has actuated or not, prior to destructive testing.

(am) Resistance Heating_occurs when there is a localised point of resistance that generates excessive heat. This includes poor connections. Heat will always be produced when electricity flows through a conductor. As in the Ohm's Law Wheel below [Figure 3.5], the relationship between power, current, voltage and resistance will influence the amount of heat that can be produced through any conductor.

(an) Problems of overheating may occur when correctly sized conductors are inadvertently thermally insulated, for instance in the attic of a property, with materials such as fibre glass insulation. If this is placed over the conductors, then the natural heat generated within the conductor may not be able to dissipate into the surrounding atmosphere quickly enough and could eventually generate enough heat, dependent upon the load being drawn on that circuit, to ignite the surrounding conductors' insulation. The investigator should carefully examine any conductors that may have been inadvertently insulated for signs of arc damage between the conductors, which would occur when the insulation breaks down or carbonises.

(ap) Loose or poor connections will increase resistance locally. The localised heating may cause an oxide to build up which in turn conducts current maintaining the flow of electricity; however it also offers a greater resistance than the metal conductors and therefore generates more heat than before the oxide started to build up. This oxide can become so hot that it glows; this is referred to as a 'glowing connection'. If there are any combustible materials close to a glowing connection then it may ignite.

(ar) If all criteria above has been satisfied and it is confirmed that the installation has been correctly installed and not modified to the detriment of the system nor had any safety systems by-passed or defeated, proceed to [3.15.16]

3.15.14 Yes

(a) It has either been identified that a faulty, incorrect installation or a by-passed safety system may be responsible for the fire;

(b) that the installation and rating of protective devices for circuitry, machinery, equipment or appliances is incorrect;
(c) that there is evidence of mechanical damage, ageing or lack of maintenance;
(d) that there is evidence of theft of electricity, sabotage or misuse of installation or equipment;
(e) or that static electricity has been generated. Proceed to [3.15.24]

3.15.15 No

(a) It has been confirmed that the installation has been correctly installed and not modified to the detriment of the system or had any safety systems by-passed or defeated.
(b) No evidence of electrical activity can be found on any of the closed circuit. Proceed to [3.15.16]

3.15.16 Is installation and rating of protective devices for circuitry, machinery, equipment or appliances incorrect?

(a) It is important that the investigator considers the link to FIRM #5: Machinery, Equipment & Appliances carefully at this stage of the investigation. The specification for all relevant items should be attained so that the electrical loading, safety features, protection specifications and associated operator use can be established. As far as the latter point is concerned, the investigator should be made aware that many fires have been attributed to 'electrical defects' when in fact they should have been listed as 'misuse of electrical equipment'.
(b) An example of this is when an oscillating fan is not fixed to a sound base and its movement allows it to become unstable and fall, mechanically damaging the outer fan casing and stalling the fan blades. The motor can now overheat, and without a thermal cut-out device in the motor casing, it is possible to ignite the plastic casing around the motor.
(c) Safety devices, where accessible, need to be checked for correct operation and ratings; machinery, equipment and appliances need to be inspected as in FIRM #5.
(d) Power (P) is measured in watts within an electrical system. Appliances are often rated in watts; for example light bulbs, heaters, etc. The inter-relationship between

power, current, voltage and resistance is extremely important to the fire investigator. (See Figure 3.5).

(e) A common example of the 'misuse' of electrical equipment is the overloading of extension leads that are supplying multiple appliances. By using Ohm's Law, the investigator will be able to calculate the total amperage of the appliances to the known rated supply lead. The determination that then has to be made is whether this caused an overload to the supply lead lasting long enough to generate enough heating of the conductors capable of igniting an adjacent fuel source, possibly the conductor's insulation.

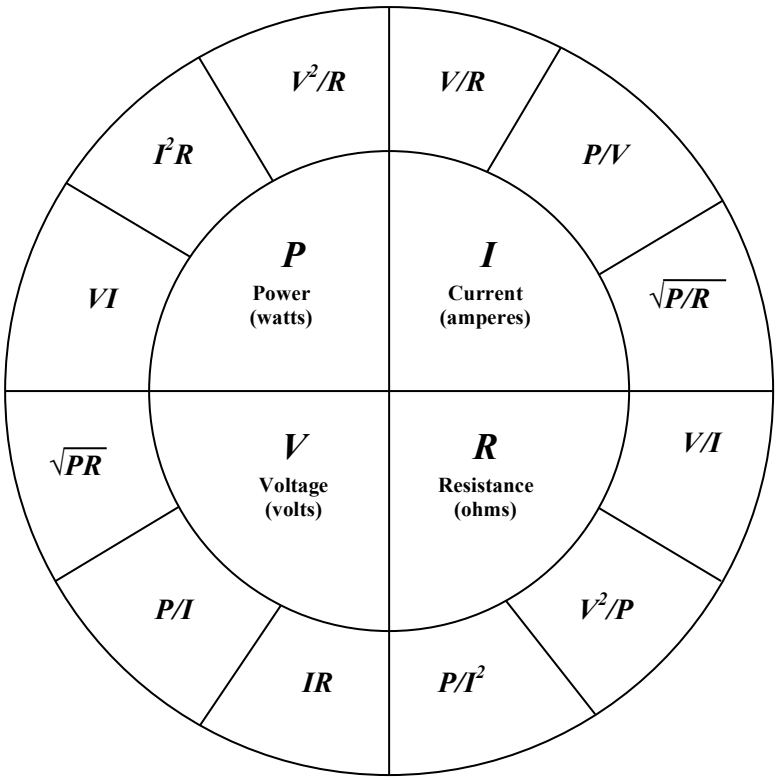
(f) An example is when a four-gang extension lead is being used to supply two, three or four electrical appliances. The capacity for the extension lead may be 13 amps; however the total load applied to it may be well in excess of that, especially if heating appliances are some of the appliances being used. Another cause of fires is when a reel extension lead is not fully unwound and used for a piece(s) of equipment that has a heavy load; the cable generates a lot of heat due to the insulating effect of the compacted cable and lack of ventilation to allow heat dissipation and can eventually ignite the wiring insulation.

(g) It must be remembered by the investigator that if it has been calculated and demonstrated that the ampacity of a conductor has been exceeded, it does not prove that the fire was caused by electrical ignition source. Adjacent fuel loads at the time of the fire must be carefully considered.

(h) Below is Ohm's Law Wheel, which can be used by the investigator to determine the total amperage relating to the part of the circuit being examined when other variables are known. It is recommended that once an answer has been determined, then the investigator should substitute the formula used for another to include the amperage calculated to cross-check the accuracy of their answer.

Figure 3.4 - Ohm's Law Wheel

V = volts
R = ohms
P = watts
I = amperes



Redrawn by Peter Mansi 2006

(j) It is often the defeating of safety devices and a fault condition that causes electrical items to overheat and ignite surrounding fuel packages. In older style consumer units, it has been known that when a fuse has blown, the occupier has installed various metallic objects ranging from silver foil wrapped around a cartridge fuse to a metal nail wedged into the cartridge fuse or re-wireable fuse holder. These will offer little or no protection to the circuit they are supposed to be protecting.

3.15.17 No

(a) The investigator has established that the electrical installation is sound and that the ratings of all safety devices are appropriate to the appliances that they are protecting and that there is nothing incorrect about the installation. Proceed to [3.15.19]

3.15.18 No

(a) No evidence of electrical activity can be found on any of the open circuits. Proceed to [3.15.35]

3.15.19 Is there evidence of mechanical damage, ageing, recent or lack of maintenance?

(a) Mechanical damage to fixed electrical conductors may be caused through frictional abrasion due to wind movement, mechanical vibration or weight transfer. Consideration must be given to all potential mechanism that could cause mechanical damage to the conductors' insulation or to connections, switches, control gear, safety devices and other parts of the installation. (See FIRM #2 – Structure)

(b) Mechanical damage can also be inflicted by rodents. (See FIRM #4 – Animals) Rodents may chew PVC insulation and it is occasionally possible to observe the chewed edges of cables in lofts, voids and under floors. The problem regarding a rodent starting a fire is when the rodent becomes the vehicle which short circuits the conductors, which can in turn ignite thermally thin adjacent or surrounding fuel packages, for instance, the rodents nest. Evidence of rodent faeces may be found in locations away from the fire damage to confirm the presence of rodents in the area.

(c) Another form of mechanical damage that has been known to cause fires is when a nail, screw or metal staple has penetrated the conductor's insulation whilst the cable is being secured to a timber backboard and subsequently made contact with one of the conductors. (See FIRM #7: Person). If the timber becomes wet, for example due to a leaking pipe, the electrical current can flow from the conductor to an earthed clip, which may also be screwed to the board. This will in turn heat the timber and carbonise it until it eventual ignites due to the increase in flow of electricity as the carbon builds up. This is known as 'carbon tracking' and can occur in such places as lofts near water tanks or leaking roofs (the owner/occupier may have to be questioned as to any history of leaks), or under kitchen sinks. Following a fire in one of these locations, evidence of the metal staple, nail or screw should still be evident and also the availability of an electrical conductor; evidence of electrical activity is necessary to consider this as a cause.

(d) Old fittings and connections, especially switchgear with moving parts, may deteriorate to such an extent that they loose the integrity of their contact surfaces. This can lead to resistive heating which will generate heat or, in the extreme, catastrophic failure of that part, depending on the amount of energy involved. ‘Joule heating' is the process by which the passage of an electric current through a conductor releases heat. The commonly known unit of power, the watt, is equivalent to one joule per second.

Joule heating can also be called ohmic heating or resistive heating because of its relationship to Ohm's Law. It is the principle of all practical applications involving electric heating. However, where heating is an unwanted by-product of current use, the diversion of energy is often referred to as resistive losses. Ring mains, used in UK houses are an example, where power is delivered to outlets at lower currents, thereby reducing Joule heating in the wires. Resistive heating at poor connections, which restricts current flow, is considered to be the most common electrical cause of fire.

(e) The investigator should check any service or maintenance records that are available for recent repairs or maintenance to any equipment that may have been involved in the fire. The type and nature of the recent work should be considered and any remaining physical evidence examined to corroborate whether the correct parts and/or materials were used for the task involved. FIRM #5: Machinery, Equipment & Appliances should also be followed.

(f) Follow FIRM #7: Person to ascertain any persons that may have carried out unauthorised repairs when not competent to do so. An example is a home owner or their acquaintance that has supposedly helped them fix the magnetic door on a washing machine but did not use the correct fittings, causing resistive heating at a connection and igniting the insulation adjacent to the connection.

(g) Older style fluorescent lights have also been recorded as starting fires by one of four mechanisms. (a) The starter switch can overheat causing internal insulation and the casing to melt and fall onto combustible materials below, which may include the plastic diffuser cover of the light fitting itself. (b) The plastic end caps that cover the fluorescent tube connections may melt or ignite if subjected to

resistive heating due to a poor connection between the tube connectors and the light fitting and, like the starter switch, can fall onto combustible materials below it. (c) The ballast in these fittings can become very hot and if secured to a combustible surface, such as chipboard, decorative boards or soft timbers may degrade the timber (pyrolysis) due to long exposure from the heat of the ballast. This allows a lower than normal ignition temperature of that material. Although more research needs to be conducted into pyrolysis, temperatures of 350K (77^0C) (Babrauskas, 2003m) have been reported to ignite dry softwood timber. (d) Ballasts maybe oil filled and if a failure of the windings within them causes local or general overheating, the pressure inside the ballast may cause the hot oil to rupture through the casing and ignite adjacent combustible materials. It is important that a maintenance regime exists regarding fluorescent lights and this should be explored with the responsible person for the premises.

3.15.20 No

(a) There is no evidence of mechanical damage, ageing, recent or lack of maintenance. Proceed to [3.15.21]

3.15.21 Is there evidence of sabotage, theft of electricity or misuse of installation or equipment?

(a) If the investigator discovers that there is a defect, fault or mechanical damage that can or cannot be satisfactorily explained, the possibility of deliberate intervention should be considered (see FIRM #7: Person). As seen in the X-rays in Photo 3.4, with appropriate knowledge it would not be difficult to by-pass the safety devices and defeat the cut-out mechanisms to cause such an appliance to ignite and make the fire appear to be accidental. Also follow FIRM #5: Machinery, Equipment and Appliances so as to ensure a thorough investigation of the item(s) is/are carried out.

(b) Gather information as to any previous vandalism, which may have been directed towards the person or business that has now suffered the loss. Although this information may not be a major factor in the fire investigation, it may well add to the holistic ‘picture’ surrounding what may be an otherwise unexplained cause.

(c) Again, by following FIRM #7: Person, the investigator should be able to establish the human agency involvement relating to this incident, especially when it comes to the theft of electricity. When individuals steal from the utility companies, they often use equipment that is not designed to a tested standard and fitted by individuals that may not be trained to work with mains electrical intakes. When dealing with electrical intakes and associated equipment, anything but a tight connection between fittings may create resistive localised heating which could easily ignite a suitable adjacent fuel package. Normally there is sufficient evidence remaining following a fire that has been caused by the by-passing of electricity company meters to clearly indicate that a crime has been committed and the investigator must call the ***electrical utility supply company*** immediately that this information comes to the investigator's attention and not proceed with the scene examination until they have attended and examined the equipment.

A growing number of cannabis factories are being discovered by both the fire service and the police throughout the UK and many parts of Europe at the time of writing. These factories are set up predominantly in residential houses and most of the rooms are converted to growing and drying rooms for the production of cannabis. This process requires an incredibly high amount of electricity to power all the necessary lighting, heating and pumping equipment. The criminals involved in this activity have 'specialists' that by-pass the mains electricity meters and house fuses by opening up the intake cable and making connections to the conductors of the intake cable whilst still energised. This is a dangerous activity for the individual carrying out this task. It is also a hazard for the emergency services or fire investigator when responding to a fire within the premise. It may be assumed that when the electrical supply has been isolated at the meter that the rest of the electrical installation is de-energised. In fact, all or some of the electrical system may still be energised. Therefore the 'best practice' of using electrical testing equipment to check for energised circuits should be adopted at all incidents where the investigator may potentially come into contact with electrical systems.

It is worth noting here that other trends that have developed at and around these premises are that bobby traps have been set, commonly involving bare metal

conductors stretched across access points (windows and doors) to the premise to stop rival criminals stealing the crops. There can also be an increase in other crimes surrounding the premise, such as an increase in burglaries and theft from the person which may be carried out in order to 'feed the habit' of the local addicts. Other crimes may also include arson attacks between the rival gangs and this should also be considered by the investigator.

(d) FIRM #7: Person and FIRM #5: Machinery, Equipment and Appliances should be adhered to when considering the misuse of an electrical installation or equipment. As previously mentioned, it is often the misuse of electrical equipment or installations that is the cause of fires involving electricity and not the items themselves. Misreporting of electrical causation fires has possibly allowed the skilled arsonist to use electrical appliances as a good ignition source in the past. It is encouraging that more fire investigation courses are covering the subject of electricity in fires more comprehensively, de-mystifying the subject and bringing a more fundamental understanding into the investigators' skill sets. Topics that the fire investigator should be familiar with are basic electrical theory, appliances and their safety devices, electrical causes of fires, arcing and arc mapping and be familiar with as many case studies as possible.

(e) Light fittings generate heat; ensure that all light sources, including low wattage bulbs, have been considered. If a cigarette, which has a heat release rate of approximately 5 watts, can start a fire given the appropriate fuel package, then a low wattage bulb is equally capable of initiating the combustion process, given the right fuel package. The investigator should therefore look for evidence of light fixtures and fittings, consider their orientation before the fire started and any adjacent fuel packages.

(f) Low voltage lighting does not mean low wattage. 12 volt lighting using halogen bulbs is becoming more popular due to the lighting effects that can be obtained with these bulbs. A problem with halogen lamps is that they generate a lot of heat. The investigator must therefore examine the way these lights were installed to ensure that combustibles, such as ceiling joists, floorboards, plastic or cardboard boxes or loft insulation has not been close to or covering the light fitting. These lights require sufficient ventilation. Many of these lamps are housed in moveable fittings, such as desk lamps. It has been recorded (London Fire Brigade, Various)

that these light stands can become unstable and bring the bulb into contact, or very close to combustible material.

(g) Older style fluorescent lights have been recorded as starting fires. Some modern fluorescent lights do not have non-electronic starter switches fitted. There are more ballasts being fitted with thermal protection so that when the temperature within the ballast reaches a set temperature, a thermal fuse opens thereby stopping the supply of electricity to the ballast windings.

3.15.22 No

(a) There is no evidence of sabotage, theft of electricity or misuse of installation or equipment. Proceed to [3.15.23]

3.15.23 Could static electricity have been generated?

(a) The production of static electricity can be complicated to understand but must be considered as it has been the cause of fires. The investigation of static ignitions relies more on the elimination of other ignition sources and the potential for the materials involved to generate static electricity. It is unlikely to find physical evidence (expect following a lightning strike) of static activity being the cause of a fire, however use of CCTV can provide such evidence. An example is taken from a petrol filling station CCTV recording when static from a driver ignited the vapours around the filling tube to the tank whilst in the process of being re-filled.

(b) NFPA 921 details the five conditions necessary for static arc ignition; they are:

1. There must be an effective means of static charge generation.
2. There must be a means of accumulating and maintaining a charge of sufficient electrical potential.
3. There must be a static electric discharge arc of sufficient energy.
4. There must be a fuel source in the appropriate mixture with minimum ignition energy less than the energy of the static electric arc.
5. The static arc and fuel source must occur together in the same place and at the same time (NFPA, 2008b).

(c) Low relative humidity, dry synthetic materials, friction (including fluid flowing though pipe work, wheel bearings, etc.) and the opportunity to discharge the static

electricity must all be considered during the investigation. An electric charge can build up on the surface of a material by rubbing one material against another; electrons are rubbed off one of the materials which then become positively charged, while the other material, which gains the electrons, becomes negatively charged. The two oppositely charged electrons then 'attract' each other; thunderstorms are caused by static electricity (Golde, 1977).

(d) Static electric discharge from the human body has been the source of ignition in many accidental fires. The potential for the human body to create static electricity is greater in dry atmospheres (as humidity allows static charge to 'leak' into the atmosphere) and requires the person to be insulated from the ground so that the static charge can build up. Upon contact with a grounded object, the energy of a discharged arc can be in the region of 20mJ to 30mJ; when this is compared with the minimum ignition energies of some gases or vapours, the potential for their ignition can be clearly seen (NFPA, 2008h).

(e) It is not the generation of the static electricity that is the ignition source but the discharge of it. Static electricity is only a potential source of energy. When an electrical charge is present on the surface of a non-conducting body, where it is trapped or prevented from escaping, it is called *'static electricity'*. (NFPA, 2008h) It is known to the author that static electricity generated by synthetic clothing ignited the vapours from a floor adhesive and engulfed the person who was laying floor tiles with the adhesive (Mansi, 1976).

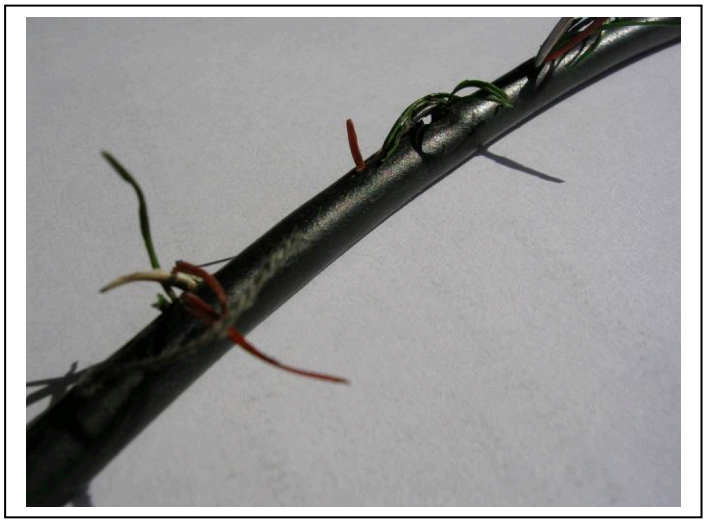
(f) All the materials need to be analysed as to whether they had the potential to create and/ or discharge static electricity. Local weather conditions should also be assessed as tests (NFPA, 2008k) have shown that with a low relative humidity, electrostatic voltages discharged from the human body can increase substantially, when compared to a higher relative humidity. In the UK and similar climates, arcs from static discharges are more likely to occur during dry winter weather than hot humid summers as the moisture will allow the potential energy to 'leak' away or disperse without the creation of a spark in most cases.

(g) Finally, it must be clearly established whether or not the static arc had enough energy and was discharged at the same time that a suitable fuel was present.

(h) Lightning Strikes are extreme forms of static electricity which can average 24,000 amperes and are capable in reaching 200,000 amperes with potential differentials of up to 15,000,000 volts (NFPA, 2008g). It would be prudent for an investigator to

check with the local or national weather centre as to whether there were any strikes within the area at the time of the fire. There are also web-site companies that can provide such information, sometimes for a small fee based in the USA, but not in the UK at the time of writing.

(j) Indications of a lightning strike include vaporised or melted copper conductors, 'threaded' telephone cables (See photo 3.7 below) or spalling of steel re-enforced concrete buildings.



Telephone cable

Photo 3.7 Telephone Cable following Lightning Strike

3.15.24 Has anything been identified to provide a suitable ignition source for an available fuel package?

(a) Evidence needs to be established to prove that a fault, defect, misuse or abuse in a component of the electrical system is capable of generating heat.

(b) Once this has been established, then the investigator must identify what fuel packages were available at the time of the fire within the area.

(c) The investigator is now able to consider any ignition source that may have been available to start the combustion or smouldering process. FIRMs [1], [2], [4], [5], [6] and [7] must all be followed to ascertain the potential for an ignition source to have been initiated from these routes.

(d) Controlled tests may need to be conducted to ascertain the temperatures possibly achieved by the problem within the electrical system and the duration sustained

against the fuel package so as to compare ignition temperatures and thermal capacities of any of those fuel packages identified.

3.15.25 Yes

(a) A fault, defect or circumstance has been identified which generates a sufficient amount of heat and one or more fuel packages have been available to start the combustion process due to that heat. Proceed to [3.15.27]

3.15.26 No

(a) Although fault, defect or circumstance has been identified which could have generated some amount of heat, no fuel packages were available to start the combustion process due to the amount of heat and the type of fuel package that were available.

(b) No static could have been generated. Proceed to [3.15.35]

3.15.27 Is there evidence to support an incendiary cause?

(a) The investigator must consider all the data gathered and decide whether the circumstances indicate that there is evidence that a non-accidental fire has occurred by the intentional bringing together of the ignition source and the available fuel package(s).

3.15.28 No

(a) Having considered all the data gathered, it has been decided that there is no evidence to indicate that a non-accidental fire has occurred. Proceed to [3.15.29]

3.15.29 Is there evidence to support an accidental cause?

(a) The investigator must consider all the data gathered and decide whether the circumstances indicate that there is evidence that an accidental fire has occurred by

the unintentional bringing together of the ignition source and the available fuel package(s).

3.15.30 Yes

(a) Having considered all the data gathered, it has been decided that there is evidence to indicate that a non-accidental fire has occurred. If the investigator arrives at this stage from [3.15.27] it is imperative that [3.15.29] is also considered. The investigator must eliminate all accidental causes otherwise any subsequent prosecution of a fire setter could fail to be successful. [Proceed to [3.15.36]

3.15.31 The police must be informed of the findings of the investigator

(a) If the investigator has evidence of a non-accidental fire occurring, as determined in [3.15.27], then the police or relevant authority must be informed immediately.

3.15.32 No

(a) Although the investigator has determined that circumstances have led to the generation of heat due to the supply of electricity and the availability of a nearby fuel package, there is no evidence to indicate that the ignition source and fuel package came together for any duration that would enable the combustion process to commence.

3.15.33 Could static electricity have been generated?

(a) It has been established that there was no electrical supply at or near to the premises or area of origin prior to the fire starting. It must now be established as to whether static electricity could have been generated so that an electrical discharge could have occurred.

(b) Refer to [3.15.23a] to [3.15.23.9j]

3.15.34 No

(a) It has been established that static electricity could not have been generated and therefore an electrical discharge due to static electricity could not have occurred.

3.15.35 Unlikely to be responsible for fire

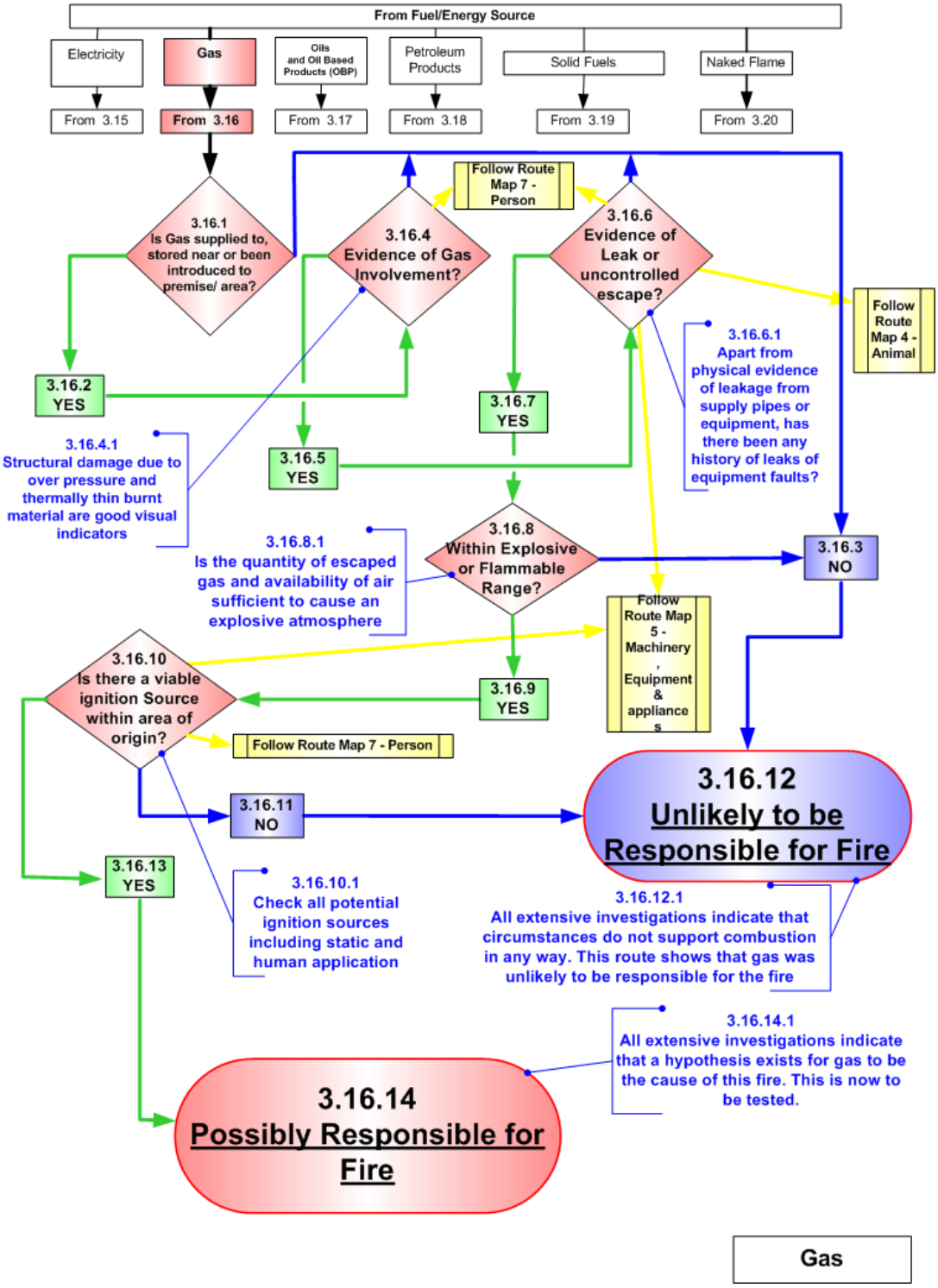
(a) All routes have now been explored so as to eliminate this category as a cause of the fire with the data that is available.

3.15.36 Possibly responsible for fire

(a) By arriving at this point in the road map a hypothesis has been created that needs to be tested and compared to any other hypotheses that may be developed during the investigation. If more than one hypothesis can be proved as possibly being the cause of the fire, then ‘undetermined’ must be recorded.

FIRE INVESTIGATION ROAD MAP #3.16

GAS



3.16 Gas

The term gas is used here to describe any fuel that is in the gaseous phase at room temperature and atmospheric pressure. If mixed with air, it will form a flammable mixture within well-defined upper and lower flammability limits. The equipment used to store and deliver gas consists of storage tanks, cylinders, 'bottles' containing liquefied petroleum gas (LPG), pipe-work of varying materials, joints, connections, including flexible connections, pressure valves, regulators and control valves to isolate or operate equipment.

When gas escapes and mixes with the atmosphere, it is initially too lean to be ignited by an energy source. As the fuel increases, an ignition at lean or at the stoichiometric mixture would be very forceful but would unlikely sustain a flame following the deflagration. If the mixture ignites when it is rich, but still below its upper flammability limits, the deflagration may be less forceful and more likely to sustain a flame. (DeHaan, 2007b)

3.16.1 Is gas supplied to, stored near to, or been introduced to the premise or area?

(a) Investigations should be made to determine whether any gas supply pipes exists within the area of origin, even if the property involved does not use gas. Gas supply pipes may pass adjacent to a premise to service other premises and details can be obtained from the utility company for that area.

(b) Gas leaks occurring underground due to, for example, a damaged supply pipe, may allow the escaping gas to travel considerable distances if the substrate is porous or has cavities. The gas may then be able to enter into an enclosure allowing a dangerous quantity to accumulate until it reaches its stoichiometric level. Some odorants can be scrubbed clean from the gas as it percolates through soil (DeHaan, 2005a) and no smells would therefore be detected.

(c) Gas may also be stored within cylinders. Gas cylinders are not always stored in correct or expected locations and efforts should be made to determine whether any cylinders are within the effected premises, adjacent premises or local vicinity. It should be determined whether any portable gas heaters, patio heaters, gas bar-b-

ques and other appliance that may use cylinders, also known as LPG (liquefied petroleum gas) Autogas, are on the site. If so, then determine the supply and storage regime of the cylinders for these appliances. LPG is heavier than air and if released, may accumulate in lower voids and compartments, not only presenting a fire hazard, but also an asphyxia hazard.

(d) Oxygen cylinders can be used in domestic residences and commercial premises as well as medical establishments, normally for medicinal purposes. Oxygen supply pipes or 'oxygen enriched air' supply pipes may be instrumental in contributing to the easier ignition of materials which would normally require greater ignition energy to start combustion.

Some medical equipment produce oxygen enriched air, by filtering the oxygen (21%) from the air and producing oxygen enriched air (known to be ~52% O_2). This is transported through plastic tubing, which may be fixed around the edges of rooms to one or more outlets so that the user can, for instance, sit and watch television whilst breathing via the supply tubes.

Because many of the users of these appliances are smokers, it has been recorded that a carelessly discarded cigarette has fallen onto the plastic tubing and melted it, allowing the oxygen enriched air to escape and form a flame which did not exist before the enriched air was present. The tubing also ignited, which ordinarily would not have, and the small flame burning the plastic tube travelled at about one metre per minute back towards the direction of the appliance. The low level smoke that was produced was enough to cause fatal injuries to the occupier who was already suffering with respiratory problems. (Mansi, 2003)

(e) Consideration should be given to wind direction and the location of any gas supplies or storage areas. A strong wind would disperse escaping gas quicker than a small breeze.

3.16.2 Yes

(a) Either gas is supplied to, stored within, or is adjacent to the premises or area of origin, or a gas supply or storage area has been identified within the vicinity.

3.16.3 No

(a) There is either no evidence of gas being supplied or stored near to the premise, no evidence of gas being involved in the fire, no evidence of any leaks or any uncontrolled escape of gas, or calculations show that the gas/air mixture was outside the flammable or explosive limits. Proceed to [3.16.12]

3.16.4 Is there evidence of gas involvement?

(a) It may be obvious to the investigator that gas has been involved in the fire due to evidence of an explosion or burn patterns from an appliance or supply pipe, or by witness testimony that gas was detected by smell or by an automatic gas alarm prior to the fire. The Investigator must proceed through [3.16.6] in order to determine how the gas escaped and whether it was a cause of the fire or an effect of it.

(b) The possibility of underground migration of fuel gases must be explored. Because the soil surrounding underground pipes have been disturbed during their installation and often surrounded with loose aggregate to allow movement, any escaping gases will tend to follow the outside of these pipe runs until they can dissipate through the soil above them. If the surface above the ground is sealed by road covering, ice or water, as examples, the gases will migrate laterally until they can escape by entering a structure that is supplied by the pipe run it is following. These gases can travel considerable distances and this possibility must be considered if gas involvement is suspected.

(c) Natural gases and propane have little or no natural odours of their own [NFPA 921] so foul smelling compounds, such as mercaptan, are added so that leaks can be detected by the sense of smell. The investigator should check with the utilities whether an odorant has been added or not. It must be noted, however, that some odorants can be scrubbed clean from the gas as it percolates through soil. (DeHaan, 2005a)

(d) The migration and pocketing effects that can be created following a gas leak can lead to multiple explosions, also known as secondary or ‘cascade’ explosions. These pockets may contain various gas/air mixtures, some being too rich or too lean to cause a fire or explosion. A situation may occur whereby a deflagration in one pocket causes structural damage allowing enough air to enter into another nearby pocket, mixing with the gas so as to be within its upper and lower flammable limits

and igniting from the first deflagration or another ignition source. Multiple explosions may possibly be identified by multiple epicentres, providing the physical evidence is not lost during the deflagration phase or any subsequent fire.

(e) Over-pressure during a deflagration can cause structural damage without leaving obvious burn patterns. Cracks at intersections where walls adjoin each other and join to ceilings and floors can be good indicators of over-pressure. The investigator must remember that low level structural damage is not an indicator of a heavier-than-air gas explosion, nor is high level damage an indicator of a lighter-than-air gas explosion; structural damage will occur at the weakest part of that structure following a deflagration, irrespective of the specific gravity of the gas involved (DeHaan, 2007b).

(f) Broken glass that is found to have been forced from within a compartment and is clean may be an indication that over-pressure has broken the glass prior to the flame front impinging upon it. It may also be an indication that a person has broken the window from within (See Road Map [7] – Person, to ascertain whether human agency has been involved with the glass breakage.

(g) Thermally thin material can be almost vaporised by a deflagration as the flame front passes over it so quickly to not cause damage to denser material adjacent to it. Other materials may be singed at the edges and may even require microscopic inspection to detect thermal damage such as melted ends of minute strands of synthetic fibres.

3.16.5 Yes

(a) There is evidence that gas was involved in the fire. Proceed to [3.16.6]

3.16.6 Is there evidence of a leak or uncontrolled escape?

(a) Cylinders, storage tanks, pipe-work and equipment must all be inspected for signs of mechanical damage, corrosion or fractures that may have occurred prior to the fire. Supply pipes can fracture and joints or connections can become loose due to minor ground movements. Incorrect trench preparations may allow the pipes to move if subjected to heavy vehicular traffic above them.

(b) Control valves should be inspected to ascertain their open/shut positions at the time of the fire. Sabotage must also be considered if valves are found to be in the open position when they should have been closed or vice versa. (See FIRM #7: Person)

(c) Pressure regulators have been known to fail due to corrosion, freezing and other types of mechanical damage. These regulators are critical in reducing the supply pressure from the utility delivery pipes down to the user pressure within the premises. Over-pressure to appliances can cause cooker valves to fail or leak and also the appliances to burn the excess gas in a manner that those appliances are not designed to do, giving larger flame formation or flames exiting by the easiest route and by-passing the designed system as it cannot cope with the increase in extra exhaust volume.

(d) Enquiries must also be made as to any history of defective equipment or prior leakage. If equipment is involved see FIRM #5: Machinery, Equipment and Appliances. It must be remembered that a leak can occur a long way from the ignition source and all surrounding cylinders, storage tanks, pipe-work and equipment must be inspected.

(e) Gases such as methane, may evolve from natural processes, such as in coal mines and open marshlands. It is estimated that approximately 15% of all methane produce is by cows and other cud chewing animals. It has not been established whether any farm buildings have been damaged by fire due to animal produced methane becoming ignited.

(f) Where a 'blow torch' effect fire pattern exists, due to ignited gas exiting a supply pipe, it can be taken that this is an effect of the fire and not a cause. All the gas will do is intensify the fire within that area and will not be contributory to the fire throughout the rest of the premises.

3.16.7 Yes

(a) Evidence exists of a leak or uncontrolled escape of gas into the area of origin. Proceed to [3.16.8]

N.B The temperature and pressure for gases and vapours need to be known as this will affect ignition temperature and air required		Limits of Flammability % by Volume in air		Specific Gravity (Air=1.0)	Air needed to burn 1m^3 of gas (m^3)	Ignition Temperature
Gas	**MJ/m^3**	**Lower**	**Upper**			**^{0}C**
Natural (Methane)	37.6 – 39.9	4.7	15.0	0.59–0.614	10.2	482-632
Blast Furnace gas	3.0 – 4.1	33.2	71.3	1.04 – 1.0	0.8	-
Coke Oven gas	21.4	4.4	34.0	0.38	4.7	-
Propane (Commercial)	93.7	2.15	9.6	1.52	24.0	293-604
Butane (commercial)	122.9	1.9	8.5	2.0	31.0	482-538
Sewage gas	24.9	6.0	17.0	0.79	6.5	-
Acetylene	208.1	2.5	81.0	0.91	11.9	305
Hydrogen	12.1	4.0	75.0	.07	2.4	500
Anhydrous ammonia	14.4	16.0	25.0	0.60	8.3	651
Carbon monoxide	11.7	12.5	74.0	0.97	2.4	609
Ethylene	59.6	2.7	36.0	0.98	14.3	490

Table 3.2 – Combustion Properties of Common Flammable Gases (NFPA, 2004a)

3.16.8 Is the gas within its explosive or flammable range?

(a) Calculations may need to be completed to ascertain whether the amount of released gas and the availability of air were within the explosive or flammable range of the gas. Above (Table 3.5) is a table that gives combustion properties of common flammable gases.

(b) To calculate the amount of gas available, the investigator may have to use data such as the line pressure, flow rate of the gas, burner port size, volume of the compartment and leakage from the compartment. Specialists may need to be consulted to obtain this data.

(c) The most violent explosions will occur when the fuel/air ratio is either at or slightly above the stoichiometric mix (slightly fuel rich) as the most efficient combustion, highest flame speeds, rates of pressure rise and maximum pressures are produced and as a result, the most physical damage is inflicted.

3.16.9 Yes

(a) Calculations ascertained that the amount of released gas and the availability of air were within the explosive or flammable range of the gas. Proceed to [3.16.10].

3.16.10 Is there a viable ignition source within the area of origin?

(a) All ignition sources need to be examined, including those from machinery, equipment or appliances FIRM #5 which also covers sparks and static electricity.

(b) The investigator must consider that the ignition source may be some distance from the leakage and not where the most severe burn patterns are. If no ignition sources are evident and the gas involvement still appears to have been within the area of origin, consult with FIRM #7 – 'Person' to see if any other human agency has had an influence on ignition sources.

(c) The investigator is now able to consider any ignition source that may have been available to start the combustion process. FIRMs #1, #4, #5, #6 and #7 must also be followed to ascertain the potential for an ignition source to have been initiated from these routes.

3.16.11 No

(a) Although gas was present prior to the start of the fire, no ignition sources could be found. Proceed to [3.16.12].

3.16.12 Unlikely to be responsible for fire

(a) All routes have now been explored so as to eliminate this category as a cause of the fire with the data that is available.

3.16.13 Yes

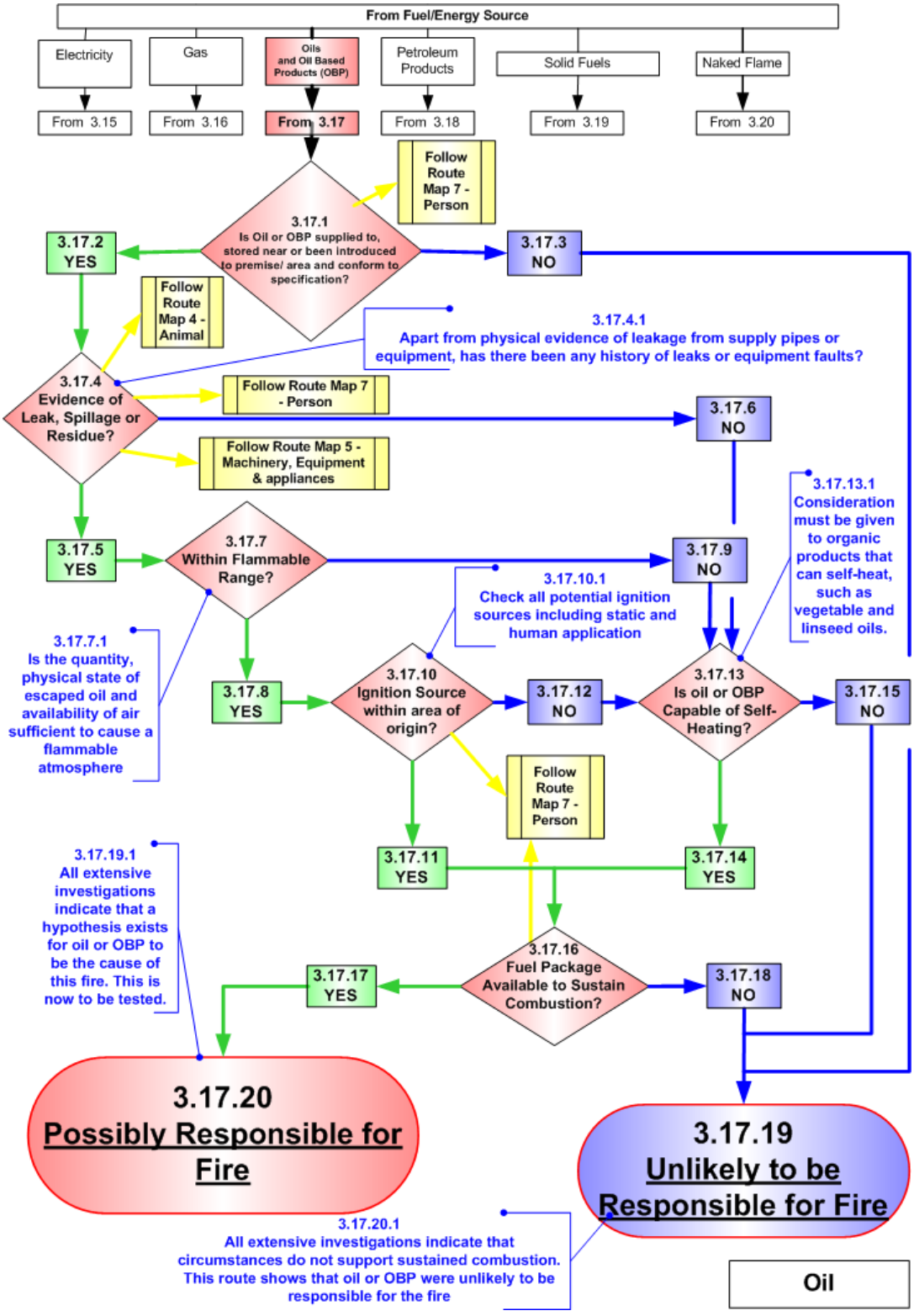
(a) An ignition source, or several ignition sources have been found that could have ignited the gas to cause the fire. Proceed to [3.16.14]

3.16.14 Possibly responsible for fire

(a) By arriving at this point in the road map a hypothesis has been created that needs to be tested and compared to any other hypotheses that may be developed during the investigation. If more than one hypothesis can be proved as possibly being the cause of the fire, then ‘undetermined’ must be recorded.

Fire Investigation Road Map #3.17

OILS AND OIL BASED PRODUCTS



3.17 Oil

Oil is a flammable substance which is usually insoluble in water and composed mainly of carbon and hydrogen. Oils may be solids, such as fats and waxes, or in liquid form. The three main types are 'Essential Oils' which are obtained from plants, 'Fixed Oils' which are obtainable from animals and plants and 'Mineral Oils' (see FIRM 3.18) which are obtained from refined petroleum or crude oil. Fixed oils are most susceptible to self-heating as they react with oxygen to generate heat.

Oil based products (OBP), as used in this road map, are any materials that contain essential and fixed oils and may be susceptible to self-heating.

It is important that the investigator is able to identify the oil so as to determine its flash point and the flammability range of the product. This may require a laboratory analysis of a sample.

This Fire Investigation Road Map #3.17 – Oil, has been separated from Fire Investigation Road Map #3.18 – Petrol/ Diesel, as the characteristics of petrol and diesel differentiate considerably from other oils in their natural state. Petrol has a flash point of approximately 235K (-38^0C), diesel has a flash point of 325-369K ($52\text{-}96^0$C) and mineral 'engine' oil has a flash point of approximately 483-530K ($210\text{-}257^0$C) (NFPA, 2004c).

Petrol and diesel are not prone to self-heating.

N.B. Flash Point

This is the temperature at which a flammable liquid will momentarily ignite across its surface with the application of pilot flame. The lowest temperatures of each product that this will occur at can only be determined by specific laboratory tests at which the liquid gives off enough vapour to support a momentary flame across its surface (NFPA, 2008f). The values may change depending upon which tests were used.

3.17.1 Is oil or are oil based products supplied to, stored near or been introduced to the premises or area of origin?

(a) The investigator must determine if oil is supplied to the premises via supply pipelines or stored in containers. The oil may be used for heating, cooking, lubricating, cleaning or production purposes. It is important that the use of the oil is determined at this stage of the investigation. The investigator should examine items and machinery that use oil for cooling, such as vehicle engines, to ensure that in case of the absence of oil, mechanical parts have not become so hot so as to be an ignition source themselves. (See FIRM #5: Machinery, Equipment and Appliances to guide the investigator through the process of identifying potential ignition sources)

(b) The investigator must be aware of the potential need for additional PPE when working with oils as they can penetrate human skin and may be carcinogenic.

(c) Oil may be stored in a remote area from the fire. Leaking pipes or containers may allow the oil to travel considerable distances, especially if on a higher level from the area of origin. All service ducts, pipe runs, voids and other conduits that would allow the oil to travel must be explored.

(d) In some circumstances, such as art studios, the occupier may not be aware that an oil has been brought onto the premises. An example is a student bringing in linseed oil to use on a piece of art work without the teacher's knowledge. There may be a ban or strict control measures on the use and disposal of linseed oil and rags, but the student may be unaware of these.

(e) The nature and use of the premises can give the investigator some guidance as to the possibility of the presence of certain products. An example of this is a launderette. It is extremely unlikely that a launderette will have an oil supply to it as most washing machines are electrically powered and most tumble dryers are either electrically or gas heated. The gathering of information as to who had been using the launderette before the fire occurred could give an indication as to the types of substances that could have been introduced to the premises, such as oil soaked cloths and tea towels from a local catering establishment. Also See FIRM #7 – Person to determine the activities, movements and habits of anyone that may have been in the vicinity of the scene at or just before the time of the fire.

(f) It is important that the investigator has asked relevant questions to all persons that have been within the area of origin during the previous 24 hours.

3.17.2 Yes

(a) It has been identified that either oil or oil based products have been supplied to, stored in or near to, or have been introduced to the area of origin.

3.17.3 No

(a) Following all possible investigations and enquiries the investigator has determined that no evidence exists that oil or oil based products have been supplied to, stored in or near to, or have been introduced to the premises.

(b) If a person has been present then follow FIRM #7: Person to ascertain their involvement or influence on the fire propagation.

3.17.4 Is there any evidence of leak, spillage or residue?

(a) Are containers, either storage or waste, damaged or defective? The investigator must look for material damage to any containers such as splits, impact or rodent damage. (See FIRM #4: Animals: to see if any damage has been caused to any form of container by any animal.)

(b) Check for any supply pipes or any parts of the system under pressure whereby a leak could cause atomisation of oil into the atmosphere, creating a high surface to mass ratio and a flammable vapour. If equipment or machinery are involved, then also follow FIRM #5: Machinery, Equipment and Appliances to ascertain if there has been a fault, defect or deliberate damage which could initiate a fire situation.

(c) Could residues have contaminated fabrics so as to start a self-heating process? As with all investigations, there may be little or no evidence within the area of origin to show the presence of any oil, but the investigator is reminded to explore areas remote from the area of origin and to ask any relevant persons specific questions about materials and substances that may have been there. (See [3.17.12])

(d) A close examination of all supply pipes, storage vessels and machinery, particularly at flanges, connections and control valves, must be carried out to ascertain any accidental or deliberate defects (sabotage). See FIRM #7: Person, to identify all persons that could have influenced the initiation of a fire situation.

3.17.5 Yes

(a) A leak, spillage or oil residue has been identified as being within, or able to get within the area of origin. Proceed to [3.17.7]

3.17.6 No

(a) No leak, spillage or oil residue has been identified as being within, or able to get within the area of origin. Proceed to [3.17.13]

3.17.7 Within flammable range?

(a) Is the oil or oil based product at a temperature and with the correct fuel/air mixture to be able to start the combustion process, or present a flammable atmosphere?

(b) Calculations may need to be completed to ascertain the possibility of a flammable atmosphere.

3.17.8 Yes

(a) The investigator has identified that the leak, spillage or residue is at a temperature and with the correct fuel/air mixture that is within the flammable range of the substance. Proceed to [3.17.10]

3.17.9 No

(a) The investigator has identified that the leak, spillage or residue is not in a suitable physical state or within the flammable range of the substance. Proceed to [3.17.13]

3.17.10 Is there an ignition source within the area of origin

(a) All ignition sources need to be examined, including those from machinery, equipment or appliances in FIRM #5, which also covers sparks and static electricity.

(b) Again, the investigator must remember that the ignition source may be some distance from the leakage and not where the most severe burn patterns are. Dispersed oil as a mist may travel some distance from the supply until it meets a viable ignition source and ignites.

(c) The investigator is now able to consider any ignition source that may have been available to start the combustion or smouldering process. Fire Investigation Road

Maps #1, #2, #4, #5, #6 and #7 must all be followed to ascertain the potential for an ignition source to have been initiated from these routes.

3.17.11 Yes

(a) An ignition source(s) has been identified while the oil is in such a physical state so as to create a flammable atmosphere, or be capable of igniting an oil based product.

3.17.12 No

(a) Although it is evident that a flammable atmosphere existed at the time of the fire, no ignition sources where found, even after following Fire Investigation Road Maps #5 and #7 (if applicable).

3.17.13 Is the oil or oil based product capable of self-heating?

(a) It needs to be established as to whether the oil or oil based product was capable of self-heating and that the right media and conditions were present to allow this to happen?

(b) Mineral oils do not normally self-heat, however there have been reports of certain circumstances where mineral oil is believed to have self-heated when absorbed in glass fibre insulation (Babrauskas, 2003g) (Bowes, 1974).

(c) Self-heating is an exothermic reaction, whereby the material involved is generating heat from within itself without taking any heat from its ambient surroundings, and dissipating less heat into those surroundings than it is generating. In other words, the rate of heat production is greater than the rate of heat loss. Self-heating can lead to thermal runaway and self-ignition of a material.

(d) It can occur in any of the states of matter; gas, liquid or solid.(Babrauskas, 2003o)

(e) A substance that can self-heat and is wrapped or covered in any form of thermal insulation will have its rate of self-heating intensified due to the cooling effect at the substance's external surfaces becoming minimised. Evidence of additional insulation must be considered during the investigation.

(f) Saturated hydrocarbons such as mineral oils have a single carbon-carbon bond, are much less reactive than unsaturated hydrocarbons and do not self-heat under normal ambient conditions. They can be capable of self-heating, leading to ignition when the temperature is significantly increased or stored in very large piles (NFPA, 2008a).

(g) Ground or shredded plastics that are used for re-cycling have been known to cause fires and this can be for several reasons. The grinding or shredding process itself can generate heat within the plastics due to friction. If other contaminants are within the plastics, such as vegetable oil from plastic bottles, or pieces of metal then they can also be heated during the grinding or shredding, which can promote the self-heating process. (DeHaan, 2007e). As ground and shredded plastics are normally stored in bulk quantities, heat dissipation is restricted.

(h) It is extremely rare for spontaneous ignition to develop into a free burning fire very quickly. It is normally a slow process, which is preceded by smoke and odours that should be detectable by anyone, or any automatic detection equipment within the area, before it becomes a flaming fire.

3.17.14 Yes

(a) It has been identified by the investigator that the oil or oil based product identified in [3.17.1] is capable of self-heating in the circumstances that existed at, or shortly before, the time of the fire. Proceed to [3.17.16]

3.17.15 No

(a) At this point in the route map, all evidence indicates that not only is an ignition source not available, but the oil or oil based product identified in [3.17.1] is not capable of self-heating in the circumstances that existed at, or shortly before, the time of the fire. Proceed to [3.17.18]

3.17.16 Was there a fuel package available to sustain combustion?

(a) Although all conditions have been met at [3.17.10] to indicate that oil or oil based products may have been the cause of the fire, it is important at this point to identify whether a fuel package was available to sustain combustion, particularly with regard to self-heating oils.

3.17.17 Yes

(a) All conditions have been identified to allow the path of the Road map to proceed to [3.17.20]

3.17.18 No

(a) All conditions have been identified to allow the path of the road map to proceed to [3.17.19]

3.17.19 Unlikely to be responsible for fire

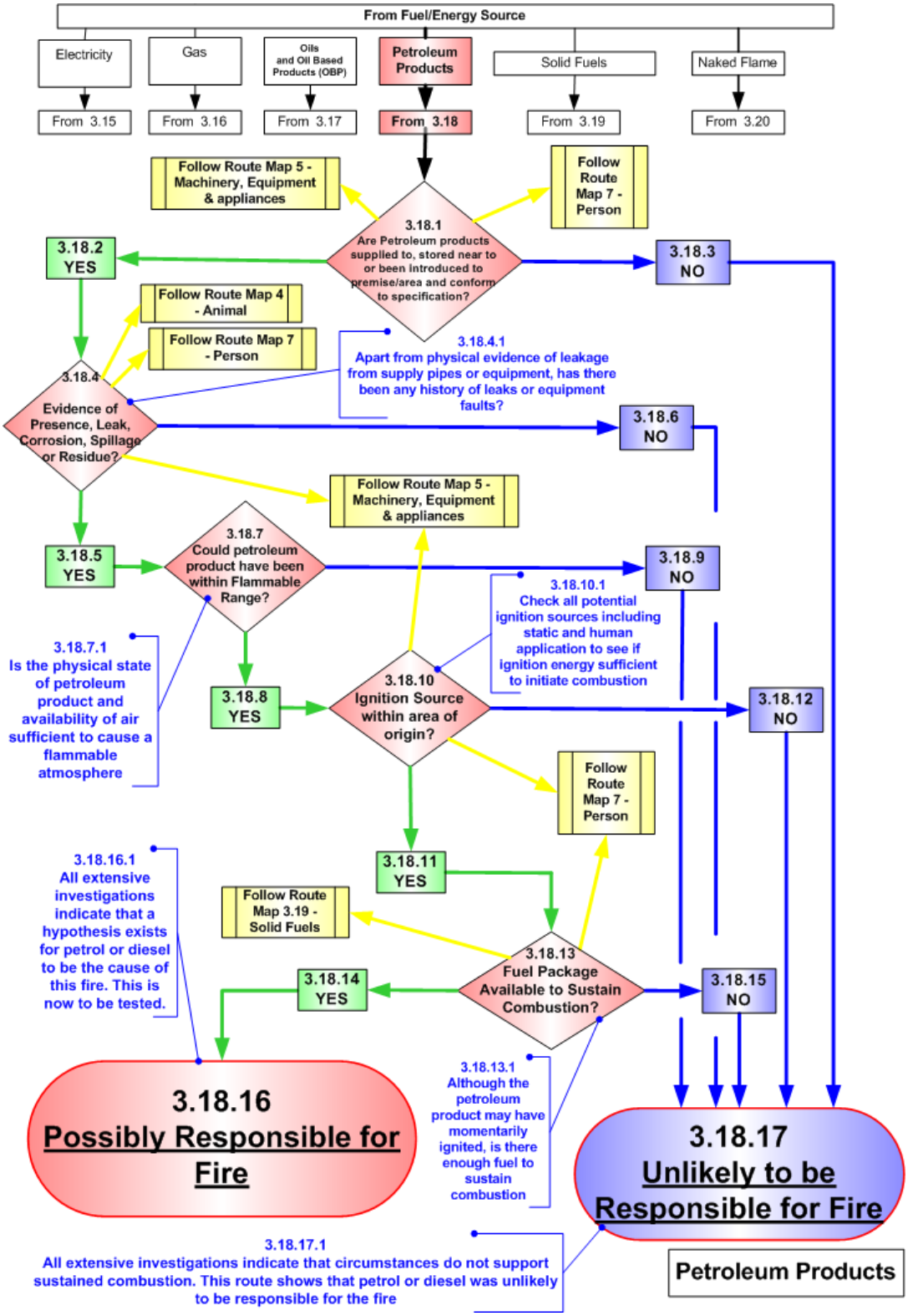
(a) All routes have now been explored so as to eliminate this category as a cause of the fire with the data that is available.

3.17.20 Possibly responsible for fire

(a) By arriving at this point in the road map a hypothesis has been created that needs to be tested and compared to any other hypotheses that may be developed during the investigation. If more than one hypothesis can be proved as possibly being the cause of the fire, then ‘undetermined’ must be recorded.

FIRE INVESTIGATION ROAD MAP #3.18

PETROLEUM PRODUCTS



3.18 Petroleum Products

Crude Oil is a dark-coloured, viscous flammable liquid occurring in sedimentary rocks, consisting mainly of hydrocarbons. Fractional distillation separates the crude oil into petrol, paraffin, diesel oil, lubricating oil and other derivatives.

Gasoline or petrol is a petroleum-derived liquid mixture consisting mostly of aliphatic hydrocarbons and enhanced with aromatic hydrocarbons, toluene, benzene or iso-octane to increase octane ratings and primarily used as fuel in internal combustion engines. Most Commonwealth countries, with the exception of Canada, use the term "petrol" (abbreviated from petroleum spirit). The term "gasoline" is commonly used in North America where it is often shortened in colloquial usage to "gas". This should be distinguished in usage from genuinely gaseous fuels used in internal combustion engines such as liquefied petroleum gas (which is stored pressurised as a liquid but is allowed to return naturally to a gaseous state before combustion). The term ‘mogas’, short for motor gasoline, distinguished automobile fuel from aviation gasoline, or avgas. The word "gasoline" can also be used in the British version of English to refer to a different petroleum derivative historically used in lamps; however, this use is now rare.

Diesel Oil: a fuel obtained from petroleum distillation that is used in diesel engines (also known as *derv – Diesel Engine Road Vehicle* (Hutchinson, 1993)).

Properties of Petroleum Products			
Petroleum Distillate	***Boiling Point Range***	***Flash Point***	***Auto-ignition Temperature***
Gasoline (low octane)	32 – 190^{0}C (90 – 375^{0}F)	– 43^{0}C (– 45^{0}F)	257^{0}C (495^{0}F)
Medium Petroleum Distillate	125 - 215^{0}C (250 - 400^{0}F)	13^{0}C (55^{0}F)	220^{0}C (428^{0}F)
Mineral Spirits		40^{0}C (104^{0}F)	245^{0}C (473^{0}F)
VM&P Naptha (regular)		-2^{0}C (28^{0}F)	232^{0}C (450^{0}F)
Kerosene (C10 – C16)	175 - 300^{0}C (350 - 500^{0}F)	>38^{0}C (100^{0}F)	210^{0}C (410^{0}F)
Fuel Oil #1:		175 - 260^{0}C (350 - 500^{0}F)	260^{0}C (500^{0}F)
Diesel Fuel (Fuel Oil #2)	200 - 350^{0}C (400 - 675^{0}F)	52^{0}C (125^{0}F)	260^{0}C (500^{0}F)

Table 3.3 – Properties of Petroleum Products (DeHaan, 2007a)

It is important that the investigator has a fundamental understanding regarding the processes of the ignition of petroleum liquid products. The following topics are outlined to assist with that understanding; auto-ignition temperature, flash point and fire point.

Auto-ignition Temperature (AIT)

This is the temperature at which the vapour from the petroleum liquid product will ignite without the introduction of an ignition source. It is the vapour that ignites and not the liquid, the more the liquid vaporises it follows that less liquid will remain until the point where no liquid remains at all. It is recommended that when dealing with the investigation of petroleum products, the investigator should know the product's AIT.

Extensive tests have been conducted to try to ascertain what the AIT is for certain liquids.

Some comparative results have been detailed in the table below (Babrauskas, 2003l).

Some of the other engineering tests that have been designed to determine the AIT do not truly reflect an 'auto-ignition' as the heated cup used is at a greater temperature than the vapours being released from the droplets (Babrauskas, 2003j).

SUBSTANCE	AIT K (^{0}C)	
	ASTM	
	D 2155	E 659
MIL-H-5606 hydraulic fluid	500 (227)	491 (218)
MIL-H-83282 hydraulic fluid	644 (371)	639 (366)
MIL-L-7808 lubricating oil	655 (382)	645 (372)
JP-4 jet fuel	527 (254)	500 (227)
JP-8 jet fuel	519 (246)	497 (224)

Table 3.4 – Auto Ignition Temperatures of Certain Liquids (Babrauskas, 2003j)

N.b. ASTM = American Society for Testing and Materials

Flash Point

This is the temperature in which a liquid petroleum product will ignite by the application of a small ignition source, such as a spark or flame. The lowest temperature of each product that this will occur at can only be determined by specific laboratory tests at which the liquid gives off enough vapour to support a momentary flame across its surface. (NFPA, 2008f). The values may change depending upon which tests were used.

As Babrauskas states: 'Piloted ignition will occur – in the gas phase – when at some particular place in the atmosphere:

1. An adequate concentration of the liquid's vapour exists above the liquid,
2. An adequate concentration of an oxidiser is mixed in with the fuel vapours,
3. A localised heat source of sufficient magnitude is present. (Babrauskas, 2003i)

Fire Point

This is the minimum temperature at which a combustible liquid will sustain a flame upon the application of a pilot flame as opposed to momentarily igniting and also known as the 'flame point'. As with gases, there are upper and lower flammable limits associated with the vapours of flammable liquids. These limits define the flammable range. This range is determined at a specific temperature and pressure of a flammable vapour from a liquid and air, expressed as a percentage of fuel by volume that can be ignited (NFPA, 2004b). The flash point associated with volatile liquid products such as methanol can often be considered as the same temperature as the fire point (DeHaan and Icove, 2011). The difference between the flash point and the fire point usually becomes greater with greater viscosity and vapour pressure.

However, the difference between the flash point and the fire point usually becomes greater with greater viscosity and vapour pressure. An example is glycerol which has a closed cup Flash Point of 433K (160^0C) and a Fire Point of 497K (224^0C).

The temperature relationships associate with liquid ignitions are as follows:

$$T_{flashpoint} \leq T_{firepoint} < T_{s.s.\ surface} < T_b$$

Where: $T_{flashpoint}$ = Flashpoint of liquid K;
$T_{firepoint}$ = Firepoint of liquid K;
$T_{s.s.\ surface}$ = Steady State Surface of liquid K;
T_b = Boiling Point of the liquid (Babrauskas, 2003k)

3.18.1 Are petroleum products supplied to, stored near to or been introduced to the premises or area of origin?

(a) The investigator must determine if petroleum products are supplied to the premises via supply pipelines, used by machinery or stored in containers. The investigator should thoroughly examine any items and machinery that use petroleum products, such as vehicle engines or portable heaters, to ascertain as to whether there are any malfunctions, leaks, or any history of such problems (See Fire Investigation Road

Map #5 – Machinery, Equipment and Appliances). Petrol, diesel or other petroleum products such as paraffin may be stored in a remote area from the fire. Leaking pipes or containers may allow the liquids to travel considerable distances, especially if on a higher level from the area of origin. All service ducts, pipe runs, voids and other conduits that would allow the liquids to travel must be explored.

(b) In some circumstances, such as in store rooms within large buildings, the occupier may not be aware that petrol has been brought onto the premises. An example is a caretaker of a school bringing in petrol to clean oily or greasy equipment. Also See Fire Investigation Road Map #7 – Person.

(c) If any significant quantities of petroleum products are stored on or near the premises, and then a petroleum licence may have been required, depending upon local regulations. It is important that the investigator ascertains whether a licence would have been required and whether the conditions of that licence had been adhered to and whether the storage of such products is legitimate.

(d) The nature and use of the premises can give the investigator some guidance as to the possibility of the presence of certain products. An example of this is a garage workshop. It would be expected to find products such as petrol, diesel, batteries and cylinders stored within a garage workshop. The investigator should try to identify items of equipment and machinery that use petroleum products such as lawn mowers, portable heaters, generators, etc. and ask the relevant person where extra fuels supplies are kept on the premises. Also see Fire Investigation Road Map #7 – Person.

(e) It is important that the investigator asks detailed relevant questions to all persons that have recently been within the area of origin or has access to it.

(f) If a person has been present then follow Fire Investigation Road Map #7 – Person.

(g) There are many ‘sniffer’ devices available that can help detect the presence of hydrocarbons. Some work by sampling air from the vicinity of the search area through a tube and passing it over a hydrogen flame. If hydrocarbons are in the air sample, a sounding device actuates thereby alerting the operator as to their presence. There are many electrical devices which are designed to detect hydrocarbons that are available to the investigator.

(h) There are other devices using different technologies that may detect the presence of hydrocarbons. One uses ultra-violet lights, which causes the hydrocarbons to fluoresce under the influence of the light. Another is termed as an ‘Ignitable Liquid

Absorbent', which is essentially a hydrophobic, hydrocarbon absorbing material and can change colour and form when it has come into contact with even trace hydrocarbon products. It is claimed to be non-contaminating and non-corrupting to an ignitable liquid evidence sample.

(j) In the case of a crime scene or suspected crime scene, no samples should be taken without the attendance of a police officer.

(k) Fire investigators should make themselves familiar with the different odours across the range of ignitable liquid accelerants so that they may be able to recognise the possible presence of such substances during an investigation or excavation simply by their sense of 'smell'. Investigators must be aware of the potential to become 'desensitised' if they are continually experiencing one particular smell. This could eventually prevent them from sensing a particular smell unless they remove themselves to uncontaminated air for a period of time.

(m) More local authority fire services and private accredited companies are providing hydrocarbon detector dogs as a tool to detect the possible presence of liquid ignitable accelerants. The dogs are capable of searching a large area in very little time with great accuracy. Current research (Nolan, 2005) has demonstrated that the olfactory senses of a trained canine are far more sensitive in detecting ignitable liquid accelerants, even when they have been significantly diluted, than some analytical equipment in a laboratory are able to detect.

(n) It is extremely important that the investigator does not state what substance is thought to have been present without a full laboratory examination and written report of the sample submitted.

(p) Many myths have been followed regarding the burn patterns associated with ignitable liquid accelerants. In fact, it used to be believed that if concrete showed signs of spalling then it must have been a liquid accelerant used. The hypothesis was that as the concrete became hot very quickly, the resultant differential in temperature between the surface and substrate caused the spalling. In fact, as it is only the vapour from the liquid which burns, the remaining liquid pool acts as a coolant to the surface, thereby preventing it from spalling.

(q) The boiling point of petrol is between 313K (40^0C) to 423K (150^0C), therefore the surface temperature beneath a pool of petrol cannot be higher than 423K (150^0C), which will not cause the structural damage due to thermal expansion to the surface

of the concrete. The duration of the liquid burning is also short so the investigator must consider what other normal fuel loads were available at the time of the fire.

(r) It is recommended that fire investigators study all available material with regard to burn patterns, especially those involving ignitable liquid accelerants.

3.18.2 Yes

(a) It has been identified that either petrol or diesel have been supplied to, stored in or near to, or have been introduced to the area of origin.

3.18.3 No

(a) Following all possible investigations and enquiries the investigator has determined that no evidence exists that petrol or diesel has been supplied to, stored in or near to, or have been introduced to the premises.

3.18.4 Is there any evidence of presence, leak, container corrosion, spillage or residue of petroleum product?

(a) The investigator should examine all containers, either storage or waste, and ascertain if they were damaged or defective prior to the fire. The investigator must look for material damage to any containers such as splits, impact or rodent damage. (See Fire Investigation Road Map #4 – Animals.) and determine if the damage was deliberate.

(b) The fuel type, quantity and physical state should try to be identified, if possible.

(c) Check for any supply pipes or any parts of the system under pressure whereby a leak could cause atomisation of petrol or diesel into the atmosphere, creating a high surface to mass ratio and a flammable vapour. If equipment or machinery is involved, then also follow Fire Investigation Road Map #5 – Machinery, Equipment and Appliances.

(d) Close examination of all supply pipes, storage vessels and machinery, particularly at flanges, connections and control valves, must be carried out to ascertain any accidental or deliberate defects (sabotage). See Fire Investigation Road Map #7 – Person. The location of storage vessels and supply pipes must be established, even if they are some distance from the area of origin.

(e) Mineral oils do not normally self-heat, however there have been reports of certain circumstances where mineral oil is believed to have self-heated when absorbed in glass fibre insulation (Babrauskas, 2003g, Bowes, 1974). Some smoke generators use petroleum products which may distribute the smoke through a network of ducting. During a recent fire investigation, it was identified that the smoke condensate degraded the gaskets between the ductwork joints allowing the condensed petroleum product to drip into the surrounding glass fibre insulation. When this insulation was heated due to the heat flux transmitted through ceiling tiles within a fire training room below it, the oil started to self-heat until it ignited. (London Fire Brigade, 2004)

3.18.5 Yes

(a) A leak, spillage or petroleum product residue has been identified as being within, or able to get within the area of origin. Proceed to [3.18.7]

3.18.6 No

(a) No leak, spillage or petroleum product residue has been identified as being within, or able to get within the area of origin. Proceed to [3.18.17]

3.18.7 Within flammable range?

(a) It is necessary for the investigator to determine whether the petroleum product could have been in at its fire point, i.e. a suitable physical state and have been available and have mixed with enough oxygen to be able to start the combustion process, or present a flammable atmosphere given a sufficient ignition source.

(b) Refer to the table in [3.18] at the beginning of this section for a guide to flash point temperatures for a selection of petroleum products. Remember that the flash point is the lowest temperature that a momentary flame will occur, but may generate enough energy to sustain combustion or ignite adjacent materials.

(c) Calculations may need to be completed to ascertain the possibility of a flammable atmosphere, particularly if the quantity of petroleum product, ambient temperature and physical state are known.

3.18.8 Yes

(a) The investigator has identified that the leak, spillage or residue is in a physical state that is within the flammable range of the substance. Proceed to [3.18.10]

3.18.9 No

(a) The investigator has identified that the leak, spillage or residue is not in a suitable physical state or within the flammable range of the substance. Proceed to [3.18.17]

3.18.10 Was there an ignition source within the area of origin

(a) All ignition sources need to be examined, including those from machinery, equipment or appliances [Road Map 5] which also covers sparks and static electricity. Ensure that any electrically operated ventilation equipment is approved for use in potentially explosive atmospheres by an EC Notified Body. (ConocoPhilps, 2006)

(b) The investigator must remember that the ignition source may be some distance from the leakage and not where the most severe burn patterns are.

(c) The investigator is now able to consider any ignition source that may have been available to start the combustion or smouldering process. Fire Investigation Road Maps #1, #2, #4, #5, #6 and #7 must all be followed to ascertain the potential for an ignition source to have been initiated from these routes.

3.18.11 Yes

(a) An ignition source(s) has been identified while the petrol or diesel is in such a physical state so as to create a flammable atmosphere.

3.18.12 No

(a) Although it is evident that a flammable atmosphere existed at the time of the fire, no ignition sources were found, even after following Fire Investigation Road Maps #5 and #7 (if applicable).

3.18.13 Was there a fuel package available to sustain combustion?

(a) Although all conditions have been met at [3.18.10] to indicate that petrol or diesel may have been the cause of the fire, it is important at this point to identify whether a fuel package was available to sustain combustion.

3.18.14 Yes

(a) All conditions have been identified to allow the path of the road map to proceed to [3.18.16]

3.18.15 No

(a) All conditions have been identified to allow the path of the road map to proceed to [3.18.17]

3.18.16 Possibly responsible for fire

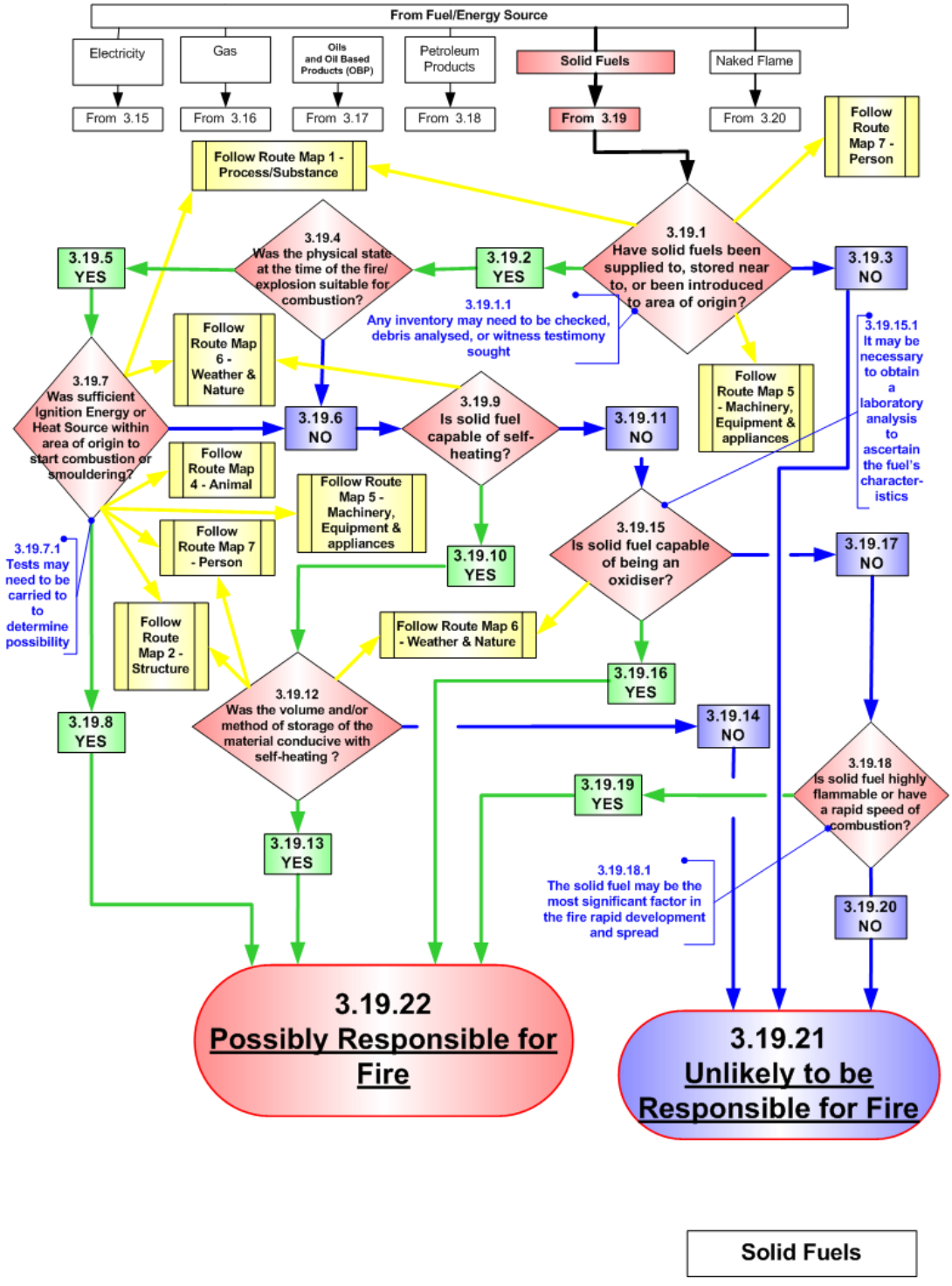
(a) By arriving at this point in the road map a hypothesis has been created that needs to be tested and compared to any other hypotheses that may be developed during the investigation. If more than one hypothesis can be proved as possibly being the cause of the fire, then 'undetermined' must be recorded.

3.18.17 Unlikely to be responsible for fire

(a) All routes have now been explored so as to eliminate this category as a cause of the fire with the data that is available.

FIRE INVESTIGATION ROAD MAP #3.19

SOLID FUEL



3.19 Solid Fuel

Throughout this Section, solid fuels will be taken to include wood, wood products, paper, plastics, multiple layers of dried paints, metals, coals, fabrics, foams, rubbers, structural polymers, synthetic fuels, vegetation, waxes and fire-lighters. Solids can ignite in two ways; external heat application (by convection, conduction and/or radiation), or self-heating. There can sometimes be a combination of both, however, for *most* solids, ignition due to external heating occurs in the gas phase as volatiles are driven off from the solid and burn freely in the surrounding atmosphere. As will be detailed in [3.19.9] self-heating occurs in the solid phase. Arc tracking through solids is covered in Fire Investigation Road Map #3.15 – Electricity.

The following summary is quoted from the Ignition Handbook and relates to some general features of the problem of the flaming ignition of solids. (Babrauskas, 2003h)

'First of all, since flames are a gas-phase phenomenon, for a solid to be capable of flaming ignition it must respond to heat by breaking down and releasing combustible vapours. This is known as the 'pyrolysis process', which is a 2-step process. Upon initial exposure to heat, large molecules break apart and release some small fragments which emerge as gas molecules. These now have the potential to ignite in the air above the solid's surface under the right conditions.

For a pyrolysing solid to ignite in a flaming mode, the same three conditions must be satisfied, as for liquid fires:

[1]. The solid must be sufficiently heated so that an adequate concentration of pyrolysate (the pyrolysed vapour) exists at some location away from the surface (of the solid).

[2]. An adequate concentration of an oxidiser (typically, air) must be mixed in with the fuel vapours so that a flammable fuel/oxidiser gas mixture exists somewhere above the surface.

[3]. Either the temperature of the pyrolysate/air mixture must become high enough (for auto-ignition to occur) or else a sufficient external energy

source such as a pilot flame or a spark must be introduced (for piloted ignition to occur).'

3.19.1 Have solid fuels been supplied to, stored near to, or been introduced to the area of origin?

(a) The investigator may find the remains of consumed or partially consumed solid fuels; it is important to ascertain that these were located within the area of origin and not the result of fire spread through conduction, convection or radiation from another seat of fire.

(b) Witness testimony, CCTV recordings, inventories, purchase and sales records are all important sources of information that can be examined to ascertain potential quantities of solid fuels that may have been in the area of origin, but by far the best indicator that there were indeed solid fuels present at the time of the fire is within the fire debris, which may have to be analysed in a laboratory to determine its physical properties and chemical composition.

(c) Follow Fire Investigation Road Map #5 – 'Machinery, Equipment & Appliances' to establish whether anything was in operation or on powered stand-by at the time of the fire. Modern appliances, such as electric coffee makers which are almost 100% plastic, (apart from the heating element and wiring), can leave little evidence of their original form once consumed in a fire. It may be necessary to x-ray the remains to ascertain what the item was and whether the correct safety devices are still in place, whether they have operated and have not been by-passed.

(d) If there is an amount of debris present where it is believed that no combustible solids should have been, then the investigator should ascertain when and who introduced them to the area of origin. Again, CCTV recordings and witness testimony may assist with this. (Follow Fire Investigation Road Map #7 – Person)

(e) If a storage facility, such as a coal bunker, is adjacent to the area of origin, it is important to determine the integrity of the compartmentation of that storage prior to, and at the time of the fire. It may be possible that if the storage compartmentation had been breached then the solid fuel may have come into contact with a viable ignition source in the adjacent compartment.

(f) Follow Fire Investigation Road Map #1 – 'Process/ Substance' as any processes that are carried out within the area of origin may involve the placement and/or removal of solid fuels from that area. There would probably be some form of machinery involved in any such process and this would be identified and considered when following Fire Investigation Road Map #5.

3.19.2 Yes

(a) It has been identified that solid fuels were within the area or origin at the time the fire started.

(b) Although it may be established that prior to the fire there were no solids known to have been within the area of origin, physical evidence of the remains of burnt solids will take the investigator to Section [3.19.4] of this FIRM.

3.19.3 No

(a) It has been identified that no solid fuels were within the area or origin at the time the fire started.

(b) By following this route, it will have been established that prior to the fire there were no solids known to have been within the area of origin and there is no physical evidence of the remains of any burnt solids. This will take the investigator to Section [3.19.21] of this FIRM.

3.19.4 Was the physical state of the solid, at the time of the fire or explosion, suitable for combustion?

(a) The moisture content of a solid fuel that can contain moisture can vary not only due to the times of the year but also between locations and the environment in which it is stored. For example, timber may have higher moisture content where the relative humidity is higher in coastal regions. Any material that has high moisture content will require a greater heat flux or a longer exposure time to heat, than a material that is dry. Although this may seem like simple physics, it is something that the investigator must consider during an investigation, especially when determining the development of a fire.

Below is a table reproduced from Babrauskas Ignition Handbook (Babrauskas, 2003c) showing the piloted ignition times of Monterey pine as a function of moisture content (MC), which demonstrates this correlation. 9mm thick wood specimens where used and subjected to radiant heat during these tests.

Heat flux (kWm^{-2})	**Ignition time (s)**			
	0%MC	15%MC	22%MC	30%MC
20	179	295	420	540
30	19	52	67	93
40	9	18	30	36
50	5	11	11	19
60	3	7	9	11

Table 3.5 - Piloted Ignition Times of Monterey Pine (Babrauskas, 2003c)

(b) In [3.19.7.j] the importance of considering the material's surface absorptivity is discussed. It must be remembered that treatments, such as multiple layers of paint on a surface will strongly affect the ignition characteristics of the material. Tests have shown that by painting a darker coloured material with white paint increases the time to ignition significantly. (Babrauskas, 2003f)

(c) An example of how difficult it is to accurately determine the effects of absorptivity of surfaces (which is 0 to 1) in fires is one that is giving by Babrauskas; 'the absorptivity of shiny aluminium is around 0.07 to 0.1 in the near infrared … if the surface truly maintains an absorptivity below 0.1, then ignition of any combustibles underneath is unlikely, except if flashover conditions develop … the absorptivity of black soot coating is around 0.98. Thus the same product that might be 'ignition resistant' originally, may ignite readily once sooted up'.

(d) Fire retardants can greatly influence and slow down the combustion process of otherwise readily combustible solids. (Babrauskas, 2003a) However, research shows that not all fire retardants are effective on all materials and that they are 'material specific'. It is recommended that the investigator studies the manufacturer's instructions closely to ascertain that the correct type of retardant has been used with the correct material in the correct manner, if evidence exists of any fire retardants having been used.

3.19.5 Yes

(a) It has been identified that the physical state of the solid, at the time of the fire or explosion, was suitable for combustion. Proceed to [3.19.7]

3.19.6 No

(a) It has been identified that the physical state of the solid, at the time of the fire or explosion, was not suitable for combustion. Proceed to [3.19.9]

3.19.7 Was there a sufficient ignition energy or heat source within the area of origin to start combustion or smouldering?

(a) Experimentally, heat flux is the driving force for the ignition of solid objects (Babrauskas, 2003b). The minimum ignition energy of a solid fuel is not a constant and therefore the investigator should be cautious when using published tables detailing the ignition energy required to sustain combustion to any material.

(b) When a solid is exposed to a heat flux from any heat source and it starts to burn, and then if that heat flux is removed, one of two things will happen; the gases above the solid will continue to flame or flaming will cease.

(c) It follows that, as detailed in 3.19 [1], [2] & [3], if a solid fuel is subjected to a large heat flux but over a short duration, then the volatiles that are released may become ignited but then flaming could cease once the heat flux is removed. If, however, the same solid fuel is subjected to a heat flux over a longer duration and that heat flux is capable of commencing the combustion process, then the removal of that heat flux may allow flaming to continue as the volatiles that are being released are due to the material being heated up in depth and the volatiles may continue to be produced. In the latter, the solid's temperature will drop gradually and the mass delivery rate of volatiles is proportional to the temperature of the surface layer.

(d) Most combustible solids do not smoulder (Babrauskas, 2003d). It is generally accepted that porous or granular materials that can char and have limited or no tendencies to melt are prone to smouldering. The investigator must also be aware that the char structure should be porous and not clogged with molten material (Ohlemiller and Rogers, 1978).

(e) Flames are not associated with smouldering. If smouldering achieves temperatures high enough to exhibit a visible glow, the combustion is generally referred to as 'glowing combustion'.

(f) Below is a list of some common materials that are known to smoulder in certain circumstances:

- Wood and wood products
- Paper
- Leather
- Cotton batting
- Carbon
- Peat and organic soils
- Various agricultural products
- Latex foam
- Some types of polyurethane, polyisocyanurate and phenol formaldehyde foams; open cell (flexible) foams are more likely to smoulder than closed cell (rigid) foams.
- Coal, charcoal, coke, cigarettes and incense sticks (produce wanted or designed smouldering)
- Dust layers of various sorts e.g. coal, cocoa and sawdust (Babrauskas, 2003d).

(g) The ignition of a solid due to a pilot (flame, spark or incandescent material) can be separated into one of three categories: (Babrauskas, 2003e)

[i] no pilot (or auto-ignition)

[ii] a pilot located in the gas phase, without direct heating effects on the solid fuel

[iii] a pilot where the flame is directly impinging on the surface of the solid fuel which is also being heated by convection and/or radiation.

The investigator must consider that although a solid fuel may be pyrolysing and producing large quantities of flammable vapours during the this process, it may be a pilot flame remote from the vapours that causes the gases to ignite and allow the fire to rapidly develop back to the fuel (Mansi, 2005).

(h) When considering the effects of a heat flux onto a solid fuel, the investigator should make every effort to ascertain the surface covering of the solid at the time of the fire. Heat can be absorbed by the material allowing its temperature to be raised, also

allowing the heat to transmit through it, or it can be reflected by the material or any surface coatings.

(j) It is important therefore, that when the investigator starts to consider material surfaces, the material's surface absorptivity should also be considered. It is not expected that the investigator completely understands or carries out complex calculations at the scene regarding surface absorptivity, suffice to say that dense and fine grain surfaces will not absorb heat as well as light and open grain or porous surfaces.

(k) The investigator is now able to consider any ignition source that may have been available to start the combustion or smouldering process. FIRMs #1, #2, #4, #5, #6 and #7 must all be followed to ascertain the potential for an ignition source to have been initiated from these routes.

(m) FIRM #1 may indicate that certain substances or processes will cause ignition of certain solids when they come into contact with each other. An example of this would be a vehicle crashing into a lamp post where the sodium bulb smashes onto the roadway, then subsequent hosing down of the road surface to remove debris causes a reaction between the sodium and the water. If this heat source were to make contact with a solid fuel, such as a vehicle tyre, then a fire could develop and involve the whole vehicle.

(n) FIRM #2 may lead the investigator to determine that a solid fuel source has come into contact with a part of the structure which is designed to be isolated from any ignition sources. An example of this would be a flue or chimney from an oven in a restaurant that has been breached by a timber structural member of a new wall that has been constructed adjacent to it, allowing the hot gases to impinge upon the timber section.

(p) FIRM #4 could demonstrate that a rodent chewing though an electric cable could become a heat source itself and transfer the heat from its charring body onto an adjacent solid fuel to start a larger fire.

(q) FIRM #5 will validate whether any machinery, equipment or appliances were in contact with any solid fuel sources, or capable of producing any form of heat in the way or sparks, friction or designed energy that could have started the combustion or smouldering process. An example of this would be when a plumber has removed an immersion heater and laid it on a timber floor believing that the power was off, when in fact it was connected to a time switch; when the switch activated, the 3kw

immersion heater ignited the timber flooring causing a serious fire (London Fire Brigade, 2005).

(r) FIRM #6 must also be followed to determine the effects of the weather or nature on a potential solid fuel. An example would be a haystack that has been exposed to the rain and with suitable conditions has self-heated. The investigator should therefore determine whether there was any rain during the previous days or weeks and whether the ambient temperatures and winds were suitable to support the self-heating theory. Sunlight must also be considered as a viable ignition source, especially when concentrated through glass or reflected by magnifying mirrors.

(s) FIRM #7 will be required to be followed as it will need to be determined what the human agency involvement was, not only at the time of the fire, but before the fire was discovered. In the absence of any feasible ignition sources, human agency involvement becomes critical during an investigation. It is also necessary to determine who was first alerted to the fire, how they were alerted and how long before they reacted. For example, research (Mizuno et al., 2001) shows that individual response times to the smell of burning without visible smoke varied between less that 1 minute to over 30 minutes.

3.19.8 Yes

(a) It has been identified that there was a sufficient ignition energy or heat source within the area of origin capable of starting the combustion or smouldering process. Proceed to [3.19.22] but still follow [3.19.9] to explore the hypothesis of self-heating.

3.19.9 Is the solid fuel capable of self-heating?

(a) Self-heating is an exothermic reaction, whereby the material involved is generating heat from within itself without taking any heat from its ambient surroundings, and dissipating less heat into those surroundings than it is generating. Self-heating can lead to thermal runaway and self-ignition of a material.

(b) It can occur in any of the states of matter including solids (Babrauskas, 2003o).

(c) Consideration must be given to types of organic products that can self-heat, and in this road map specifically coal (in large quantities), activated charcoal and haystacks. Their size, shape and surroundings all have to be considered as to the

possibility of self-heating and the materials must be porous, permeable (allow oxygen in) and oxidizable.

(d) A substance that can self-heat and is wrapped or covered in any form of thermal insulation will have its rate of self-heating intensified due to the cooling effect at the substance's external surfaces becoming reduced. Evidence of additional insulation must be considered during the investigation.

(e) Cotton fabrics that have been impregnated with vegetable (organic) oils, washed and then heat dried can self-heat to combustion within a few hours. Some of these oils are not very soluble in water and therefore can be retained within the fabric following the washing process, even with the use of detergents. If a fire has occurred within a tumble drier or due to other methods of heat drying, the water within the pump of the washing machine that was used may be analysed to detect residues of the oil (Mann and Fritz, 1999).

(f) Ground or shredded plastics that are used for re-cycling have been known to cause fires due to several reasons. The grinding or shredding process itself can generate heat within the plastics due to friction. If other contaminants are within the plastics, such as vegetable oil from plastic bottles, or pieces of metal then they can also be heated during the grinding or shredding, which can promote the self-heating process (DeHaan, 2007e). As ground and shredded plastics are normally stored in bulk quantities, heat dissipation is restricted.

(g) Pyrophoric materials are those which spontaneously combust when exposed to air. Some examples are white phosphorus, sodium and potassium (NFPA, 2008d). See [Road Map 1]

(h) It is extremely rare for spontaneous ignition to develop into a free burning fire very quickly. Paragraphs [6.7.8], [6.7.9] and [6.7.10] in Road Map [6] – 'Weather & Nature' are examples of when it can occur. It is normally a slow process, which is preceded by smoke and odours that should be detectable by anyone with normal senses (see [3.19.7.16] above), or any automatic detection equipment within the area, before it becomes a flaming fire.

3.19.10 Yes

(a) It has been identified that the solid fuel has the potential to self-heat. Proceed to [3.19.12].

3.19.11 No

(a) It has been identified that the solid fuel does not have the potential to self-heat. Proceed to [3.19.15].

3.19.12 Was the volume and/or the method of storage of the material conducive with self-heating?

(a) If all indications are that the storage of the material(s) involved in the area of origin of the fire was correct and in the appropriate volumes, the investigator must consider all other ignition sources and follow FIRM #7 - Person.

(b) If it appears that the storage was not satisfactory, it will be important to examine all method statements, operating notes and risk assessments regarding the correct storing of such materials. (Also, follow FIRM #2 – Structure). Ventilation and humidity will often be an important factor with regard to minimising self-heating. The structure and its components may have an important effect on both of these control measures.

(c) If large quantities of organic material, such as a coal pile or haystack have been involved in a fire, it may be necessary to use a probe thermometer to test the internal temperature of identical adjacent materials or fuel packages, if they are available. If not, then investigate the methods used for monitoring the temperatures of such materials by the owner/ occupier. Biological activity can generate enough heat to start a thermal runaway within the stacks. This can also occur in compost heaps and rubbish heaps. (See FIRM #6 – Weather & Nature)

3.19.13 Yes

(a) The volume and/or the method of storage of the material is conducive with self-heating. Proceed to [3.19.22]

3.19.14 No

(a) The volume and/or the method of storage of the material is not conducive with self-heating. Proceed to [3.19.21]

3.19.15 Is the solid fuel capable of being an oxidiser?

(a) Oxidising agents are chemical substances that may not be combustible by themselves but can rapidly increase the rate of burning within other substances

(NFPA, 2008c) or result in spontaneous combustion when combined with other substances. An example is chlorine contaminated with certain organic materials.

(b) Some inorganic materials, for example metal powders, may undergo rapid oxidation leading to self-heating and self-ignition under isolated conditions.

3.19.16 Yes

(a) The solid fuel has been identified as capable of being an oxidiser. Proceed to [3.19.22]

3.19.17 No

(a) The solid fuel has not been identified as capable of being an oxidiser. Proceed to [3.19.18]

3.19.18 Is the solid fuel highly flammable or have a high heat release rate?

(a) The characteristics of the solid fuel are such that any ignition would lead to very rapid fire development. This must be compared to witness testimony, CCTV recordings and any other method of demonstrating the speed at which the fire developed to ascertain whether or not the fuel was responsible for the cause of the fire as opposed to the development of it.

(b) The problem with any fuel that is highly flammable is that the investigator may be drawn to a premature hypothesis that it was the fuel that was the initial cause of the fire, when further investigations may reveal that the smell of burning was witnessed sometime before the fire developed; this may suggest that the highly flammable fuel would not have been capable of starting slowly thereby allowing persons to detect the burning smell, when any ignition would have resulted in rapid flaming combustion.

3.19.19 Yes

(a) It has been identified that the solid fuel is highly flammable and/or has a rapid speed of combustion. Proceed to [3.19.22]

3.19.20 No

(a) It has been identified that the solid fuel is not highly flammable nor has a rapid speed of combustion. Proceed to [3.19.21]

3.19.21 Unlikely to be responsible for the fire

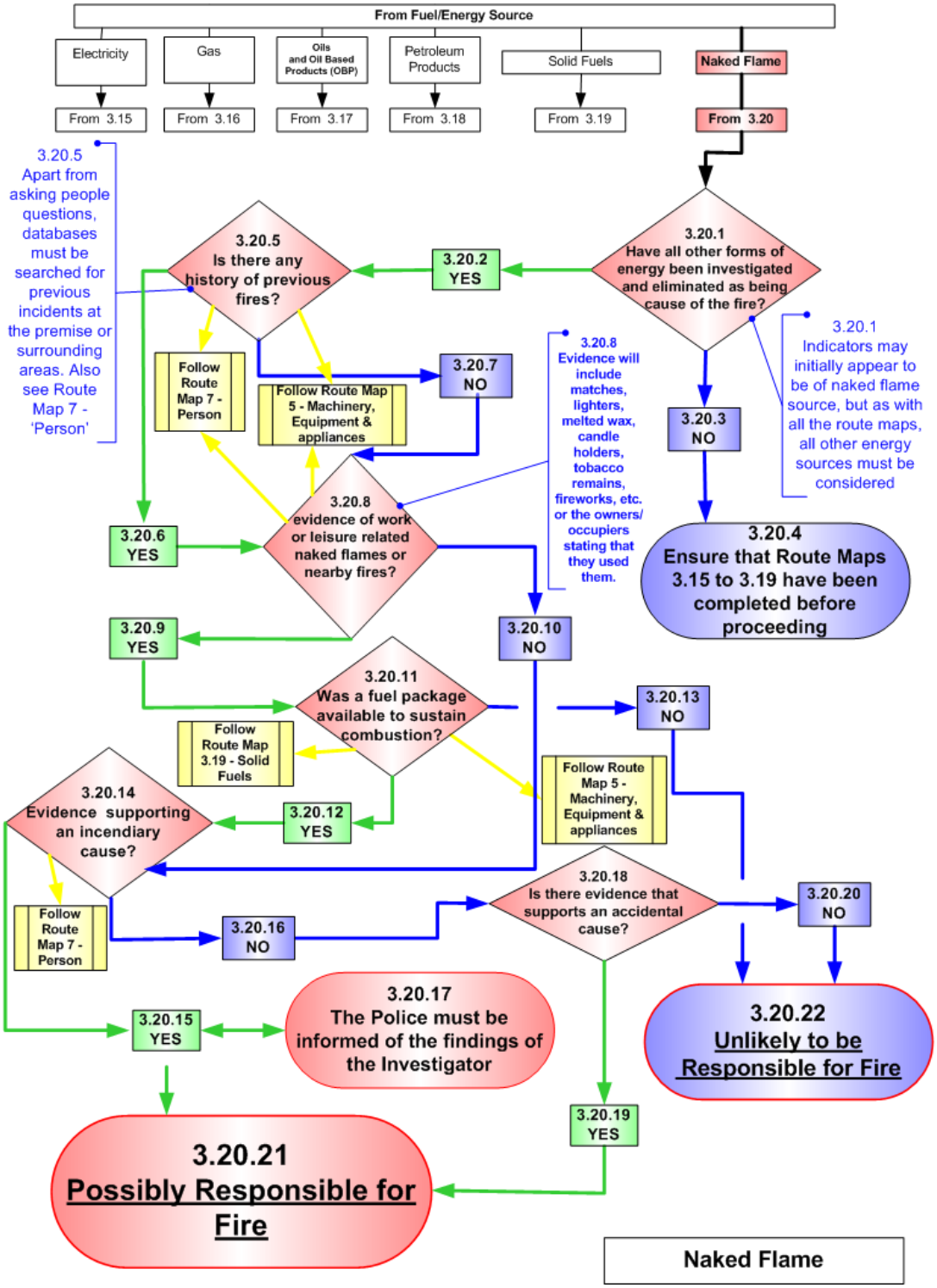
(a) All routes have now been explored so as to eliminate this category as a cause of the fire with the data that is available.

3.19.22 POSSIBLY RESPONSIBLE FOR THE FIRE

(a) By arriving at this point in the road map a hypothesis has been created that needs to be tested and compared to any other hypotheses that may be developed during the investigation. If more than one hypothesis can be proved as possibly being the cause of the fire, then ‘undetermined’ must be recorded

FIRE INVESTIGATION ROAD MAP #3.20

NAKED FLAME



3.20 Naked Flame

This Fire Investigation Road Map deals with all forms of naked flame, irrespective of the ignited fuels and the rate that they are burning. It encompasses matches, lighters, smoking materials, bonfires, domestic fires such as gas, log, synthetic logs or coal fires, fireworks and flares, heaters, cooking equipment, burnt food items including cooking oils, fats and alcohol, camping equipment, hot-works equipment such as blow lamps and welding torches, and candles.

Although smoking materials constitute a smouldering fire, they are included within this chapter as a naked flame due to their burning characteristics and propensity to start fires in upholstery and paper products, although there will be some cross-reference to Fire Investigation Road Map #3.19 – Solid Fuels.

3.20.1 Have all other forms of energy been eliminated as possibly being the cause of the fire?

(a) Even if the evidence strongly indicates that a naked flame could be the cause of a fire within the area of origin, it is imperative that all other energy sources have been investigated and, either eliminated, or hypotheses have been developed that are to be tested.

3.20.2 Yes

(a) Other energy supplies have been investigated, hypotheses tested and eliminated as being responsible for the fire. Proceed to [3.20.5]

3.20.3 NO

(a) Other forms of energy have not been investigated. Proceed to [3.20.4]

3.20.4 Ensure that Fire Investigation Road Maps #3.15 to #3.19 have been completed before proceeding

(a) As with all of the other road maps that have to be investigated, a naked flame may be hypothesised after all of the other energy sources have been considered following the testing of their hypotheses.

(b) If any of the other energy sources remain as a potential cause of the fire, continue with this Road map as the investigator may arrive at [3.20.21] and therefore 'Undetermined' would be the eventual conclusion of the investigation.

3.20.5 Is there any history of previous fires?

(a) It needs to be established whether any fires have previously occurred at the premise(s). This can be done by witness testimony and checking fire service records.

(b) The investigator must remember that the fire service may not have attended previous fires at the premises as the occupier (or another) may have put the fire out themselves. Burn damage and smoke staining are good indicators of previous fires.

(c) It is important therefore, that the investigator carries out a thorough visual examination around the premises or surrounding area in order to identify any other independent burn patterns or smoke damage that would indicate previous fires. If these are identified, then the owner, occupier or witness may be questioned about the origins of the identified damage. (Follow FIRM #7 – 'Person', to ascertain whether the identified damage is known about and attempting to be concealed or what involvement any person(s) may have had with that fire damage.

(d) If a naked flame has been identified, it must be established whether the flame is by accident or design. For example, some machinery and equipment (Follow FIRM #5 – Machinery, Equipment and Appliances) are designed to use a flame during their operation, such as a blow lamp used by a plumber, decorator or even a chef. However, a carelessly discarded match, although designed to ignite smoking materials, it is not part of the design *function* to remain ignited for more than a brief moment when discarded.

(e) Another consideration for the investigator is whether any identified naked flame was being used for work or for leisure. If the flame was being used for leisure, for example when igniting brandy on a 'Christmas' pudding, then the control measures for the safety of that flame may be considered in conjunction with any fuel

packages that were available at the time of, or just prior to the fire. (Also follow FIRM #7 – 'Person' to ascertain actions of person using the flame for leisure).

Open fires and candles may be used for a 'social' effect, even within centrally heated premises. With the introduction of synthetic logs, it may be that a change of fuel type within the fire grate has produced unexpected fire behaviour to which the occupier is used to seeing. Some of the fabricate logs produce bigger flames than natural logs and may lead to the onset of a chimney fire if the chimney flue has not been cleaned for some time and is heavily sooted. The investigator should explore any changes in fuel types that may have produced an effect which may have contributed to the fire being investigated.

If the flame is for work purposes, then the investigator can certainly be more focused on any available technical information for the characteristics of that flame; size of flame, angle of developed flame, flame velocity, whether it was premixed or diffused, temperature of flame, etc.

(f) Although [3.20.6] and [3.20.7] both lead to [3.20.8], the investigator must evaluate any information gathered here about previous fires as to the coincidence of a fire occurring at the same premises as opposed to the un-likelihood of a similar fire occurring.

(g) Also follow Road Map [7] – 'Person' to identify any relevant person(s) and their actions prior to, or at the time of any previous fire(s).

3.20.6 Yes

(a) It has been established that a fire(s) has previously occurred at the premises or location.

(b) As stated in [3.20.5.6] the investigator must now compare the data relating to the origin and cause of any previous fires with the data collected throughout the rest of this road map.

3.20.7 No

(a) No history of previous fires can be established. Proceed to [3.20.8]

3.20.8 Is there any evidence of work or leisure related naked flames or nearby fires?

(a) The investigator must examine in detail the room or area of origin for the remains of any evidence so as to determine whether any of the following could have been a potential ignition source for the available fuel package(s); matches, lighters, smoking materials, bonfires, domestic fires such as gas, log or coal fires, fireworks and flares, heaters such as paraffin heaters, cooking equipment, burnt food items including cooking oils, fats and alcohol, camping equipment, hot-works equipment such as blow lamps and welding torches, and candles. This list is not exhaustive and does not include every possible type of naked flame, but it does attempt to encourage the investigator to consider all equipment and materials that sustain a naked flame.

(b) The investigator must also examine in detail other rooms in the premises or locations away from the area of origin to see if there is any evidence of use of the above items elsewhere. This will offer the possibility that if items such as candles or cigarettes are being used elsewhere, then they could potentially have been used in the area of origin. Follow Road Map [7] – Person, to see if any of the items were used or introduced by any person(s).

(c) Establish whether any persons had witnessed or had themselves been using fireworks prior to the fire, even if it was some considerable distance away from the area of origin. Fireworks, other pyrotechnic devices and burning material discharging from them can travel long distances at low wind speeds. It is also necessary to consider the possible use of flares, particularly if near open water or a boat yard where such devices may be found.

(d) By asking the occupier to sketch or recall the location of any items of furniture, appliances, candles and/or candle holders, ashtrays, or any other information that will assist the investigator, the information can be compared to associated fuel packages, burn patterns and fire damage within the area of origin.

(e) Follow Fire Investigation Road Map #7 – 'Person' to identify any relevant persons and their actions prior to, or at the time of the fire.

3.20.9 Yes

(a) By physical evidence, witness testimony or previous history, confirmation of either use of, or introduction of, the items discussed in [3.20.8.a] has been established.

3.20.10 No

(a) Neither physical evidence, witness testimony nor previous history of use or introduction of any of the items been identified. Proceed to [3.20.14]

3.20.11 Was a fuel package available to sustain combustion?

(a) Although evidence discovered in [3.20.8] has identified a potential ignition source, the investigator must establish whether a fuel package was available and suitable for the ignition source identified. It must be clearly determined that the ignition source came together with the fuel source for sufficient duration to allow the ignition energy to be transferred into the fuel package to initiate the combustion process. An example is a cooking pan filled with oil left on top of a gas burner. (See Fire Investigation Road Map #5 – Machinery, equipment & appliances, and also Fire Investigation Road Map #7 – Person)

3.20.12 Yes

(a) A suitable fuel package has potentially been identified by either physical evidence or witness testimony.

(b) The investigator is now able to consider any ignition source that may have been available to start the flamming or smouldering process. FIRMs #1, #2, #4, #5, #6 and #7 must all be followed to ascertain the potential for an ignition source to have been initiated from these routes.

3.20.13 No

(a) No suitable fuel package has been identified by either physical evidence or witness testimony. Proceed to [3.20.22]

3.20.14 Is there evidence that supports an incendiary cause?

(a) The investigator must make a decision with the information that has been gathered as to whether that evidence supports the potential for a deliberate ignition.
(b) Follow Fire Investigation Road Map #7 – 'Person' to identify any relevant persons and their actions prior to, or at the time of the fire.
(c) The investigator must be perceptive and take note of any claims of deliberate ignition, even if the evidence so far suggests that this fire was not an incendiary fire.

3.20.15 Yes

(a) At this point in the road map, data exists to indicate the possibility of a deliberate ignition. Proceed to both [3.20.17] and [3.20.21]

3.20.16 No

(a) At this point in the road map, no data exists to indicate the possibility of a deliberate ignition. Proceed to [3.20.18]

3.20.17 The police must be informed of the findings by the investigator

(a) If the investigator has evidence to suggest that there is a possibility the fire has been started deliberately, then he or she MUST contact the police and continue the investigation in accordance with local procedures, memoranda of understanding, etc.

3.20.18 Is there evidence that supports an accidental cause?

(a) At this point in the road map, enough data may exist to indicate the possibility of an accidental ignition and the investigator must consider all available data.

3.20.19 Yes

(a) At this point in the road map, data exists to indicate the possibility of an accidental ignition. Proceed to [3.20.21]

3.20.20 No

(a) At this point in the road map, no data exists to indicate the possibility of an accidental ignition. Proceed to [3.20.22]

3.20.21 Possibly responsible for the fire

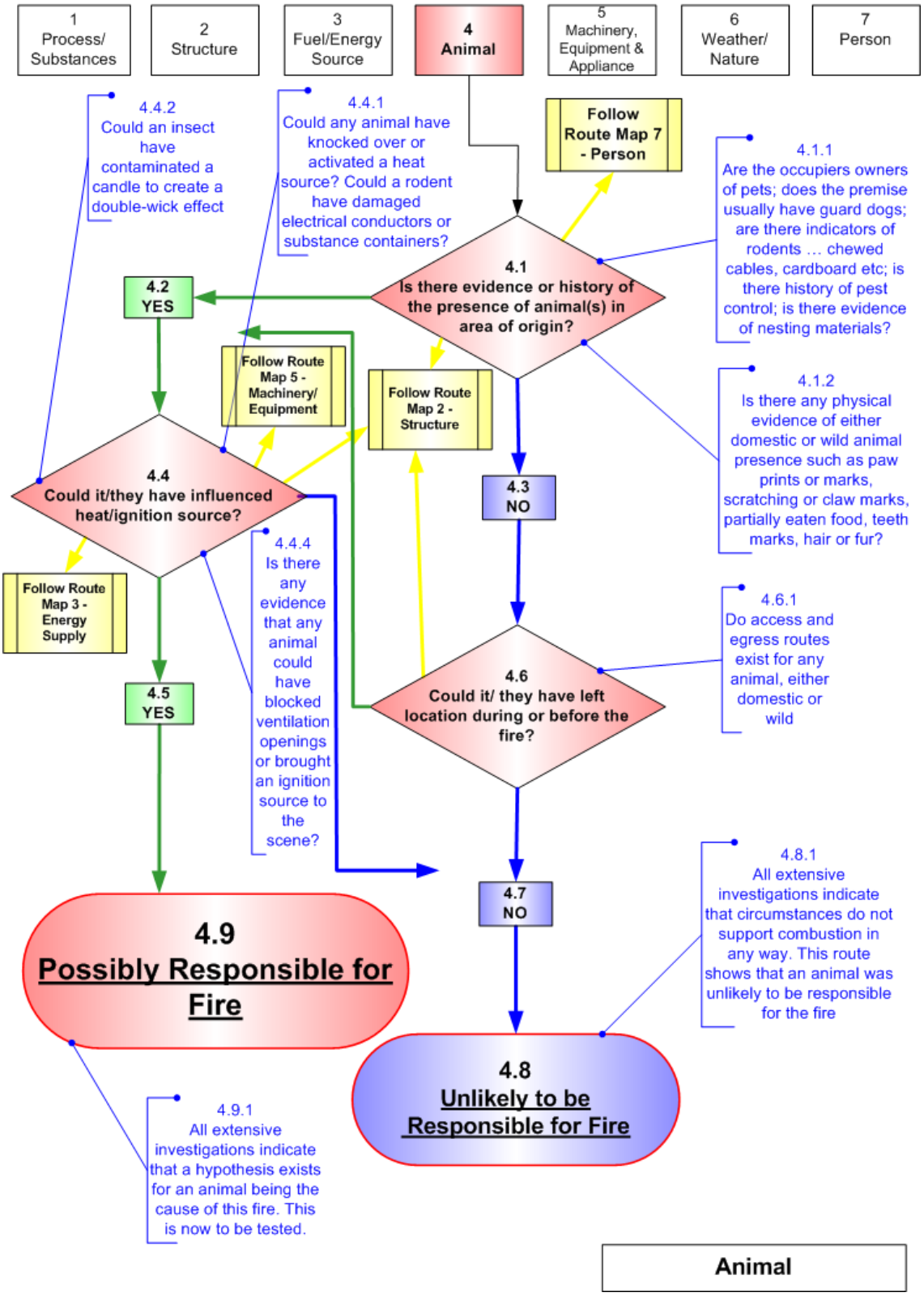
(a) By arriving at this point in the road map a hypothesis has been created that needs to be tested and compared to any other hypotheses that may be developed during the investigation. If more than one hypothesis can be proved as possibly being the cause of the fire, then ‘undetermined’ must be recorded.

3.20.22 Unlikely to be responsible for the fire

(a) All routes have now been explored so as to eliminate this category as a cause of the fire with the data that is available.

FIRE INVESTIGATION ROAD MAP #4

ANIMAL



4 Animal

The ‘Animal’ Fire Investigation Road Map includes any living organism, mammal, bird, insect, fish, reptile etc, characterised by voluntary movement, the possession of specialised sensory organs enabling rapid response to stimuli, and the ingestion of complex organic substance (Hanks, 1989b). Person protective equipment to prevent infection and biohazard issues must be considered when dealing with animals, particularly known vermin.

4.1 Is there any evidence or history of animals within the area of origin?

(a) Animal faeces and/ or urine, chewed food, bedding or nesting materials found within the Area or Room of Origin will indicate the possibility that animals, for example rodents or birds, were able to be within the vicinity of the site. Rats and mice often nest below floor boards and can squeeze through gaps the size of a small pencil, therefore the investigator must explore all the gaps and voids, wherever possible, that are adjacent to the Area of Origin so as to search for any possible animal presence. Squirrels and bats will often build nests within roof voids; these areas should also be carefully inspected if a fire has occurred within the vicinity of the roof.

(b) Nesting material and animal fur can be a very good fuel package when exposed to a range of ignition sources, for example, an arc or a smouldering cigarette. Unless the fire is smouldering, there will almost certainly be nothing left of such material within the area of origin following a fire, however, by finding any nesting material or fur near to, in or on other parts of the structure, the investigator can begin to move onto [4.2] and [4.6]. Such material is also often responsible for blocking ventilation paths (See [4.7.4] below)

(c) Paw prints embedded in the earth or other soft materials or paw marks caused by dirty or wet paws leaving marks on surfaces are an obvious sign that an animal has been present. Investigators must be aware that these marks will soon become blemished or difficult to see if personnel movement is uncontrolled.

(d) Scratch marks, claw marks and teeth marks are also good indicators of animal presence. It is important to differentiate between other mechanical damage and that

of an animal and close inspection of all such markings should be made by the investigator.

(e) Chewed food or the remnants of food stuff could be an indicator of animal presence. The investigator must ascertain whether it was indeed an animal or a person that has introduced the food stuff into the area of origin. (See Fire Investigation Road Map #7 – Person)

(f) The investigator must be aware of any materials that seem unusual or 'out of place'. Different animals use different materials to build nests, collecting and scavenging a range of materials such as old newspapers, tissues, wood pulp, twigs, cotton fabrics, grass and cardboard as examples. All of these materials offer good insulation for the animals' nests and will also readily ignite given the right ignition source.

(g) The investigator must look for evidence in roof spaces and voids that have not been affected by the fire for the removal or damage of materials that can be used for nest building, for instance pipe insulation, storage boxes, etc.

(h) Enquiries should be made as to whether any bricks, vents or apertures have been sealed recently. This could trap rodents within the premises and force them to survive on whatever is available (see 4.1.10)

(j) If no evidence can be found then the owner(s)/ occupier(s) should be asked if there is, or has been, any history of animals within the vicinity, any nesting or any other infestations. If vermin extermination companies have been used, then they should be contacted to ascertain the method of extinction, measures taken to prevent re-infestation and time scales involved. Check with the owner(s)/ occupier(s) as to whether they possess pets, strays or guard dogs, or are aware of wild animals that frequent the area of origin.

(k) Rodents, ants and snakes have been known to cause damage to wiring (Babrauskas, 2003p) by attacking the insulating sleeve exposing the conductors within. Rodents often attack PVC material that is the main material used in electrical cable insulation. Once a foreign body that can sustain a current flow has come into contact with the conductors, including the faeces and anatomy of the animal, the heat that can be generated can lead to degradation of the protective insulation to the point of its ignition and any other fuel package that is close enough to be ignited by it. This type of event is probably the single most significant contribution of fire causation by animals (DeHaan, 2007d).

(m) Both the bodies and faeces of vermin have enough electrical conductivity within them to create an electrical fault should they make contact with the live conductors or electrical components (Babrauskas, 2003p) as long as the body contains moisture.

(n) Finally in this section of the road map, the investigator must consider as to whether any animal was capable of transferring flame from another location into the apparent area of origin due to ignition of its own coat from another external source. It is possible for an animal, such as a cat or dog, to have its coat ignited from one source, and in its desperation to get away from the flames and heat, transfer the fire to multiple points around a structure or within dry vegetation or wild land, giving the appearance of multi-seated fires.

4.2 Yes

(a) Investigations have revealed that animals were present before or during the fire. Proceed to [4.7]

4.3 No

(a) Investigations in [4.1] have revealed that no evidence exists, either physically or by witness testimony, that there was an animal presence possible within the Area of Origin. Proceed to [4.3]

4.4 Could anything identified in [4.1] have influenced a heat source, ignition source or both?

(a) The investigator will need to identify any evidence that demonstrates the possibility of an animal moving or initiating a heat source allowing it to come into contact with combustible material.

(b) It is possible for animals to have an influence on heat or ignition sources by displacing them and allowing them to come together with a fuel package and starting a fire, for example, knocking over a heating appliance.

(c) Animals can interfere with energy carrying conductors or pipe work, which could cause a fuel to escape, an ignition source to be generated, or both. Evidence of damaged conductors or pipe work by animals, either within or away from the area

of origin, would provide the investigator with evidence that an escape of energy supply was possible. (See Fire Investigation Road Map #3 – Energy Supply)

(d) Animals can block supply pipes, obstruct or restrict ventilation paths, and jam or stall machinery due to their own physical presence or that of their bedding or nesting materials. Birds, for example, have been known to nest in extractor fans, with the fans still functioning correctly. If any of the nesting material, or indeed a bird, becomes trapped within the fan blades, the motor can stall and eventually over-heat. (See Fire Investigation Road Map #5 – Machinery, Equipment and Appliances) Birds have also been reported to have carried smouldering ignition source, such as a glowing cigarette, back to their nest which has started a fire, spreading to any adjacent structure. (See Fire Investigation Road Map #2 – Structure). The reason for the latter actions may be due to a process that birds used called 'anting'. Anting is the method believed to be used for removing parasites from the wings and feathers of birds; it is carried out by them spreading their wings on top of ants' nests or over smoke from a burning cigarette in order to remove the unwanted parasites (Drisdelle, 2008).

(e) Examples of animals physically causing an ignition source and fuel source to come together could be demonstrated in the knocking over a candlestick or the pushing against a control valve or switch to an appliance, and are detailed below.

(f) Example one: If a candlestick, which is in the Area of Origin and found to be 'out of position' or laying down instead of upright, it will first need to be established as to whether it had a lit candle in it prior to the fire. If the findings are that it did have a lit candle, it will then be necessary to determine whether it came to be in this position due to fire-fighting activities, falling debris or human action prior to, or after the fire. If it is now determined that a lit candle was in a safe holder and in the correct location and orientation, the investigator must determine whether an animal could have been in the Area of Origin at the time of, or before the fire started. If the findings are positive, then the possibility exists that the animal knocked over the candle stick with a lit candle in it.

(g) Example two: If the fire had centred around a cooking appliance that had not been switched on by the occupier some time before the fire but the occupier had left a fuel source, for example a bag of shopping, on top of the hob area, the same process as in [4.7.3] would be applied.

If it is discovered that the animal was capable of making contact with one of the appliance's control valves or switches thereby rendering the appliance 'live', then the hypothesis would exist that an animal could have initiated a heat source under a fuel package that started the fire.

(h) The PVC insulation around any electrical conductors within the area of origin must be inspected. If the insulation in the Area of Origin has been completely burned away, careful checks should be made along the conductor length until sound insulation can be found. Any evidence of teeth marks caused by rodents should be identifiable. If teeth marks are found then the conductors should be inspected as per Fire Investigation Road Map #3.8 - Electricity to check for any arcing to the circuit. If any doubt exists as to any damage to metal conductors, a metallurgist should be consulted to interpret the identified damage.

(j) Tests have been done that demonstrate that an insect, such as a fly or a moth that falls into the wax of a candle adjacent to the wick can initiate the 'double-wick' effect (Townsend, 2002). This effectively creates a 'wide' based wick, which then ignites the whole surface of the molten wax causing a non-designed fire.

4.5 Yes

(a) Evidence gathered from [4.1] and [4.7] indicate that the route should proceed to [4.9]

4.6 Could anything identified in [4.1] have left the location during the fire?

(a) It may be that there is no evidence whatsoever to indicate the presence of an animal(s) within the Area of Origin due to the destruction of the fire. The investigator must therefore look to other parts of the structure or elsewhere within the vicinity of the fire, as animal faeces and/ or nesting material found elsewhere would indicate the possibility that animals, such as rodents or birds, may have been within the area of origin. If mice or rat faeces are in one part of a structure, or along a travel route used by the rodents, then it is possible that the animals could have been nesting within the area of origin.

(b) The investigator is now able to consider any ignition source that may have been available to start the flaming combustion or smouldering process. Fire Investigation Road Maps #1, #2, #3, #5, #6 and #7 must all be followed to ascertain the potential for an ignition source to have been initiated from these routes.

(c) The investigator must establish whether any access or egress routes existed for any animals before the fire started. This could consist of identifying service ducts, voids between structural elements, cat and/ or dog flaps, broken air-vents, etc.

(d) The investigator must also establish if there were any broken windows, holes in walls, floors or doors leading to outside the premise through which any animal capable of causing the action to start a fire could have escaped?

(e) If the fire was outside a structure in an unconfined space, then all animal interventions must be considered and the investigator must move to [4.6]

4.7 No

(a) There is no evidence to suggest that any animal was present before or during the fire. Proceed to [4.5].

4.8 Unlikely to be responsible for fire

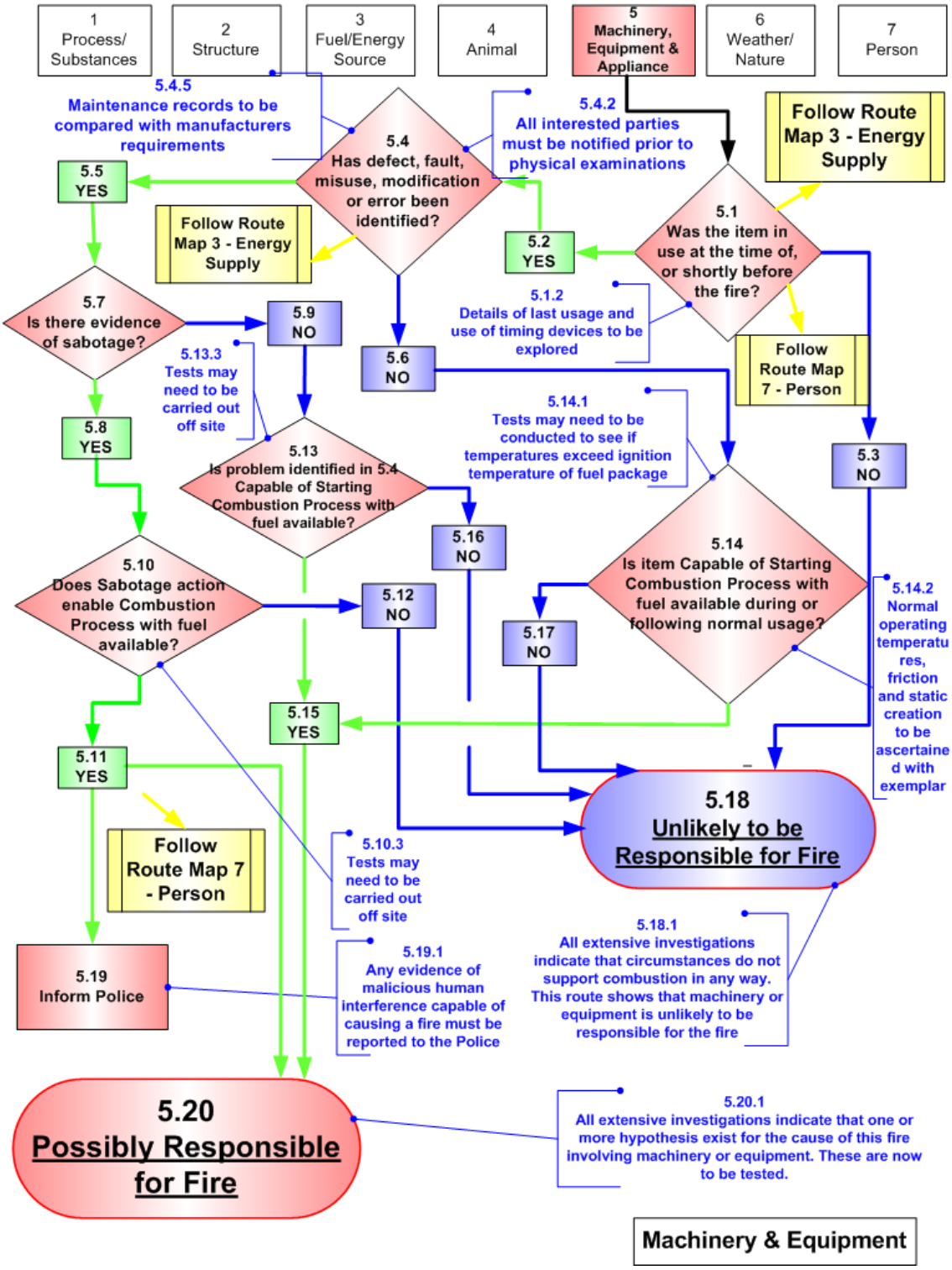
(a) All routes have now been explored so as to eliminate this category as a cause of the fire with the data that is available.

4.9 Possibly responsible for fire

(a) By arriving at this point in the road map a hypothesis has been created that needs to be tested and compared to any other hypotheses that may be developed during the investigation. If more than one hypothesis can be proved as possibly being the cause of the fire, then ‘undetermined’ must be recorded.

FIRE INVESTIGATION ROAD MAP #5

MACHINERY, EQUIPMENT AND APPLIANCES



5. Machinery, Equipment And Appliances

Mechanically or electrically operated devices that either have a specific function, automatically performs tasks, or assists in performing tasks (Hanks, 1989c) for either industrial, commercial or domestic purposes.

It also includes any means of transportation.

If the item is either within the area of origin, or it is recognised that it could have started a fire in the area of origin, even if the item is remote from it, then it must be examined so as to confirm or eliminate it as a cause of the fire. An example of an item appearing to be remote from the area of origin is one where a fire has spread from a defective overhead heater due to burning materials dropping from the heater onto a fuel package below.

5.1 Was the item in use at the time of, or shortly before the fire?

(a) The item should be examined to ascertain whether it was in use either at the time of, or shortly before, the fire. Interviewing of operatives may be required to ascertain time scales of when the item was last used and other information about its operating characteristics. If the item is powered, then the energy supply must be identified and established that it was available for the item to use it. (Also follow Fire Investigation Road Map #3 - Energy Supply)

(b) The time of day that the item was last used or being used should be compared against the normal operating times and also with the time that the fire occurred. If the time frame is considerably long, devices such as time control mechanisms should be looked for.

(c) Operator skills and experience required to use the item must be explored by the investigator. Comparing the manufacturer's operating instructions with an account, if possible, of how the operator was using the item may identify the potential for combustion within or adjacent to the item.

(d) The investigator should ascertain whether common or specific faults existed with the item during normal use; for instance, an electrical circuit breaker that occasionally tripped during normal usage and would simply be reset and the item continued to be used.

5.2 Yes

(a) It has been established that the item was either in use at the time of, or shortly before the fire. If the item normally cools down following use, the 'cool-down' period should be established as should the normal operating temperatures of the item.

5.3 No

(a) It has been established that the item was not in use at the time of, or shortly before the fire. By following this route, the investigator must be sure that the last usage of the item would not have led to the generation of heat so as to cause ignition of an adjacent fuel package.

5.4 Has defect, fault, misuse, modification or error been identified?

(a) A thorough visual inspection must be carried out prior to any subsequent examinations. All observations from such an inspection must be recorded. The investigator should gather information regarding the location and use of surrounding items, such as combustible materials, other machinery, equipment and appliances. Annotations and plan drawings that the investigator will be making of the scene should include the location of all items, even if they appear unrelated.

(b) A thorough physical examination of the item(s) must be conducted, which may involve the use of a laboratory and the possible destruction of the item(s). The investigator that has possession of the item must ensure that all interested parties, including insurance companies and manufacturers, have been informed prior to any examination and invited to participate with the examination. All phases of the examination should be recorded and photographed, including the method used to remove the item from the scene.

(c) All markings, labels and any relevant information attached to, or associated with the appliance must be recorded and also photographed if possible. Any other associated information, such as manufacturers' instructions, maintenance requirements and product suppliers should be obtained whenever possible.

(d) The age of the item, its relevant technology and safety devices should be identified and recorded.

(e) Maintenance records should be sought and compared with the manufacturer's stated maintenance requirements to confirm whether these requirements have been met. If

a maintenance contract exists then the maintenance company should be able to provide a detailed record of all works carried out on the item and when that work was done.

(f) Enquiries should be made as to any previous repairs that may have been carried out to the item and how those repairs were affected. It may be that the owner is not aware of any repairs or may conceal the fact that unauthorised repairs or alterations have been carried out by unqualified personnel.

(g) An exemplar should be obtained whenever possible prior to the examination, so as to compare undamaged components of the item and their locations with the damaged components. This may also confirm whether repairs or alterations have been made to the item or safety devices by-passed or removed. If there are similar undamaged items of the same age within the premise, the condition of that item should be closely examined to detect the condition of its components and signs of deterioration or damage that could lead to the causation of a fire.

(h) Wherever possible, new and old components should be identified as to whether they are manufacturer's recommended or pattern parts and their interaction during normal use should be considered.

(j) Information regarding the use of the item, its configuration, orientation and location to other objects should be sought and recorded. It is important that the investigator uses this information in conjunction with the physical evidence already gathered or to be collected.

(k) Very often, portable heating appliances are placed too close to combustible materials. This is primarily due to the user having little understanding of the effects of radiated heat from the appliance onto surrounding material. The same may happen if materials, such as damp clothing, are placed too close to a fixed heating appliance. As the clothing dries out the ignition temperature of the material can quickly be reached causing the material to ignite.

(m) If the item is powered by a fuel, then the means of transmitting that fuel to the item must be examined. Any conductors, connections, pipe work, valves, generators, transformers, instrumentation gauges, etc. should be inspected to ensure that the correct fuel and quantity of fuel are being delivered to the item(s).

(n) The item should be examined to ascertain whether it was capable of generating heat by either mechanical (friction or sparks) or electrical means (including static

electricity and resistive heating), or capable of supplying a fuel to an ignition source. (Also follow FIRM #3 - Energy Supply).

(p) Friction and impact between two moving surfaces will generate heat. In some circumstances, such as wheel bearings, lubricants are used that are designed to control the heat that is generated from increasing too much thereby preventing the heat from damaging the materials that are causing the friction. Lack of lubrication may cause the surfaces to become so hot that they could be a good ignition source for any adjacent fuel package.

(q) In circumstances when frictional heat becomes extreme, it can lead to disintegration of hot materials spreading them onto the surface of combustible materials as a shower of incandescent particles (DeHaan, 2007c). This can occur with any moving machinery, especially when bearings seize whilst other components are still in motion.

(r) Mechanical sparks are caused when most metals are struck by, or they strike a suitable object, such as an exhaust pipe on the surface of a roadway. The spark itself is a fragment of the metal which is separated from the main material by highly localised frictional contact (DeHaan, 2007c) which is heated beyond its ignition temperature. The particle ignites in the air and burns, sometimes leaving an incandescent flake of carbon and iron oxide as ash. This mechanism is responsible for starting many fires along railway tracks as the sparks from the wheels and brakes fall onto dry vegetation and other combustibles such as newspaper.

5.5 Yes

(a) A defect, fault, misuse or error has been identified within the item. Proceed to [5.7].

5.6 No

(a) No defect, fault, misuse or error has been identified within the item. Proceed to [5.16].

5.7 Is there evidence of sabotage?

(a) The investigator now needs to establish whether there is any evidence of deliberate human interference that has caused the item to become defective, faulty or misused. The history of previous vandalism or damage to the item must also be explored. (Also follow Fire Investigation Road Map #7 – Person).

(b) Any persons with access to the area of origin must be identified and any disputes or concerns regarding these persons must be explored. Previous employment or residence may also be a source of information with regard to any other fires that may have occurred.

5.8 Yes

(a) Evidence exists of deliberate human interference. Proceed to [5.10]

5.9 No

(a) No evidence exists of deliberate human interference. Proceed to [5.13]

5.10 Does sabotage action enable combustion process with fuel available?

(a) It needs to be determined whether the evidence discovered in [5.4] and [5.7] could be capable of starting a fire.

(b) It is imperative that any heat or ignition source identified reaches a temperature that is capable of being higher than the ignition temperature of any fuel source identified AND is in contact with that fuel source long enough to impart the ignition energy into the fuel so as to initiate the combustion process.

(c) If this cannot be determined at the scene, it may be necessary to replicate the situation away from the scene, for instance, in a laboratory.

(d) If the action is capable of starting a fire, then proceed to [5.11].

(e) If it does not, then the owner may wish to inform the police themselves regarding the criminal damage.

5.11 Yes

(a) It is evident or possible that deliberate human interference has presented a condition that could be capable of starting a fire. (Also follow Fire Investigation Road Map #7 – Person to determine whether an individual has potentially been responsible for starting the fire.)

(b) It has now been identified that the problem or defect could generate enough heat or produce an ignition source to start the combustion process with the fuel that was available at the time of the fire. Proceed to [5.19] and [5.20]

5.12 No

(a) It has now been identified that the problem could not generate enough heat or produce an ignition source to start the combustion process with the fuel that was available at the time of the fire. Proceed to [5.18]

5.13 Is the problem or defect identified in [5.4] capable of starting combustion process with fuel available?

(a) It needs to be determined whether the evidence discovered in [5.4] could be capable of starting a fire.

(b) It is imperative that any heat or ignition source identified reaches a temperature that is capable of being higher than the ignition temperature of any fuel source identified AND is in contact with that fuel source long enough to impart the ignition energy into the fuel so as to commence the combustion process.

(c) If this cannot be determined at the scene, it may be necessary to replicate the situation away from the scene, for instance, in a laboratory.

5.14 Is action capable of starting combustion process with fuel available during or following normal usage?

(a) The normal operation of some items produces heat, sparks and static electricity which could all be viable ignition sources, if the appropriate fuel is available.

(b) The investigator may be able to observe and record an exemplar item operating in normal conditions. Operating temperatures at normal ambient temperatures should be recorded. If normal ambient temperatures did not exist at the time of the fire, then the adverse temperatures should be considered as to what effect they would have on the item.

(c) Consideration must be given to convection, conduction and radiation of heat onto a fuel package from any item that could generate heat.

(d) The investigator is now able to consider any ignition source that may have been available to start the combustion or smouldering process. Fire Investigation Road Maps #1, #2, #3, #4, #6 and #7 must all be followed to ascertain the potential for an ignition source to have been initiated from these routes.

5.15 Yes

(a) It has now been suggested that either the problem identified in [5.4] or normal usage could generate enough heat or produce an ignition source to start the combustion process with the fuel that was available at the time of the fire. Proceed to [5.20]

5.16 No

(a) It has now been suggested that the problem identified in [5.4] could not generate enough heat or produce an ignition source to start the combustion process with the fuel that was available at the time of the fire. Proceed to [5.18]

5.17 No

(a) It has now been identified that the problem could not generate enough heat or produce an ignition source to start the combustion process during normal usage with the fuel that was available at the time of the fire. Proceed to [5.18]

5.18 Unlikely to be responsible for fire

(a) All routes have now been explored so as to eliminate this category as a cause of the fire with the data that is available.

5.19 Inform Police

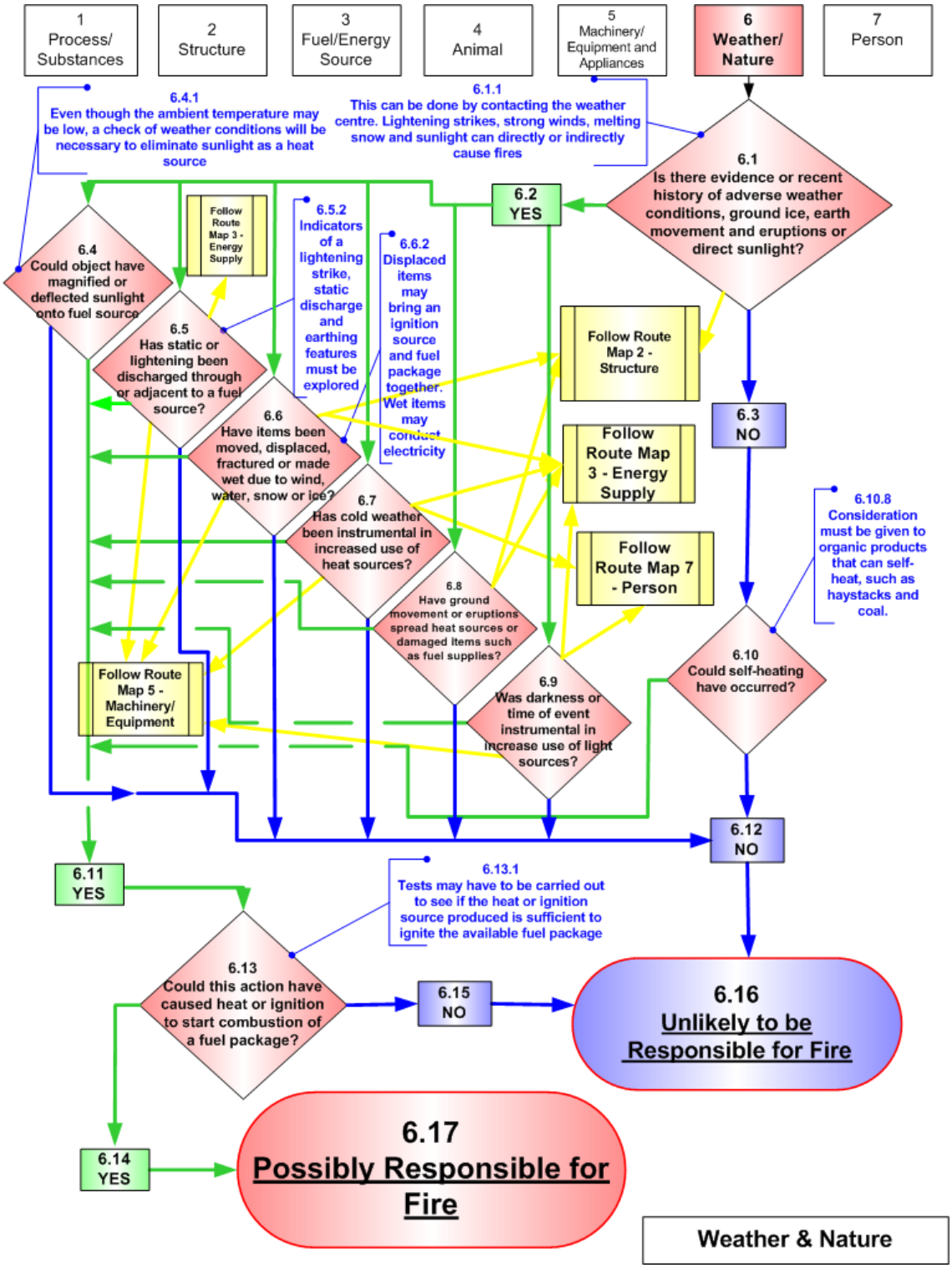
(a) The police must be informed as, although criminal damage may have been committed, the intent may also have been to set an incendiary fire. The Investigator should detail their preliminary findings with regard to the deliberate fire setting.

5.20 Possibly responsible for fire

(a) By arriving at this point in the road map, a hypothesis has been created that needs to be tested and compared to any other hypotheses that may be developed during the investigation. If more than one hypothesis can be proved as possibly being the cause of the fire, then ‘undetermined’ must be recorded.

FIRE INVESTIGATION ROAD MAP #6

WEATHER AND NATURE



6 Weather and Nature

This Fire Investigation Road Map focuses on the weather conditions and any other identifiable acts of nature at the time of, or shortly before the incident to assess if there were any contributory factors resulting with the fire or explosion's initiation.

6.1 Is there evidence or history of adverse weather conditions, earth movement or direct sunlight?

(a) Apart from the investigator's local knowledge, or by asking the owner/ occupier as to the recent weather conditions, the Local or National Weather Centre can be contacted to ascertain the weather conditions at the time of, or shortly before the fire.

(b) In this Road Map, 'Adverse' is defined as 'unfavourable' or 'hostile'; 'Nature' is defined as 'forces and events of all physical life that is not controlled by man' (Hanks, 1989a) but excluding animal life.

(c) Other than an overcast day with no wind, no rain, no lightning strikes and normal ambient temperature, weather effects need to be explored by the investigator.

(d) Lightning strikes and wind strengths are recorded by the local weather station. Although lightning strikes may be an obvious source of direct ignition, strong winds, sunlight, water, snow and ice can damage structures or cause their movement, which can then influence other ignition sources within or around them. Ice is capable of fracturing pipes, depending upon the materials involved. If it can be identified that a structure is involved then proceed to [Fire Investigation Road Map 2 - Structure] to determine the interaction between the weather and the structure and what way the structure has potentially been involved in contributing to the cause of the fire.

(e) Lightning strikes can be identified by the complete vaporisation of metallic items such as lightning conductors, or extensive arc damage to metallic structures and destruction of masonry work. Electrical conductors and co-axial aerial cable may show signs of 'splintering' along their entire length where the metal conductors appear to have ruptured through the outer insulating sleeve.

(f) Ground movements can range from a small landslide to a major earthquake. Eruptions can include natural gas leaks from the ground, (not service pipes) including oxides of sulphur, to volcanoes sending burning fragments over long distances.

6.2 Yes

(a) All enquiries have revealed that there were either adverse weather conditions, earth movement, direct sunlight or more than one of these events. Proceed to [6.4]

6.3 No

(a) Weather conditions at, or shortly before the fire, have been identified as not being adverse. It must be clearly determined that it was not raining, winds were still, there was no lightning activity and it was either overcast or between sunset and sunrise to be able to continue through this route.

(b) All enquiries have also revealed that there is no evidence of earth movement or direct sunlight.

6.4 Could an object have magnified and/or deflected the sunlight onto a fuel source?

(a) The investigator needs to establish whether there was direct sunlight onto, or adjacent to, the area of origin at the time of the fire. A map and a compass may be of use to determine the path of the sun at that time of year and the orientation of any rooms, windows or apertures.

(b) In the Northern Hemisphere, the sun is low in the sky during winter months (November to February) and many fires have been caused during these periods due to the sun's rays being magnified or concentrated, into compartments and onto a fuel package. The same can be said for the Southern Hemisphere during the months of June to September. This does not mean that these fires do not occur outside of these parameters, but it is less likely.

(c) It is important to consider that the ambient weather conditions need not have been hot at, or just before, the time of the fire. Magnified sunlight will increase the heat flux whatever the ambient temperature.

(d) Are there any objects, such as mirrors, glassware or water containers, in a position which would allow sunlight to be magnified and so create a heat source which could then be directed onto a fuel package? The natural rays from direct sunlight would deliver a heat flux of approximately $1kW/m^2$ and would not be hot enough to ignite most common fuels, however when concentrated by reflecting off of a concave reflective surface, or through a transparent object that is round in cross-

section, the heat flux can be increased to between 10 to 20kW/m^2 at the focal point of the light path (DeHaan, 2007f).

(e) A concave mirror's shape is segment of a sphere. Imagine a line passing through the centre of the completed sphere and attaching to the centre of the mirror. This line is known as the **Centre Line**. The centre of the sphere is known as the **Centre of Curvature** and is denoted by the letters **CV** in Diagram 6.1 below. The point on the mirror's surface where the Centre Line meets the mirror is known as the **Vertex** and is denoted by the letter **V**. Midway between the **Vertex** and the **Centre of Curvature** is a point known as the **Focal Point** and is denoted by the letters **FP**. The distance from the **Vertex** to the **Centre of Curvature** is known as the **Radius of Curvature,** represented by **RC.** Finally, the distance from the mirror to the **Focal Point** is known as the **Focal Length and** represented by **FL**. The focal length is therefore half the radius of curvature (Henderson, 2009).

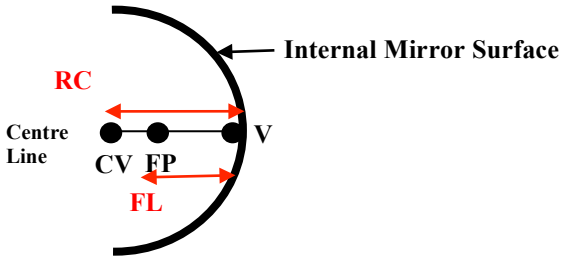


Figure 6.1 Concave Mirror

(e) It may be necessary to carry out tests to replicate the location of any such items to observe the effects of the sun passing through, or reflecting from, the item(s) on a day with similar weather conditions. Again, this can be done by contacting the Local or National Weather Centre to obtain weather records.

6.5 Has static been discharged through, or adjacent to, a fuel source?

(a) Objects that may have caused static electricity or been capable of static electricity discharging to earth through it must be identified by the investigator. Any evidence of the involvement of static electricity should be referred to in Fire Investigation Road Map [3.8]

(b) Television aerial co-axial cable gives clear damage patterns when struck by lightning identified by signs of 'splintering' along their entire length where the metal conductors appear to have ruptured through the outer insulating sleeve, which could also lead to a television fire. Damaged cables must be examined, metal structural components and any other objects that could be prone to being struck by lightning, even if they are remote from the area of origin. Almost any solid object struck by lightning will be ignited due to the heat generated by the flow of current through it. These downward currents can vary dramatically, depending upon whether in the negative or positive stroke, but can be in the region of 11,000 Amperes to 350,000 amperes (Golde, 1977).

6.6 Have items been moved, displaced or made wet due to wind, water, snow or ice?

(a) The investigator must identify any objects that have been displaced by strong winds or by water absorption causing damage to themselves or other items. Inspections should be carried out as to whether water or other contaminants could have entered machinery, equipment or appliances causing abnormal electrical activity. (Follow Fire Investigation Road Map #5 – Machinery/ Equipment)

(b) Some absorbent materials can become unstable when wet due to the centre of gravity changing as the water is absorbed within it, altering its weight distribution. An example of this is a stack of cardboard boxes full of fabrics that become wet on one side. This may be due to rain passing through an aperture, a leaking water pipe [Road Map 2] or defective roof [Road Map 2]. The wetted side can absorb the water and become heavier than the dry side. The boxes then have the potential to fall towards the wetted side and in doing so could knock over a heat source or fall onto a heat source.

(c) Similarly, strong winds could have the same effect. Anything that can become dislodged or displaced will end up in a different position to where it originated. This final resting-place may be on top of a heat source or displacing a heat source from a place of safety to a place capable of causing ignition of a fuel package.

(d) Wind direction and strength must be carefully considered during an investigation with regard to fire spread and the location of the fire's Point of Origin. Wind can spread a fire to larger fuel packages, quickly giving a false indication as to the Point of Origin, which may have been a significantly smaller fuel package. Sparks can

also be carried for a considerable distance from what may be a controlled fire to begin with, starting a second uncontrolled fire far remote from its location.

6.7 Has cold weather been instrumental in an increased use of heat sources?

(a) Lower temperatures are uncomfortable to most people. As the weather gets colder, there is inevitably more use of heating appliances. Many domestic, commercial and industrial premises have modern central heating systems or portable heating appliances. It can often be the misuse of these heating systems that can cause fires. (See Fire Investigation Road Map #5 - Machinery and Equipment, and also Fire Investigation Road Map #7 – Person)

(b) Both the elderly and very young infants are at a higher risk of hypothermia than other categories of people due to their inability to adjust their own body temperatures efficiently. Older people may use open flame fires and sit for many hours in front of these fires and sometimes they will sit too close to the fire. Any combustible clothing or blankets that are too close to the heat source can ignite due to the radiated heat. These vulnerable people often cannot feel the temperature increasing, or they fall asleep.

(c) One international trend in most developed countries due to changing economic and social conditions is population ageing. In New Zealand, for example, there has been an increase of older people (65 year olds and above) from 8% in the 1960s to 12% in 2006. The mortality rates for older people from fires triple for each decade beyond age 75 (NZFSC, 2007). In the USA, the elderly are 2.5 times more likely to die in a fire than the rest of the population (USFA, 2004). In the UK, the 2000 British Crime Survey suggested that older people were less likely to experience a fire than younger people but when they do, the consequences are often more serious (ODPM, 2002). With an ageing population, the investigator should take these increased risks into account during an investigation.

(d) Older people also use electric blankets more than most and are prone to either misusing them, not maintaining the appliances, or both. Under-blankets are designed to work well with the weight of a normal amount of bed linen on top of it and over blankets usually have fewer coverings. Evidence of the use of electric blankets will allow the investigator to exam excessive insulation on top of the appliance, or whether the appliance was actually on at the time of the fire. Folding of electric blankets is a common cause of over heating and if the scene is well

preserved, evidence of elements that are bunched together and on top of each other can indicate that the blanket has been folded at least once.

(e) Blankets and other bedding material can fall onto electric heaters that are placed too close to beds, chairs or cots (cribs) causing flammable fabrics to ignite. It is important to remember that all people at risk from these hazards, but older children and adults are more responsive to increasing temperatures than infants and the elderly. Research in New Zealand has identified that more older people are killed in fires during the winter months than any other age group (NZFSC, 2007)

(f) People traditionally have more hot food in colder weather than in warmer weather. Evidence of cooking appliances will enable the investigator to ascertain that the correct use and location of the appliances were, or were not, in place.

(g) The investigator should establish whether there has been any recent loss in services due to inclement weather, such as:

- a fractured gas pipe due to earth movement during freezing weather, which could leave a large area without normal heating methods. Such a situation may force occupiers to use temporary heating appliances, such as portable electric heaters or paraffin heaters, whose operation they may not be familiar with.
- Loss of electricity where heating appliances may have been switched on at the time of or during the power loss but not switched back off again when it was discovered that they were not working; when the power is subsequently reinstated there is a risk that an appliance may start to operate and cause a fire, such as a heater close to combustibles, or an electric cooking hob with a pan on the heater.
- Frozen water pipes can cause rupture(s) to the pipe work so that when thawed, the water will start flowing again and could come into contact with electric equipment or supplies.

6.8 Have ground movements or eruptions damaged items such as fuel supplies or spread heat sources?

(a) Any sort of ground movement can damage fuel supply pipes and cables that are buried underground. Although most utility companies surround their pipes and cables with a medium that allows for minor ground movement, any substantial

movement can cause the supply pipes or cables to fail, releasing the fuel or energy from within them.

(b) Roads can collapse when the earth beneath the road surface moves, leaving the surface unsupported. This can happen, for example, when burst pipes wash away the earth or when service tunnels collapse. The unsupported surface material can be extremely heavy and may eventually collapse into the newly formed void below, possibly fracturing any services that are left suspended in the void. These services may then release fuel and ignition sources to create a fire or explosive situation.

(c) Trench collapse, tunnel collapse, landslides and earth quakes will all have the same effect on services if any supply pipes or cables within the area are not flexible enough to maintain their integrity. Gas may travel considerable distances from the source of the leak and enter basements and other compartments and create a flammable atmosphere.

(d) Eruptions can be in the form of gas leaks that find an ignition source (See FIRM #3.9: Gas) causing a deflagration that can bring about structural collapse of buildings. It is unlikely that a deflagration will occur below ground level due to the lack of oxygen to bring the gas within its upper and lower explosive limits. Many structural collapses have occurred in this way leading to well developed fires due to the endless fuel supply from the fractured service pipes.

(e) The ultimate eruption is a volcano, which releases massive amounts of molten rock and lava into its surrounding area igniting everything it comes into contact with. The burning particles can travel great distances starting remote fires from the volcanic activity. Earth-quakes and ground movement can follow an eruption of a volcano many hundreds of miles away.

6.9 Was darkness or the time of the event instrumental in an increase use of light sources?

(a) In the Northern and Southern Hemispheres, as the seasons change into the winter months, there is inevitably more use of lighting appliances. Many domestic, commercial and industrial premises have modern lighting systems or portable lighting appliances. It can often be the misuse of these lighting systems that can cause fires. (See Fire Investigation Road Map #5 - Machinery and Equipment, and also Fire Investigation Road Map #7 – Person). Any lighting that is placed too close to a fuel package has the potential to ignite that fuel package.

(b) There is an increasing use of candles for 'social' lighting. Television programmes about home and environment improvements are endorsing the use of candles to create relaxing atmospheres. What is not being promoted as much as it should be is the 'safe' use of candles. There is a marked increase in such fires due to the misuse of candles in the home. (See Fire Investigation Road Map #3.13 – Naked Flames and also Fire Investigation Road Map #7 – Person)

(c) Candles are also used for religious purposes and many 'shrine' fires have been reported due to the candles coming into contact with flammable decorative materials.

(d) Some candles are simply designed badly and fail in various ways. Candles have been known to burn down until they are a molten pool of wax, which can then ignite to become a liquid pool fire. Others may have flammable decorations around the base which ignite as the candle burns down.

(e) The 'tea-light' candle has proven to be a serious problem when used on top of combustible items such as television sets. Although the foil base does get hot, the main problem develops when some form of contamination, such as the end of a spent match, gets onto the wax surface of the small disc-like candle. The whole of the wax surface can then ignite, raising the base temperature of the foil. This is known as the 'double-wick effect'. The temperature of the base can now soften the plastic casing of the surface it is resting upon until it slowly melts through the casing, igniting it as it passes through.

(f) Other candles are so wide at the base that they support themselves and occupiers believe that there is no need for a candle holder to be used. When the candle reaches the base, it can pool and ignite the wax which can flow and spread the fire over its surface.

(g) Halogen lighting has also become more popular in recent times due to its natural light qualities. Halogen lights present other problems apart from the high temperatures that the filament envelope reaches, which is approximately 1123K (850^0C), (See Fire Investigation Road Map #5 - Machinery and Equipment, Fire Investigation Road Map #3.8 – Electricity and also Fire Investigation Road Map #7 – Person). One of the problems is that of resistive heating, which is covered in Fire Investigation Road Map #3.8 – Electricity.

6.10 Could self-heating have occurred?

(a) Self-heating is an exothermic reaction, whereby the material involved is generating heat from within itself without taking any heat from its ambient surroundings, and dissipating less heat into those surroundings than it is generating. Self-heating can lead to thermal runaway and self-ignition of a material.

(b) It can occur in any of the states of matter; gas, liquid or solid (Babrauskas, 2003o).

(c) Consideration must be given to types of organic products that can self-heat such as linseed oil, fish oil, Soya bean oil, coal (in large quantities), activated charcoal and haystacks. Their size, shape and surroundings all have to be considered as to the possibility of self-heating and the materials must be porous, permeable (allow oxygen in) and oxidizable.

(d) A substance that can self-heat and is wrapped or covered in any form of thermal insulation will have its rate of self-heating intensified due to the cooling effect at the substance's external surfaces becoming minimised. Evidence of additional insulation must be considered during the investigation.

(e) Cotton fabrics that have been impregnated with vegetable (organic) oils, washed and then heat dried can self-heat to combustion within a few hours. Some of these oils are not very soluble in water and therefore can be retained within the fabric following the washing process. If a fire has occurred within a tumble drier or due to other methods of heat drying, the water within the pump of the washing machine that was used may be analysed to detect residues of the oil (Mann and Fritz, 1999).

(f) If organic oil is unsaturated, the unsaturated part will be seen as a carbon-carbon double bond, showing that it is capable of self-heating. Samples should therefore be retrieved whenever possible and tested at a laboratory to see if it contains the correct constituents to be capable of self-heating by using suitable equipment, such as infra-red spectra. This will identify the peak range characteristic regions showing whether a carbon-carbon double bond exists or not. If there are no peaks within the range then there are no unsaturated double bonds and the oil is not capable of self-heating.

(g) Saturated hydrocarbons such as mineral oils have a single carbon-carbon bond, are much less reactive than unsaturated hydrocarbons and do not self-heat under normal ambient conditions. They can be capable of self-heating, leading to ignition when the temperature is significantly increased or stored in very large piles (NFPA, 2008e).

(h) If large quantities of organic material, such as a coal pile or haystack have been involved in a fire, it may be necessary to use a probe thermometer to test the internal temperature of identical adjacent materials or fuel packages, if they are available. If not, then investigate the methods used for monitoring the temperatures of such materials by the owner/ occupier. Biological activity can generate enough heat to start a thermal runaway within the stacks. This can also occur in compost heaps and rubbish heaps.

(j) Ground or shredded plastics that are used for re-cycling have been known to cause fires and this can be for several reasons. The grinding or shredding process itself can generate heat within the plastics due to friction. If other contaminants are within the plastics, such as vegetable oil from plastic bottles, or pieces of metal then they can also be heated during the grinding or shredding, which can promote the self-heating process (DeHaan, 2007e). As ground and shredded plastics are normally stored in bulk quantities, heat dissipation is restricted.

(k) Some inorganic materials, for example metal powders, may undergo rapid oxidation leading to self-heating and self-ignition under isolated conditions.

(m) Oxidising agents are chemical substances that may not be combustible by themselves but can rapidly increase the rate of burning within other substances (NFPA, 2008c) or result in spontaneous combustion when combined with other substances. An example is chlorine contaminated with certain organic materials. Weather conditions are not always a factor here as heat loss is considerably slower than heat gain.

(n) Pyrophoric materials are those which spontaneously combust when exposed to air. Some examples are white phosphorus, sodium and potassium (NFPA, 2008d). See [Road Map 1]

(p) It is extremely rare for spontaneous ignition to develop into a free burning fire very quickly. Paragraphs 6.7.8, 6.7.9 and 6.7.10 are examples of when it can. It is normally a slow process, which is preceded by smoke and odours that should be detectable by anyone, or any automatic detection equipment within the area, before it becomes a flaming fire.

6.11 Yes

(a) It has been established that a situation existed whereby a heat or ignition source could be initiated due to weather conditions, acts of nature or self-heating of materials. Proceed to [6.13]

6.12 No

(a) It has been established that no situation existed whereby neither heat nor ignition source could be initiated due to weather conditions nor was there any potential for self-heating of materials. Proceed to [6.16]

6.13 Could this action have caused heat or ignition to start combustion of fuel package?

(a) It is imperative that any heat or ignition source reaches a temperature that is capable of being higher than the ignition temperature of the fuel source AND is in contact with the fuel source long enough to impart the ignition energy into the fuel so as to commence the combustion process.

(b) If this cannot be determined at the scene, it may be necessary to replicate the situation away from the scene, for instance, in a laboratory.

(c) The investigator is now able to consider any ignition source that may have been available to start the combustion or smouldering process. FIRM #1, #2, #3, #4, #5 and #7 must all be followed to ascertain the potential for an ignition source to have been initiated from these routes.

6.14 Yes

(a) There is evidence that conditions existed for one of the criteria in [6.13] to have occurred. Proceed to [6.17]

6.15 No

(a) There is no evidence that conditions existed for one of the criteria in [6.13] to have occurred. Proceed to [6.16]

6.16 Unlikely to be responsible for fire

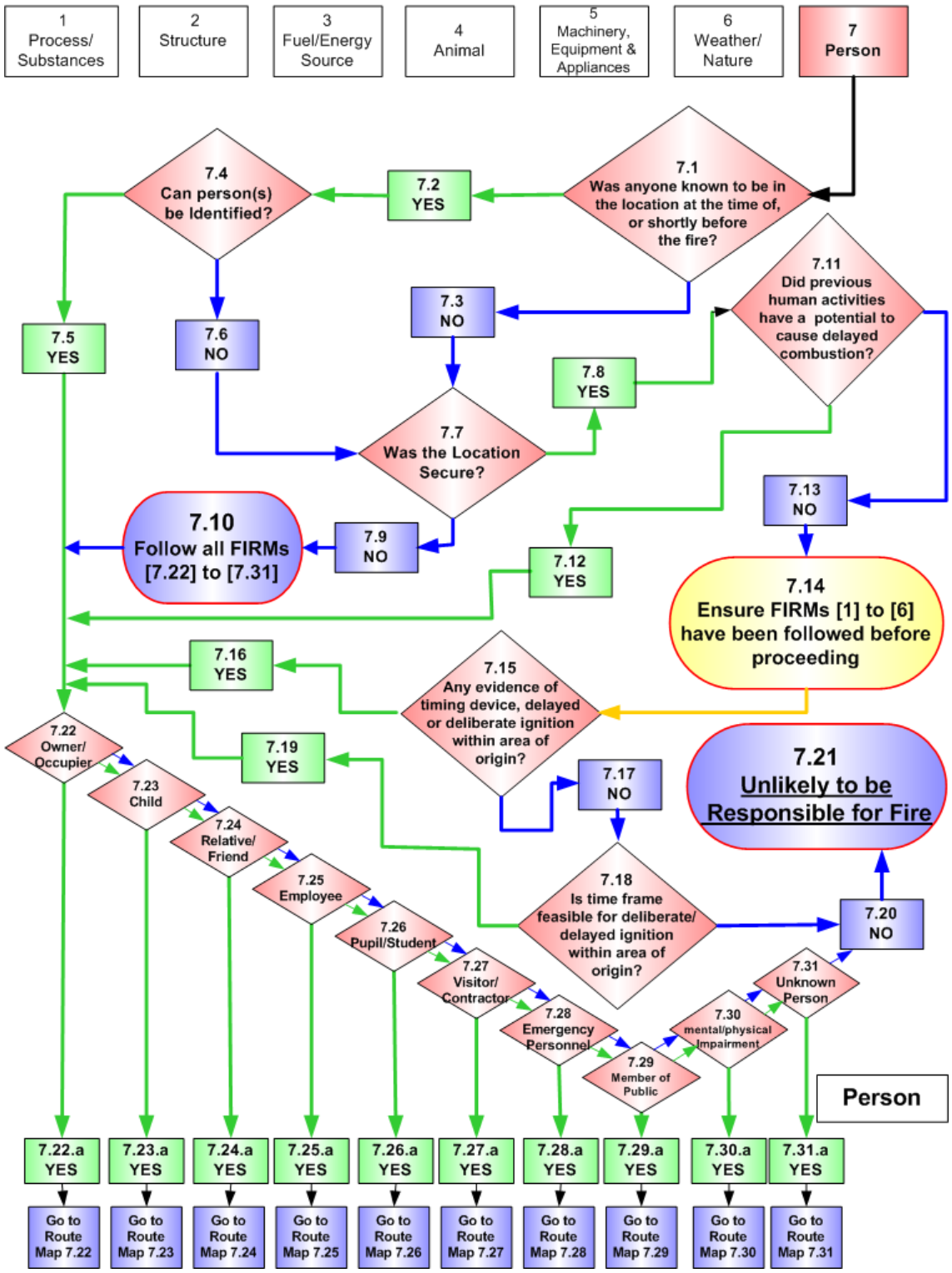
(a) All routes have now been explored so as to eliminate this category as a cause of the fire with the data that is available.

6.17 Possibly responsible for fire

(a) By arriving at this point in the road map, a hypothesis has been created that needs to be tested and compared to any other hypotheses that may be developed during the investigation. If more than one hypothesis can be proved as possibly being the cause of the fire, then ‘undetermined’ must be recorded.

FIRE INVESTIGATION ROAD MAP #7

THE PERSON (HUMAN AGENCY INVOLVEMENT)



7 The Person

The investigator needs to establish if any 'human agency involvement' existed. 'The Person' is defined as any human being actually involved with or with a potential to have been involved with the pre-fire scene. The investigator must not only establish if any person(s) had access to the area of origin at the time of, or shortly before the fire, but identify any persons that may have contributed to the initiation of the fire by accident or design. This will involve the usual cross-referencing of FIRMs to consider other influences; for example, FIRM #5 – Machinery, Equipment and Appliances, where the maintenance regime will need to be examined in accordance with FIRM #7.27 to ensure correct maintenance has been carried out to any identified items. A more specific example of this may be the cleaning (or lack of it) of cooking extractor hoods and associated ducting (Carey, 2002). Previous history of the person's involvement with fire must be considered in all of the sub-FIRMs for the 'Person'.

As discussed in Chapter Six [6.1], a fire or explosion may involve one or more persons in various roles, but depending upon the circumstances, the nature of the incident and the 'status' that the person(s) had at the time and location of the incident, the person(s), irrespective of those roles, may have:

(i) caused the fire by accident or design
(ii) become a victim of fire, suffering injury or death
(iii) been the rescuer and/or fire fighter
(iv) acted as a witness or observer
(v) undertaking the subsequent investigation.

The investigator first needs to identify whether any person was at, or involved with the scene at the time of, or shortly before the incident. In Chapter Six [6.2] ten specific 'roles' that the person could fulfil has been outlined and can be used within these FIRMs. If the person involved has received fatal injuries, the information that would have been requested from them must be sought from one or more of the following: a relative, friend, carer, neighbour and/or any other person that could give information about their last movements and life style.

The involvement of any person(s) must be positively excluded from having any influence with the scene if the application of this FIRM is not to be followed.

7.1 Was anyone known to have been in the location at the time of, or shortly before the fire?

(a) Apart from asking any relevant persons whether they were or are aware of any persons being within the area of fire origin or having access to it, the examination of any available CCTV and access/egress equipment, such as logged swipe card systems should be carefully examined.

(b) The investigator should take the opportunity if possible, to ask any first responders, such as the police, fire service, etc. if they saw or were aware of any persons being within the area of origin when they arrived.

(c) It should be established very early on as to how the fire department were notified of the fire. The first caller telephone number will allow the investigator to contact that caller to establish how they became aware of the fire and what they were doing at that time.

7.2 Yes

(a) A person has been identified as being within the area of origin at the time of or at a reasonable time before the fire. A 'reasonable time' will be relevant to all available data associated with the scene and at the discretion of the fire investigator.

7.3 No

(a) No person can be identified as being within the area of origin at the time of the fire, or some reasonable time before the fire. There is also no physical evidence to suggest human agency involvement.

7.4 Can person's(s') role be identified?

(a) If a person has been identified, the investigator needs to ascertain if that identified person can be defined as to their 'role' at the scene at the time of, or at a reasonable time before the fire.

(b) It is important that the '*role'* of the person is clearly defined. An example is a fire officer attending a university to complete a research degree; the fire officer is not at the university as a fire officer, but as a student of the university. Therefore the role

of the identified person, if it were an off duty fire officer, would be a 'pupil or student'. The investigator must always consider the specialist or technical knowledge of that person within their other roles in society. People's behaviour in fire depends upon the roles that they perceive to be relevant to their responsibilities at the time of the fire (BRE, 1993).

(c) Another example would be if a lecturer's son, who was a student at another educational establishment, was seen at the university for the purpose of visiting his father, the role of that individual would be as a 'relative or friend'.

(d) It is not to say that the knowledge of the individual will not be considered when investigating the human agency involvement (such as the knowledge of an off-duty fire officer regarding fire-setting) but the role of the person is the *primary* focus when screening for such human agency involvement.

(e) The one exception to the primary role only being considered, is if the person can be identified as having any mental or physical impairment. If this is the case, then both FIRMs should be followed; that is the role of the person and FIRM #7.25.

7.5 Yes

(a) If the role of the person can be identified then follow FIRMs #7.22 to #30.

7.6 No

(a) If a person has been identified as being within or near the area of origin but their role is not known, then follow FIRM #31.

7.7 Was the location secure?

(a) A physical examination of the scene must be conducted to ascertain whether the area of origin was secure at the time of, or shortly before the fire began.

(b) Again, the accuracy of witness testimony would need to be corroborated if possible, however the use of CCTV and other monitoring systems can be very effective in identifying human agency movement. The investigator must remember to verify all timing devices fitted within the monitoring equipment by comparing the equipments' displayed times to the 'talking clock' or some other recognised accurate datum time.

(c) Key holders to secured premises should be identified and questioned as to their location at the time of or reasonably shortly before the fire.

(d) Consideration must be given to the use of timing devices to initiate a fire if there is no evidence of forced entry to the premises.

7.8 Yes

(a) All enquiries and examinations have confirmed that the premises was secure at the time of the fire. Proceed to [7.11]

7.9 No

(a) All enquiries and examinations have confirmed that the premises was not secure at the time of the fire.

(b) As it would then be possible for someone to have entered the area of origin, the investigator must now go to [7.10].

7.10 Follow all FIRMs #7.22 To #7.31

(a) All the 'Person' sub-FIRMs should now be considered to eliminate or confirm the potential for any individual(s) to have been within or near to the area of origin at the time of or at some reasonable time before the fire.

7.11 Did previous human activities have a potential to cause delayed combustion?

(a) It has been identified that no persons had access to or near the area of origin at the time of or at some reasonable time before the fire. The investigator must now consider the last time anyone was in the area of origin and who that person was.

(b) The investigator must consider any human activities which had the potential to cause delayed combustion. An example of this may be where a waiter or waitress is clearing the establishment at the end of an evening, emptying all the bins and ash trays into a rubbish bag. The rubbish bag may have then been left within the premises with a smouldering cigarette within it and following a considerable time delay, possibly a couple of hours, the smouldering transitions to a free-flaming fire.

Another example is if a person empties a tumble drier that contained towels that had previously been washed having had oils soaked into them, and places the now hot towels into a pile (CCTV Footage, 2008). It would be possible for self-heating

of the towels to occur, leading to thermal runaway and ignition of the towels some considerable time after the person had left the premises.

7.12 Yes

(a) Previous human activities have been identified that may have lead to a delayed ignition. Follow FIRMs # 7.22 to 7.31.

7.13 No

(a) No previous human activities have been identified that may have lead to a delayed ignition. Go to [7.14]

7.14 Ensure FIRMs #1 to #6 have been followed before proceeding

(a) As there is no evidence of human agency involvement, forced entry or previous human activity, the investigator must ensure that FIRMs #1 to #6 have been considered before proceeding.

7.15 Any evidence of timing device, delayed or deliberate ignition within area of origin?

(a) The investigator should consider any evidence found within the area of origin that could resemble a timing device or the remains of such a device, which would be capable of a delayed ignition.

7.16 Yes

(a) A device or materials have been located within the area of origin. The investigator must now proceed to FIRMs #7.22 to #7.31 to ascertain who positioned it within the area of origin.

7.17 No

(a) The investigator has found no physical evidence of any device or materials that could have been an incendiary device within the area of origin. Proceed to [7.18].

7.18 Is the time frame feasible for a deliberate or delayed ignition within the area of origin?

(a) Although no device or materials have been physically found within the area of origin, the investigator must consider all possibilities of human agency involvement with regard to the time frame, materials ignited and the potential for any delayed ignition.

(b) During most investigations, some form of human agency involvement will have contributed to the causation of a fire; lack of maintenance (FIRM #5), misuse or inappropriate storage of chemicals or substances (FIRM #1), etc.

(c) The investigator should consider that arsonists normally start their 'career' by setting small fires, escalating to more serious and destructive fires. Their fires, like other criminal activity, may start close to the perpetrator's residence, spiralling outwards over time and severity of fire (Canter, 2003). To this end, data regarding all fires within a defined area and time scale (which can extend or reduce) around the fire being investigated should be obtained and analysed to see if there is a pattern or trend relating to:

- Types of fire
- Type of building
- Modus Operandi
- Times
- Dates
- Travel patterns

If a pattern can be recognised, it may be possible to start to identify potential fire setters by focussing on where they live, work or socialise (Allen, 2007).

(d) An example that may be used when considering that no human agency involvement was possible, would be when a fire has occurred and this FIRM #7 has been followed through to this section [7.18(d)] and the use of other FIRMs have identified a possible cause of the fire.

7.19 Yes

(d) A time frame feasible for a deliberate or delayed ignition within the area of origin has been established. Follow FIRMs #7.22 to #7.31.

7.20 No

(a) A time frame feasible for a deliberate or delayed ignition within the area of origin has not been established. Go to [7.21].

7.21 Unlikely to be responsible for fire

(a) All routes have now been explored so as to eliminate this category as a cause of the fire with the data that is available.

GENERIC DECISION AND PROCESS POINTS FOR FIRMS RELATING TO THE PERSON

The following Fire Investigation Road Map references relate to decision and process points within all the 'Person' road maps that are generic in nature. When gathering data about a person within their role at or near a fire scene, a very similar process will be followed during each investigation, however the generic decision points may vary in the order in which they are processed and the investigator will apply each decision point with relevance to the person in question. Although the alphabetical order of the decision references may not appear to be sequential within some of the road maps, the investigator will note that the individual roles will require individual decisions that will be unique to that role and they are referenced accordingly.

With all the FIRMs relating to human agency involvement, the individual qualities of the person must be explored by the investigator wherever possible, irrespective of the FIRM being followed. This, of course, does not mean the investigator has to conduct a complete and in-depth character, skills, abilities, knowledge or training analysis of all persons involved, but should consider asking questions that may relate to the incident.

A simple example of the latter is if an owner/occupier has a fire in his or her garage due to what may appear to have been amateur welding activities. By asking the owner/occupier if they have had any formal training in welding, they may reveal that they used to be a professional welder but would have been embarrassed to have offered that information freely, in light of the subsequent accidental, albeit careless or reckless fire. In contrast, during an investigation into the cause of an explosion and fire in London, the owner/occupier was asked about a propane cylinder found within the area of origin and had admitted to never having received training or instruction on how to change the cylinder for an associated space heater; due to the incorrect fitting and testing of the gas valve, a leak occurred which caused the explosion and fire.

By exploring the individual attributes and limitations of the person(s) will greatly assist in the investigation of the origin, cause and development of any fire or explosion.

7A Does the person know how the fire started?

(i) The first thing an investigator should ask the person is: 'do you know how the fire started?' followed by 'What alerted you to the fire?'. Even if the witness testimony from this person does not bear any resemblance to the physical evidence, it is important that the information is recorded as to what the person is saying and why they believe what they are saying is accurate. The individual's sensory facilities should be considered when evaluating their answers; for example, an elderly person or someone with hearing impairment may not have good hearing and may not have heard glass breaking or the smoke detector sounding.

(ii) People may say things that are not accurate or may appear to be complete untruths, however it is important that the investigator maintains an open mind and considers that the person may be in shock or extremely upset and their version of how the fire may have started is only their perception, however inaccurate it may be.

(iii) Some people may be extremely frugal with information; this may not necessarily be a sign of their guilt of deliberately setting a fire, but may indicate that they are embarrassed at being the accidental cause of a fire, or believe that they may be in breach of policy and not be insured if they admit to accidentally causing a fire (such is the situation with most vehicle accidents; an admission of guilt could invalidate the policy).

(iv) If the investigator is dealing with a child, subject to the situation and organisational protocols, it may be necessary to obtain permission from the guardian of the child, the police or the social service before the child can be questioned.

(v) If a child can or cannot be questioned, the investigator needs to establish whether the child knows how the fire started and what alerted them to the fire. This may be done by the investigator asking in a manner appropriate to the age of the child, or by the carer, police, social worker or other responsible adult.

(vi) Consider allowing the person(s) to use an anonymous method of naming anyone they believe may be involved in the causation of the fire. Some people, whatever their age, do not want to tell tales, or 'grass' on others, even if they are not their personal friends.

(vii) Whatever information is given to the investigator by the person, it must be treated as witness testimony, recorded in the correct manner (in accordance with the

investigator's training, organisational policies and legal framework) as it may be of important evidential value to the investigation.

(viii) The investigator must consider that any relationships between the person that the investigator is interviewing and the subject(s) of the fire may cause that person to feel a need, possibly an unwarranted need, to protect those subjects and may be extremely frugal or diversionary with information. The investigator must also determine whether the person has been instrumental in starting the fire and not just being a third party witness to one of the other human agency FIRMs.

(ix) A person may not give accurate information for many reasons; one of the most common is personal culpability. If someone can be identified as having any part what-so-ever in the causation of a fire that may result in not only physical damage and personal injury or death, but also loss of continuity of business, he or she may be reluctant to provide data that may get either themselves or others into trouble.

(x) It would be prudent and ethical for the investigator to seek all appropriate permissions if required, before approaching any person for information.

(xi) The investigator should carefully consider, as always, the types of questions and method of interviewing prior to carrying out the task; however, where there are multiple individuals to interview, it is advantageous to the investigator to have a generic list of questions to ask every person for several reasons:

(a) No one can claim they have been targeted as culpable as all will have been interviewed in the same manner.

(b) Any discrepancies in data will be more easily identified.

(c) Cross-referencing and verification of information will be easier.

The targeting of individuals for supplementary questioning will be easier and more effective if initial interviews are carried out as above.

(xii) The investigator must remember that an individual's perception of time may vary greatly following a traumatic event; this does not mean to say that the person is being untruthful although their integrity will not be known by the investigator. It would be prudent to verify timings with 'hard time' recordings, such as mobile phone statements, CCTV recordings, etc.

(xiii) If the person has been using any type of equipment or machinery, they may be able to give a full account of the situation or the equipment involved at the time of or shortly before the fire. Establish what the person was doing before the fire

became apparent and again, what made them aware of the fire. Consider their actions and movements around or close to the premises/location of the fire.

(xiv) Any persons carrying out hot works, such as welding, cutting metal with angle grinders, plumbing and asphalting are all high risks with regard to starting fires. Contractors should have provided method statements and extinguishing media prior to works commencing. The investigator should ask to see all contractors' method statements, which will include the appropriate type and quantity of stand-by extinguishing media and make a physical check to see if that media was in place at the time of the fire. Metal case extinguishers, such as water and CO_2 survive some of the most severe fires.

(xv) All persons should be asked if they are smokers and evidence should be sought to see if smoking was occurring at, or close to the fire scene.

(xvi) Always ask what the person's opinion may be as to how the fire may have started, and why they have formulated that opinion.

7B Yes

(i) The person has stated that they know how the fire started. It is important that the investigator documents the information that the person is giving them accurately and the time and date it was recorded.

7C No

(i) The person has stated that they do not know how the fire has started. It is also important that the investigator documents the denial that the person is giving them accurately and the time and date it was recorded as it may be referred to if the investigation becomes a criminal investigation. By accepting this denial, the investigator must have established, as much as is possible, the truthfulness of this information. Cross-referencing data with other persons and with other data may add weight to this denial.

(ii) A denial does not mean that they do not know about the fire or did not start it, however, by following all the FIRMs, additional data should be able to highlight any anomalies with their account(s).

7D Has the person admitted to starting the fire?

(i) Any person that starts a fire could have done so through one of two actions:

- Accidentally
- Deliberately

It may not be the investigator's role to determine the motive for deliberately starting a fire, but all information regarding the initiation of a deliberately set fire must be very well documented for others that may need to determine motivation.

(ii) The question that needs to be asked to the person if they say they know how the fire started, appear vague with their account of how it started but have not admitted to it is: 'Did you start the fire?' If they are asked this question early in the investigation, they may admit to starting the fire, albeit starting it accidentally. Another directly relevant question is: 'were you or was anyone else smoking in or near to the area of origin shortly before the fire started (within a few hours)'. Presented either with sufficient evidence or such a direct line of questioning, the person will have to admit or deny that they were responsible for the fire. The author has been informed that following some arsonists' convictions, although having been previously questioned about the fire(s), they have reported that they had never actually been asked the obvious question as to whether they were responsible for the fire(s); therefore they had not been lying about the fire when being questioned!

(iii) It is possible that they started the fire accidentally; however, if foul play is suspected by the investigator, the person may still admit to having started the fire. They could believe that the investigator has evidence to demonstrate that they did and it would be foolish to start lying about the cause.

(iv) If the person started the fire accidentally, the investigator must remember that no-one would want to be responsible for accidentally starting a fire and may not voluntarily admit to it. If, however, all the scene evidence and other data so far reflect that they were very unlikely to be the cause of the fire, it may be unnecessary and insensitive to ask if they were responsible.

(v) Whatever their response is, their account must always be completely documented. If they admit to setting the fire deliberately, and the investigator is not a law enforcement officer, the investigation may have to stop until the police arrive at the scene.

7E Yes

(i) The person has admitted to starting the fire. This may be due to an accidental or deliberate ignition. It may also be due to a deliberate ignition that subsequently

becomes uncontrolled by the person; for instance a small bonfire spreading to a shed or other structure.

(ii) If the person states that they started the fire accidentally, it is imperative that the investigator documents exactly how the person describes the fire's initiation process and corroborate their account to all other data, especially from the scene. An example of this occurred when the author was conducting a cold case review of a fire in the late 1990's and discovered that the fire was recorded as 'accidental' as the owner had admitted to leaving a cooking pan on the stove (Restricted, 1997). The kitchen was upstairs with the bedrooms on a lower level. When the photos were retrieved from the archives, it was apparent by the fire patterns and recent knowledge of the building construction that the fire had started downstairs and not upstairs, as described by the owner.

(iii) If, however, the person states that they started the fire deliberately and the resultant fire damage appears to be clearly non-accidental, then the investigator, if not a law enforcement officer, should consider stopping the investigation and informing the police and/or social services, in accordance with current legislation or their organisation's protocols.

7F No

(i) The person has denied setting the fire. At this stage in this FIRM, consideration must be given to the knowledge that the person has about the incident, as they have alleged that they did not start the fire but claim to know how the fire started. Their knowledge of the circumstances must reflect the circumstances reasonably associated with the scene. A simple example would be a teenage male sibling saying: 'I didn't start the fire but I know it was started by my (teenage) sister playing with a disposable lighter whilst lighting candles in the bathroom whilst she was in the bath'. The investigator would need to establish how the teenager knew his sister was 'playing' with a lighter in the bathroom, when it would be considered unlikely he was in the bathroom whilst his sister was bathing.

(ii) It may also be that the person is claiming to know how and where the fire started but the physical evidence does not reflect the area of origin, ignition source or first fuel package to be ignited (See 7(u)).

(iii) The person has denied starting the fire; as with 7(f)(i) above, if they appear to have extensive knowledge about how the fire started, the investigator should evaluate this information carefully to assess the truthfulness of their account(s).

7G Was the person there legitimately?

(i) Although the person may appear to have every right to be at, or associated with the premises where the fire occurred, the investigator needs to ascertain whether there are any restrictions that would prevent the person being there, or in any restricted area of the premises at the time of, or shortly before the fire.

(ii) An example of this is when the person is the manager or key holder of a shop. If that person was at the premises outside of normal working hours, the investigator needs to discover why the person was there; that may, for example, involve contacting the owner or head office of the company. It needs to be established through the employer or line manager whether the employee was legitimately working at the location of the fire and with permission.

(iii) Another example is where a local arrangement has been made between the owner(s) of a garage and one of their employee mechanics, allowing the mechanic to carry out personal work at the premises, out of hours, providing he covers his own public liability insurance for his private work not associated with the garage owner(s). If a fire occurs out of hours whilst the mechanic is at the premises carrying out private work, at the time of or shortly before the fire, then it can be concluded that he was there legitimately. If no formal arrangements had been made between the mechanic and the owner(s) it can be concluded that he was there illegitimately, although the fire may still have been accidental in cause.

(iv) Another would be a vehicle seen and identified on CCTV in the early hours within a reasonable vicinity of a fire, with the driver explaining that he or she was returning from a late shift at work, which can easily be verified. If, however, they say they were restless, could not sleep and just went for a drive, it may arouse suspicions if they were seen circling the area three or four times in their vehicle and/or they actually live some considerable distance from where the fire started.

(v) A final example is if a child was within a school premises during a school break and was lawfully there due to the school running holiday activities. However, another child that had not registered for holiday activities would not be allowed to be within the school premises during those times. This may be achieved by

confirming with the establishment's secretary the status of the pupil/student; for example the pupil/student may be suspended or recorded as being off sick at the time of, or shortly before the fire.

(vi) It should also be considered that in some domestic disputes, one or more players in the dispute may have been prohibited from being in or near the property, even though that person(s) still has keys and full access. The investigator will need to ask questions to clarify the person's right to be there and ensure all communications are recorded correctly. If practicable, try to seek information from the subject of the fire or other colleagues, relatives, friends, neighbours, etc. that can clarify the legitimacy of the person in question being at the location at the time of, or shortly before the fire. The investigator should make every effort to establish and substantiate the reason for the person being in the area of origin at or shortly before the time of the fire.

7H Yes

(i) The investigator has confirmed by various means that the person was allowed to be in, or close to the area of origin at the time of, or shortly before the fire and was there for legitimate reasons.

7i No

(i) The investigator has confirmed by various means that the person was not allowed to be in or close to the area of origin at the time of or shortly before the fire and was there without permission. The investigator must consider informing the police immediately, if the police are not in attendance.

7J Is the person aware of anyone else having been in the area of origin?

(i) The person must be asked about anyone else that they are aware of having been in or near the area of origin, or even within the premises at the time of, or shortly before the fire. The role of any persons identified needs to be established and recorded.

(ii) It is important to encourage the person to consider all other people that they may have seen or been aware of being in, or close to the area of origin, such as delivery personnel, maintenance personnel, visitors, etc. and not just friends, colleagues or family that are there regularly.

(iii) The investigator should make every effort to obtain information from the person about third party presence by allowing them to 'tell their story'; whether it is about their journey home from work or an account of what they saw concerning the fire development, etc. as they could remember information, which to them may seem irrelevant, but to the investigator may be crucial.

7K Yes

(i) The person is aware of someone else being in or near to the area of origin at the time of or shortly before the fire.

7L No

(i) The person is not aware of anyone else being in or near to the area of origin at the time of or shortly before the fire.

7M Is the person aware of anyone else having had access to the area of origin?

(i) The person must be asked about the structure of the family, group or organisation with the person and anyone else that may have had access to the area of origin. This would include any key holders, such as contractors, staff, family, friends and even security staff agencies or other organisations.

(ii) An example of this may be the sibling of an elderly person who knows that a home helper or home help organisation has keys and full access to the premises.

7N Yes

(i) The person is aware of another person(s) that has access to, or near to the area of origin.

7o No

(i) The person is not aware of any other person(s) that has access to, or near to the area of origin.

7P Can a third person be identified?

(i) In 7N, the person has stated that someone else, other than themselves, had access to the area of origin. The investigator must now try to establish who that person may

have been. If the person cannot be identified, for instance, if a cleaning contractor sources various cleaning personnel, then the organisation with access to the premise must be established.

(ii) By working with other agencies such as the police, local authority or business owners that have access to CCTV recordings, the investigator may be able to obtain images within a reasonable radius of the area of origin and within the correct time frame to ask the person if anyone on those images resemble any third person that they claim to have seen.

7Q Yes

(i) A third person or organisation can be identified, either by the person in question or by other means of data provision. The role of any persons identified needs to be recorded, as do any contact details for that third person or organisation. Proceed to 7Q(2).

7Q(2) Use appropriate FIRMs from #7.22 to #7.30

(i) The investigator must now follow the FIRM(s) that relates to the role of the third person(s) identified at the time of, or shortly before the fire, but must also continue with the FIRM in process. Remember that the role of an individual at the time of the fire may differ from their main role within society. An example is a full time student who is working part time in the university bar in the evenings. If the fire is in the bar and occurs when the student is or was working there, then the person will be classified as an employee and not a student\pupil, although their secondary role and associated knowledge should be considered.

7R No

(i) The third person, or organisation, cannot be identified. Once the investigator has established why the person believes that a third person had access to the area of origin, but cannot identify them, proceed to 7R(2).

7R(2) Use FIRM #31

(i) The investigator must continue completing the FIRM in progress, but must now also follow FIRM#7.31 to try to establish the identity of the unknown person.

7S Is their account accurate in terms of the scene and all available data?

(i) The importance of documenting what the person has said relative to the fire cannot be over stated. It will be during the scene examination and the subsequent examination of all data so far collected that the accuracy of their evidence will be exposed.

(ii) The investigator must take time to validate what the person has said, remembering that the information which is inaccurate does not necessarily mean that the person is deliberately lying. Careful analysis of the data gathered so far should be conducted when deciding if the person is deliberately being misleading or not.

(iii) An example of the latter may be a person giving information when distressed and the accuracy of their timings may be completely different from the hard timings the investigator has obtained, for instance, from a telephone call log. An individual's sense of time may be totally distorted due to the situation that they have experienced and may not be an indicator of deceit.

(iv) When a person gives an account of how they tried to tackle the fire, particularly employees, including security guards and caretakers, the investigator should consider the detail in how close the fire was to the person and the injuries that they sustained, or did not sustain to see if it reflects what may be expected from fire-fighting activities without correct fire fighting Personal Protective Equipment. An example may be if a security guard claims to have tackled a fire using a 9 litre water extinguisher, getting within a couple of metres of a fully developed pallet fire in a small store room, describing the flames as almost reaching the ceiling, it would be expected that the person would have sustained some sort of injury such as smoke inhalation or thermal damage. If there are no indications of such damage, the accuracy of their account should be questioned. In this example, it would also be of value to excavate where he or she claimed to have left the extinguisher on their exit as some part of it would most probably have survived the fire.

7T Yes

(i) The investigator has corroborating evidence that the person has given an accurate account so far. The person's account fits in with the physical evidence and any other data obtained during the investigation.

7U No

(i) The investigator has corroborating evidence that the person has not given an accurate account so far. The person's account does not fit in with the physical evidence and other data obtained during the investigation.

(ii) It must be remembered that although the person's account is not in accord with the available data, the investigator should explore why there are inaccuracies when considering the person's intent to deceive the investigation process. At this stage of the FIRM, it would be expected that the investigator has enough evidence to suggest that the person *may* or may not be responsible for the fire.

7V Consider informing the police and/or social services

(i) If the investigator has concluded that the person may have been responsible for the fire, this does not mean that their intention was to deliberately set the fire. It may be that the fire was accidental in its causation. If, however, there is sufficient data to indicate that this may have been a deliberately set fire, then the police must be informed at the earliest opportunity and the investigation of the fire may have to be suspended pending their attendance, if the police are not already part of the investigation.

(ii) If a minor (child) is involved, it may be necessary to inform the police and/or social services so that the child can:

- be protected
- be interviewed
- be dealt with regarding any welfare issues.

If it is believed that the child may be responsible for the starting of the fire, the investigator should balance the seriousness of the actions of the child with the consequences of the fire and the potential for recidivism (Merriam-Webster, 2010). Upon evaluation of all available data, the investigator must consider the importance of informing the police or social services of his or her concerns and/or findings.

7W Yes – there is negative history regarding this person(s)

(i) The investigator has either been told by the person or has discovered that there have been previous fires experienced by the person or associated property in question. When selecting this route, the investigator must be satisfied that the 'negativity' of

the data is indicative of potential responsibility of the fire causation. The investigator should try to establish whether the person not only has any history of fire setting or fire play, but also if there has been any negative events that the person may have recently been involved with.

7X No – there is no negative history regarding this person(s)

(i) All enquiries indicate that there is no negative history relating to either the person or the premises.

7Y Yes – this person(s) may have benefitted from the fire

(i) There is sufficient data to indicate to the investigator that the person may have benefitted from the fire.

(ii) The investigator must consider all other relevant FIRMs. To arrive at this point indicates that this is only one potential hypothesis and all others must be explored.

7Z No –this person(s) would not have benefitted from the fire

(i) There is data to indicate to the investigator that the person would not have benefitted from the fire.

7AA Unlikely to be responsible for fire

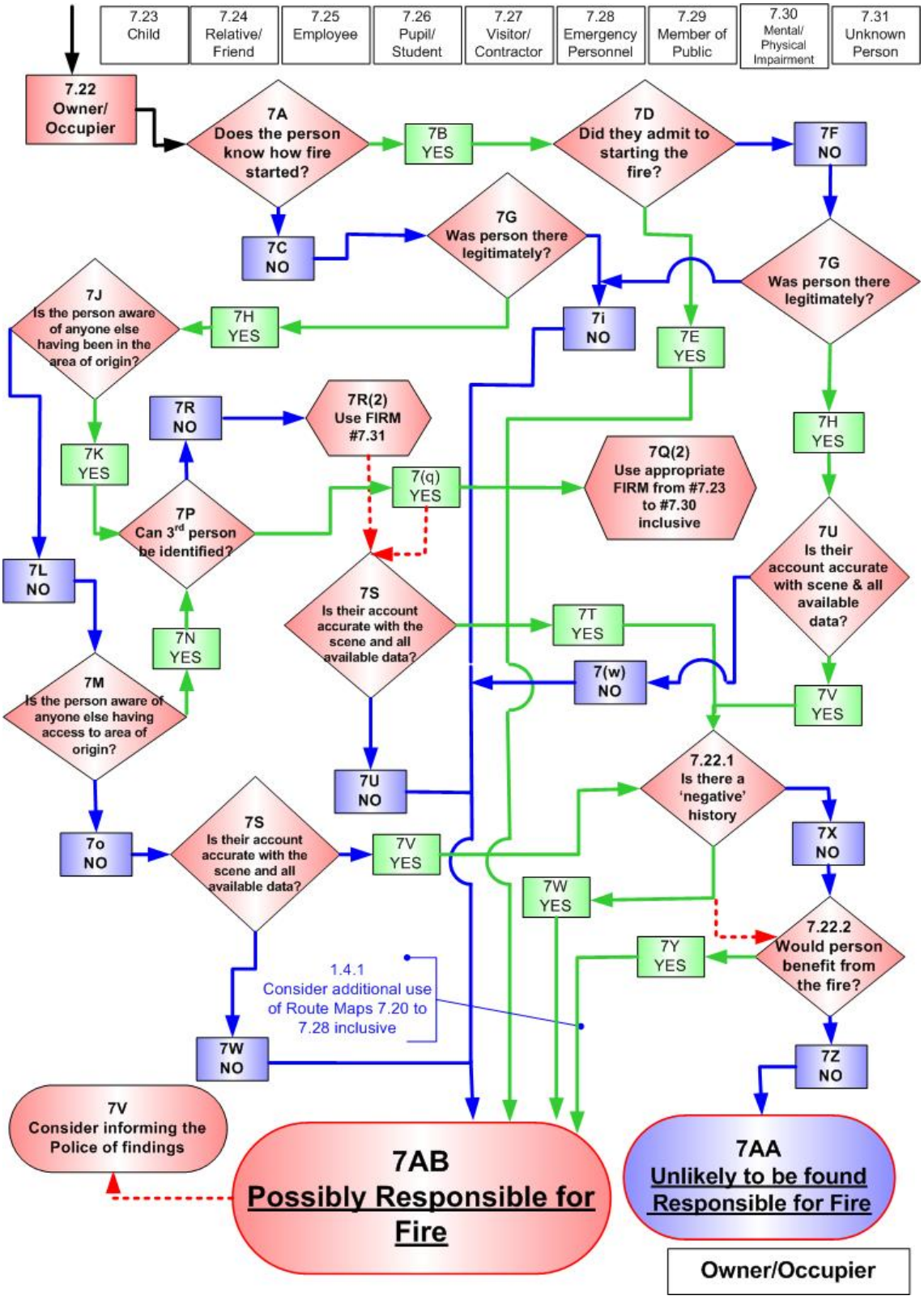
(a) All routes have now been explored so as to eliminate this category as a cause of the fire with the data that is available.

7AB Possibly responsible for the fire

(a) All available data indicates that the owner/occupier may have been responsible for the fire. All this data will need to be analysed and any hypotheses formulated will need to be tested with all other possible hypotheses. If two or more hypotheses cannot be eliminated then 'undetermined' must be recorded.

FIRE INVESTIGATION ROAD MAP #7.22

OWNER/ OCCUPIER



7.22 Owner/Occupier

This person will have overall or partial responsibility for the property at the time of the incident. This will include managers, head teachers, landlords and persons residing at a premise with or without lawful reason, e.g. a resident, squatter, protester or inmate of a detention centre. It does not include hotel or similar establishments as these would be dealt with in FIRM #7.27 (Visitors/Contractors). It will include the employer of another person(s). This person can also be referred to as the 'key holder' for the premise in most cases.

The owner/occupier should have a greater knowledge of the premises affected by the fire than most others. They should, but not necessarily will have an awareness of where the service isolation controls are, a layout of the premises and in particular, the security of the premises.

During a study carried out between 1996 and 2000 in London, it was identified that most injuries and deaths by fire occurred in unintentional dwelling fires involving the owner(s) and/or occupier(s) (Holborn et al., 2003). When an owner/occupier survives a fire, the investigator should study all the circumstances that allowed them to escape or control the fire:

- What alerted them?
- What was the 'state' of the fire when they became aware of it?
- How did they escape?
- Who called the emergency services? etc.

Their limitations may be that they will most probably have experienced more stress and anxiety after a fire at their premises due to the direct losses they have experienced, as opposed to say, a visitor or member of public. This may limit the quality of their evidence or may lead them to be frugal with it if an insurance claim is possible.

The owner/occupier must be positively excluded from having any involvement with the scene if the application of this FIRM is not to be followed.

7.22.1 Is there a 'negative' history?

(a) It is necessary to ask the owner/occupier if they have 'experienced' any previous fires, either at the premises where this fire has occurred, or at any other premises that they were associated with, by either being there at the time or having responsibility for it. The likelihood of a responsible owner/occupier experiencing a fire is small; the likelihood of such a person experiencing two or more fires in their lifetime is even more remote as he or she should have taken appropriate actions to prevent it from happening again. However, some people can be careless or may have alcohol/drugs problems or even learning/physical disabilities (See FIRM #7.30), which may increase their risk of causing a fire accidentally.

(b) It may also be prudent to enquire through various agencies, such as the fire service, police, insurance agencies or landlords whether there is any history of previous fires on any of their databases, relating to either the property or the person. When a small fire occurs and is successfully extinguished by the owner/occupier, they may inform their insurance company, landlord or call the police and may not have informed the fire department.

(c) Owners may set fires to make fraudulent insurance claims (Ahuja, 2009), as was the extreme case of a syndicate of UK insurance fraudsters headed by insurance assessor Leopold Harris in the early 1930's. Businesses were over insured, in other words, paying too high a premium for the value of the assets, subsequently experiencing a fire with Harris handling their fire damage claims. With today's modern technology, the cross-linking of names, addresses and other identifying data can highlight repeat 'victims' of fires, allowing the investigators to establish whether the fires were accidental or deliberate. The following points should be considered when gathering historical data from the owner/occupier regarding a potential insurance fraud and when utilising the previously mentioned technology (U.S. Department of Justice, 2001):

    - How much was the property worth when acquired?
    - How much is the property worth now?
        - The owner may be in 'negative equity' and recovering the loss through the insurance policy
    - How much is it insured for?
        - If it worth more than the current market value, suspicions should be aroused because the owner is paying more for a premium than they should.

- Who are the financial lenders (if any) and what are the account numbers?
  - The investigator should work with the financial lenders to obtain a full history of debts, etc.
- Who else has an interest in the property?
- What other loans/debts are held by the owner/occupier?
  - Other lenders may be putting pressure on the owner/occupier to recover the monies lent to them
- Amounts of any previous claims and circumstances?
- Location of owner/occupier at the time of the fire with any alibis?
- How did the owner/occupier learn about the fire; from who; what time and what did they do once informed?
  - The investigator should consider what may be deemed an acceptable reaction to someone who has discovered that they have had a fire; lack of upset or shock and evidence of knowledge not expected to be held by the person at that time should be recorded and considered.
- Any evidence or proof of loss (receipts, invoices, etc.)?
- Is the owner/occupier the beneficiary of any loss claim?
  - The investigator should check to see if the owner has any evidence of items that are claimed to have been lost in the fire as the items may not have existed at all.
- Is the current policy a new policy or renewal; if the latter, has there been any recent changes in the policy and are the premium payments up to date?
  - Again, if the investigator is not working on behalf of an insurance company, it would be wise to work together to address these important issues and identify any fraudulent activities.

(d) The investigator should establish whether the owner/occupier has any other properties or business locations. This information could then be used to check if any of these locations have experienced similar fires. An example is when the owner of a dry cleaning business had an ‘accidental’ electrical fire in his shop in London (Insurance Fraud Bureau, 2006). Through the Bureau’s telephone ‘cheat line’, information was given stating that the owner had several other shops around the UK where at least three other fires had occurred. This information was shared with the author as a member of the International Association of Arson Investigators

– UK (IAAI-UK) Chapter, who then passed it onto the relevant fire and police investigators, who were also IAAI-UK members to take into consideration as part of their investigations. It is understood that the owner was charged with the arsons.

(e) Occupiers of social housing have been known to set fires within their own properties in order to get re-housed. A large sprawling council estate used to exist in Moss Side, an urban area of Manchester in the UK. It was a very deprived area with many social issues. During the late 1980's and early 1990's many of these premises were 'torched' so that residents could escape to better housing. The more fires there were, the more the estate fell into disarray. The history of any tenancies involved in a fire should be studied to look at any previous issues relating to them that may have led to a deliberate fire being set.

(f) The status of owner/occupier could also relate to a vehicle, boat or caravan. With the ever changing economic climate in many countries, the investigator should explore any loans still in place for assets acquired and any insurance policies relating to those assets. An example is when a vehicle is bought on an insured loan; the loss of that vehicle due to a fire may secure the repayment of the loan. However, the true value of the vehicle may be considerably less than the original loan, putting the owner into 'negative equity'. The only way to realise the full value would be to claim on the insurance policy following a total loss.

7.22.3 Would the owner/occupier benefit from the fire?

(a) Most people would not benefit from the results of a fire at their premises or involving their property. Personal effects, irreplaceable memorabilia and loss of their surroundings, whether it is business continuity or domicile relocation, will have a potentially traumatic effect on most people. However, the investigator should make every enquiry as to whether the owner/occupier would benefit by the results of the fire by any form of material gain. The last example in [7.22.1(d) and (f)] are good examples of the owners fraudulently claiming for damages to their properties due to staged accidental fires. When considering why someone would stage an accidental fire, the investigator must explore all circumstances relevant to the material loss and the history of that loss in relation to direct association with the owner, whether insured or not. The following are some examples that should be considered:

- What contents have been removed or added shortly prior to the fire?

- If valuable or personal possessions have been removed prior to the fire (always check the owner/ occupier's vehicle or outbuildings to see if they contain such items) suspicions should be raised and explored. On the contrary, if many invaluable items or stock have been put into the premises shortly before the fire to appear to be 'normally' stocked, then the investigator should also explore the reasons why.

- The occupier of a rental property that wants to be relocated and has had difficulty in getting the landlord/local authority to agree to this (see [7.22.2(e)] above).
  - To stage a fire, even if it is a small fire, would create damage, especially smoke damage, that would force the landlord/local authority to relocate them.
- Reclaiming insurance money to a greater value than the resale of the loss.
  - As detailed in [7.22(c)] above, by carrying out all checks regarding negative history relating to the owner/occupier, it will be clear to identify a real financial benefit to them.
- Psychiatric disorders
  - It may be that the person gets pleasure either from the fire or the repercussions of the fire, such as the attendance of the emergency service(s).
- Family arguments
  - Revenge following any disputes should be explored; many murders are caused by family/partners, so fire setting should also be taken as a realistic option of retaliation.
- Children playing with ignition sources.
  - Parents have been known to lie to investigators to cover up the fact that their child or child in their care has caused a fire to prevent any repercussions for them from social services or police (due to the claim of neglect by them).

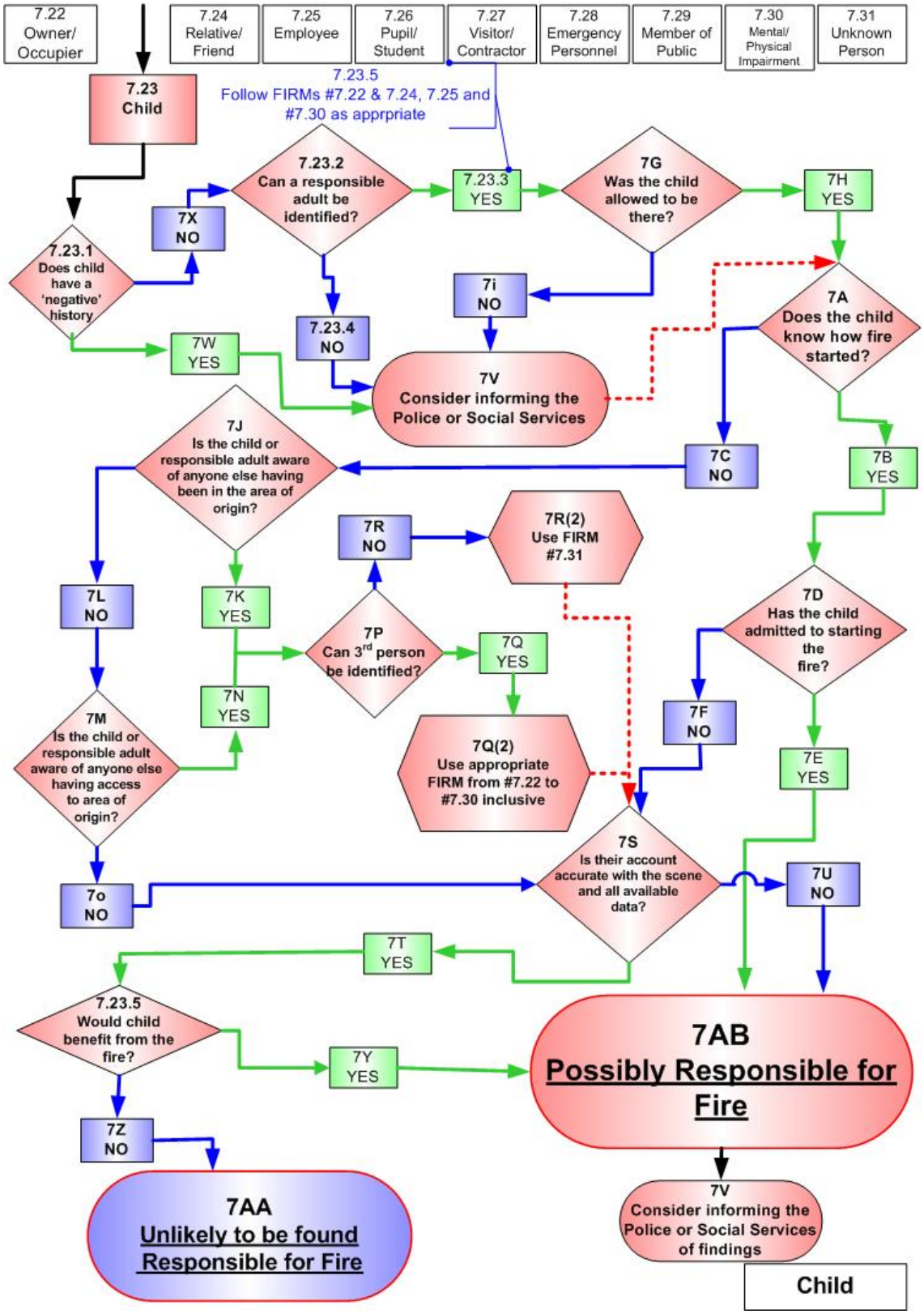
(b) Another situation exists, particularly during a financial recession, when the destruction by fire of a single occupancy premises that has been refused planning permission to be redeveloped into multiple units, subsequently allows the planning application to go ahead. This may be the only way a developer can realise his or her

investment and, in many cases, is not done for an insurance claim. In the UK, the London Fire Brigade has developed the Potential Arson Target Database, which identifies properties that have been refused planning permission or had their licences revoked and enters them onto a database as a potential arson target; this information is then shared with front line personnel for their own safety (Carpenter, 2009). The scheme is being adopted in other regions and should be explored by the investigator if investigating a disused building or premises with a refused planning application.

(c) A case study of a family benefiting from a fire in their home was highlighted during an investigation which exposed them having removed furniture and belongings only hours before a fire destroyed their home (Arson Control Forum, 2003). The owner fraudulently tried to claim £60,000 on his contents policy and £40,000 on his buildings policy. He was subsequently jailed for seven years.

FIRE INVESTIGATION ROAD MAP #7.23

CHILD



7.23 Child

In the UK, children under the age of 10 years old would not be prosecuted for arson if they were found guilty of deliberate fire setting, however after this age a child may be prosecuted for arson. This FIRM includes all children up to 18 years old and anyone of any age where their learning difficulties or mental state has not allowed them to develop to maturity. It may be necessary in certain circumstances to cross-reference this FIRM with FIRM #7.30 – Mental or Physical Impairment, depending upon the age of the person. For this FIRM, the author refers to two categories of child fire setters; curiosity or experimental fire setters and delinquent fire setters.

It is important that the investigator considers all children that could possibly be associated with the scene; for example the primary adult person, whichever FIRM is being followed, may have had a (grand/step) son, (grand/step) daughter, niece, nephew, or one of their friends in or close to the area of origin at the time of or shortly before the fire.

Some children can, at times, demonstrate honesty beyond that which is required. Suffice to say, that they may give information to investigators that parents or other guardians may wish to conceal. An example is a case in the USA where a young boy was reported to have climbed into a home-made hot air balloon (Goldman and James, 2009). The father had got the six-year old to hide in the attic and stage the accident for publicity, but the boy readily admitted on camera to the world press that the father did it for the money!

Their limitations are that they may be emotionally affected by being questioned, especially about such a traumatic event and the need to ‘manage’ children with the correctly trained specialists is paramount.

Curiosity about fire is quite normal in two to seven year olds (Dr. Kenneth Fineman et al., 1988a). In fact, experimentation is a normal part of the childhood experience (Williams, 2005c) although their cognitive development at these ages may differ from their logical development, often giving them little ability to recognise the consequences of their actions. Curiosity fire setting in children under seven years old is predominantly a spontaneous and opportunistic act and it is unusual to find curiosity fire setting in

children over ten years old. Unfortunately it is many of the curiosity fire setters below the age of seven that are seriously injured or killed in the fires that they set.

Children in developed countries often grow up in environments where no naked flames exist due to, for example, the installation of central heating, electric ovens and hobs, etc. In many urban areas, it is now unacceptable to have bonfires in gardens, where at least some children may have learned to relate to the heat given off by such fires. It should therefore not be a surprise that many children are fascinated with fire. Curiosity fire setting is simply a child exploring their environment and sometimes even mimicking an adult they have seen using fire (for cooking, heat, smoking etc.). The child needs to understand how a fire looks, feels, burns and what it does; that is normal developmental behaviour, albeit a potentially very dangerous behaviour.

When a child has been involved in more than one 'accidental' fire, this may indicate a more serious problem with the child's personal circumstances and may require additional professional help.

Children of socially accepted, normal development between the ages of seven and thirteen are not expected to be curious or experimental with fire as the under seven year olds previously discussed. This is because they would have been exposed to fires in their developing years such as seeing fire engines in the streets, fires on television, candles on birthday cakes, playing with toy ovens, etc. It would be normal for the child to be educated by responsible adults with regard to the dangers of fire when they make those early associations. However, the investigator should consider what is 'normal' in the child's own personal environment; if neglectful parents/carers allow children to behave antisocially or dangerously, such as smoking, drinking underage or staying out late unsupervised, then setting small fires or causing other minor criminal damage may not offer any consequences or deterrents for them. It is important for the investigator to consider the potential for juvenile firesetting in the context of what is expected both developmentally and environmentally in relation to the child and their age.

Most school fires are set by angry fire setters, using fire to 'burn away' their angry feelings (Muckley, 2004). Children are experts at gaining access without detection, especially at schools with low fencing, flat roofs and lack of security in most premises.

The fire setters have usually either attended or are attending the school they have set fire to. The investigator should explore with school staff any previous vandalism or minor fires (see FIRM #7.26 - Pupil/Student).

Children must be positively excluded from having any involvement with the scene if the application of this FIRM is not to be followed.

7.23.1 Does the child have any negative history?

(a) The investigator should try to establish whether the child not only has any history of fire setting or fire play, but also if there have been any negative events that the child may have recently been involved with.
    - The investigator may be able to do this by contacting the local fire department to see if the child is registered on any juvenile fire setters intervention scheme.

(b) Research suggests that children who regularly set fires often live in problematic circumstances, such as exposure to drug and alcohol abuse, child abuse, domestic violence or other criminal behaviour (Dr. Kenneth Fineman et al., 1988b).
    - The investigator should be aware of any visual evidence of such abuse, document their observations and pass them to the appropriate authorities such as the police or social services.

(d) One single fire related incident involving a child may be deemed an 'accident' and may be difficult for the investigator to prove a deliberate intention, however, more than one fire associated with a child should be serious cause for concern. The investigator should ask, either through the responsible adult or, with permissions, the child himself/herself, some direct questions such as:
    - How many fires have you ever seen?
        - The investigator would not expect a child to have seen many 'real' fires, so it is important to establish where the fires were; on TV? On a computer game? etc.
    - Have any of your friends ever set a fire?
        - If the child is aware of friends setting fires, the investigator needs to establish how the child knows; did he/she see them doing it? If so, what did they feel about them setting fires? Were they only told that their friend(s) had set a fire(s) and do they believe their friend(s)? etc.

- How many fires have your friends set?
  - The investigator should try to establish if their friends are simply 'bragging' or whether the child saw them setting them, which would put them at the scene of the fire.
- Did your friend(s) set this fire?
  - The child may identify who started the fire; if they say their friend(s) did not start the fire, ask:
- Have you ever set a fire?
  - The child may admit to setting a fire if he/she believes that their responsibility is lessened due to others involvement; if they were alone they may still admit to setting a fire but not the one in question.
- How many fires have you set yourselves?
  - If the child admits or suggests that they have set more than one fire, the investigator should establish where the others were started and if there was a fire service attendance, check all available records to verify those claims.
- Did you start this fire?
  - The child may, by this stage, admit to starting the fire as all available data may put them at the scene, albeit with other friends.

(d) Problem fire setting children frequently collect fire setting materials and ignition sources such as disposable lighters. Common sense will lead the investigator to establish that the younger the child, the closer to home the fires will be set. The older they are, the more they would be able to travel away from their home without supervision and may set fires more remotely from where they live. Fire setters between 11 to 13 years old will seldom show any remorse for what they have done (Dr. Kenneth Fineman et al., 1988b) and may use fire setting as an outlet for their adolescent anger. The investigator should try to establish through the responsible adult or the child himself/herself some of the following information:

- Do you smoke?
  - If yes, then they will either carry or secrete matches or lighters but will definitely have used them
- Do you normally have matches or lighters with you?

- If the child does not admit to smoking, they may admit to carrying such items as they may actually have them on their person at the time of being asked and fear they will be discovered.

- Where do you hang out with your friends?
  - This may be in or close to the area where the fire(s) has/have been started.
- Do your friends smoke?
  - If the child admits to their friends smoking, then they would also have ready access to ignition sources whilst they were with them.

(e) Delinquency reflects biological, social, familial and environmental factors (Williams, 2005a) and motives for delinquent fire setters can be varied indeed. Delinquent fire setters between 14 and 18 years old often have a childhood history of fire play which has been planned in the company of one or more friends. They have normally actively acquired combustible materials (planned, not opportunistic) and are more prone to peer pressure, setting fires to impress others without regard for consequences of their actions. Their fire setting is often accompanied by other antisocial behaviour, such as drug abuse or vandalism and their targets are normally another person's and not theirs. They are often angry at someone or some institution they feel should be protecting them and has let them down (Muckley, 2004). Therefore, the setting of the fires does not normally make them 'feel' better. Few take personal responsibility for their actions, blaming their peers but admitting their behaviour (Michael Bazerman PhD et al., 1988, Williams, 2005a).

7.23.2 Can a responsible adult be identified?

(a) If a responsible adult has not been identified, then the investigator should ensure that one is identified before proceeding with the investigation.

(b) A responsible adult may be, for example and not exhaustive, a:

- parent
  - The investigator should establish the person with ultimate legal responsibility for the child at the earliest opportunity; this may be the natural parent, adopted parent or foster parent.
- carer

- If the child does not have a parent as detailed above, the carer who has legitimate responsibility for the child should therefore be established.

- relative
  - The child may be staying with a relative who has been charged with their safe keeping by one of the above; the investigator should try to establish through the relative who the parent or carer is and make contact with them to ascertain if the relative has the authority to safeguard the child whilst questions may be asked.
- teacher
  - The investigator should ask the teacher to contact the child's lawful guardian, whose contact details should be recorded in the school office, and ascertain if the teacher can be given authority to safeguard the child whilst questions may be asked.
- child minder
  - It would be prudent for the investigator to ensure that the legal guardian of the child is contacted and asked to attend the scene before proceeding with a childminder as their safeguard. It would also be wise to establish whether the childminder is registered with the local authority or not.

The name, details and contact number(s) for any of the adults above should be recorded immediately and the relationship with the child established and verified as appropriate.

7.23.3 Yes

(a) A responsible adult has been identified; the relationship has been verified as appropriate to communicate with the investigator and full details recorded.

7.23.4 No

(a) A responsible adult cannot be identified.

7.23.5 Would the child have benefitted from the fire?

(a) The investigator needs to establish if the child would have benefited from the fire. For the investigator to consider this question, he or she must try to understand what

may be important to that child. In most cases, if the child is below seven years old, the most common benefit is to quench a curiosity and nothing more. However, the investigator must consider the not-so-common benefits for the potential for the child to have set a fire. These benefits or 'rewards' may be internal or external in nature. The child may experience some internal gratification or release following a fire set, which may relate to psychological problems or other negative influences upon their lives and this type of child would require support beyond the skill sets of most fire investigators. If in any doubt, the investigator should contact the police and/or social services.

- The investigator should try to explore the child's personal circumstances with the responsible adult and within the boundaries of their own competencies and levels of responsibilities. Information about the child's character, relationships with others, energy levels, hobbies and other related data may all have a bearing on data relating to the fire; it could be characteristic or completely uncharacteristic of the child to have been responsible for such an event.

(b) External rewards may include acceptance into a group or 'gang'. A child may be bullied or coerced by peer pressure into setting a fire and carry out the task in order to be/feel accepted by the other person(s). Peer pressure and acceptance within a group should not be underestimated.

- The investigator should consider that in these circumstances, the child would not have been the instigator of the act and may be very remorseful of their actions.

(c) A similar example of this may be if the child is unhappy at school due to history of being bullied and by starting a fire may have believed that the school would then be closed and he or she could be safe at home away from the hostile environment (see FIRM #7.26).

- The investigator should consider asking the teacher or other responsible adult about any history of the child having been bullied.
- It may be worth considering talking to the child's 'best friend' with the appropriate permissions from both the child's and best friend's responsible adults, as the friend should want the best for them and may offer information that will be in the child's interest and for the child's benefit.

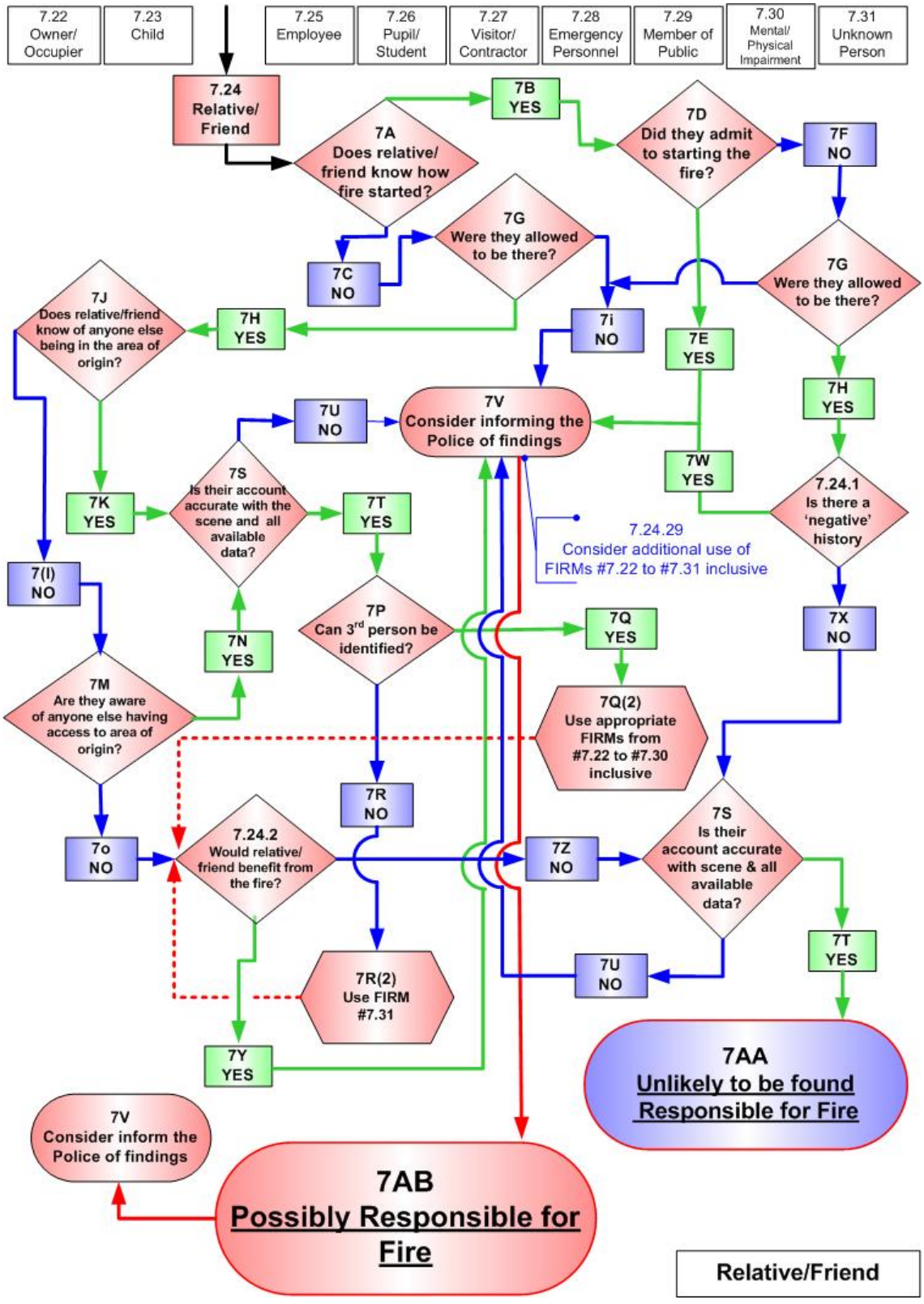
(d) A major crisis in a child's life may not be completely apparent to an investigator, but questions about recent negative circumstances, such as a family death, the death of a pet, moving home or parental/guardian separation may cause the child to demonstrate destructive behaviour.

- It may be prudent to ask the responsible person these questions as direct questioning to the child may be upsetting for them.
- The investigator should also establish if there have been any other signs of negative behaviour following any personal upset to the child.

(e) An older child could use fire as revenge against another family member, particularly another sibling's property if jealousy is evident or against the partner of a family member. The investigator should be cognisant of circumstances surrounding a fire involving a child, which may relate to any bedding or sleeping areas; it is unusual for a child to set a fire in their own bed as they normally feel most secure and safe there. If a child has set fire to their own bed, it may be an indicator that some abuse may have occurred and it could be the child's method to stop it continuing. Although most fire investigators are not trained social workers or child psychologists, it would be prudent to raise any issues of concern with the appropriate authorities as soon as is practicable and not with the responsible adult.

FIRE INVESTIGATION ROAD MAP #7.24

IMMEDIATE FAMILY, RELATIVE OR FRIEND



7.24 Immediate Family, Relative or Friend

This person will be related to the primary person who was involved in, or associated with the fire or explosion and will be a lawful (step/foster/-in-law, in all cases) father, mother, sister, brother, (grand) son, (grand) daughter, aunt, uncle, nephew, niece or cousin. It will also include current and recent friends of a social nature of any of those persons mentioned above, including boyfriends and girlfriends.

People involved in these close and personal relationships will have some level of intimate knowledge about each other, either by design or by accident. In many situations, particularly following a moment of discourse, the negative knowledge can be used against each other out of indiscretion, spite, jealousy or revenge. The investigator should consider any allegations made against each other with its relevance to the investigation.

The positive knowledge possessed by each person may, however, prove to be a very important source of data during an investigation, particularly a fatal fire investigation requiring personal details such as habits, substance use and daily routines, as examples.

7.24.1 Is there a negative history?

(a) The investigator should try to establish whether the relative/friend has any history of fire setting or fire play.
   - As previously discussed, relatives or friends may have personal information about each other that no one else would know.
   - Most relatives and friends care about those they are close to and may assist the investigation understanding that by sharing any personal issues the subject may, in order to get them the necessary help they need before they harm themselves or others.

(b) It may also be possible to check whether any records exist of previous fires at the relative/friend's home and work addresses.
   - The investigator should obtain any current and previous domicile and business addresses, either from the relative/friend or the primary person.
   - The investigator should work with any other agencies involved in the investigation of this fire (as with all fires) and examine any available databases

containing details of previous fires or fire claims involving the relative/friend and/or any associated addresses or properties.

- The first place to start would be the local fire department; any attendance by them would be recorded.
- In the UK, the Insurance Fraud Investigation Bureau (IFIB) shares such data with its members, linking individuals to properties across the UK.

(c) The investigator must always consider, if appropriate, to ask questions directly to the relative or friend, for example:

- Do you know of, or have you experienced any other fires at your own home or work, or at any other persons' home or work?
  - The reason for this is that most people never personally experience a fire in their life-time. To have experienced two or more would be unusual and may require further investigation.

(d) Ask the relative/friend if they have had any concerns about their relative's (the primary person) health or safety and vice versa. The most stable of people can develop mental health issues due to various influences such as bereavement, substance abuse, irrational phobias, etc, which may not be obvious to the investigator but may be known or suspected by the relative/friend (See FIRM #30). Williams describes the 'Thought-disordered Fire setter' as someone whose associations loose their continuity and their thinking becomes bizarre, confused and incorrect (Williams, 2005d). These people may be thought of as being schizophrenic and although many people suffer from this illness, much of it can be controlled by modern drugs but the condition would otherwise be undetected by most observers and acquaintances.

- The investigator should ask about any mental health issues and/or medication as it is often only those that are close to them that may be able to reveal their condition, which may have a bearing on the investigation.

(e) Another type of fire setter that may only be known to the family/friend is the 'Disordered Coping Fire setter', who after suffering intense anxiety and/or rage, may set a fire to return to a state of emotional equilibrium (Williams, 2005b). As children, they seem to be in trouble with everything they do, but the older they get, the less they are able to deal with stress or anxiety and will not accept help. This may only be known by family or very close friends and should be explored.

(f) They should be asked if they have had or know of any disputes that may have existed between the primary person and themselves or a third party.

- As mentioned above, relatives and friends often obtain personal and confidential information about each other and may be willing to share that information in the course of trying to protect, who they may consider to be a vulnerable person.

7.24.2 Would family/ relative or friend benefit from the fire?

(a) There are several ways in which a relative or friend of the primary person can benefit from having a fire, or being instrumental in starting a fire and some examples may include:

- raising money through an insurance claim
  - the investigator should establish if any insurance policies exist that relate to the fire and also any named persons on the policy. This can then be explored as in [7.24.1(b)] above.
- being re-housed if one of the party is living in an undesirable location or social housing stock
  - either the relative/friend or the subject may be living in a premises that they have been trying to relocate from. History of their occupancy should be obtained by the landlord to see if there are any disputes in progress or requests to be relocated which are outstanding.
- inheritance of property or other material goods if a fatality is involved.
  - People have been known to be murdered for financial gain; close relatives and/or friends may be the subject(s) of inheritance and may be aware of the disclosure of the primary person's Last Will and Testament. It would be prudent of the investigator during a fatal fire investigation to establish the contents of the subjects Last Will and Testament and who the beneficiaries would be.

(b) The issues discussed in (a) above may be used as evidence of a motive if a prosecution is realised.

(c) As with other sub-FIRMs of FIRM #7, revenge can be a benefit if the fire setter has a grievance or even a perceived grievance against the primary person. It is believed that most murder victims knew their attackers. An example is when an old school

friend who had harboured a grudge for years, poured petrol through the letterbox of a terraced house on the 6th March 1999 in Bellamy Road, Chingford, North-East London. The subsequent fire killed a family of seven, including a two-year-old boy, twin girls aged four, their father and his girlfriend, together with the children's grandmother and great-grandmother (Rowe, 1999). Uncontrolled rage can erupt between people in close relationships when one or the other has been or feels as if they have been wronged. Domestic violence can lead to murder and there have been many cases where a family member(s), friend or friends have set fire to another's, or even their own home to reap their revenge.

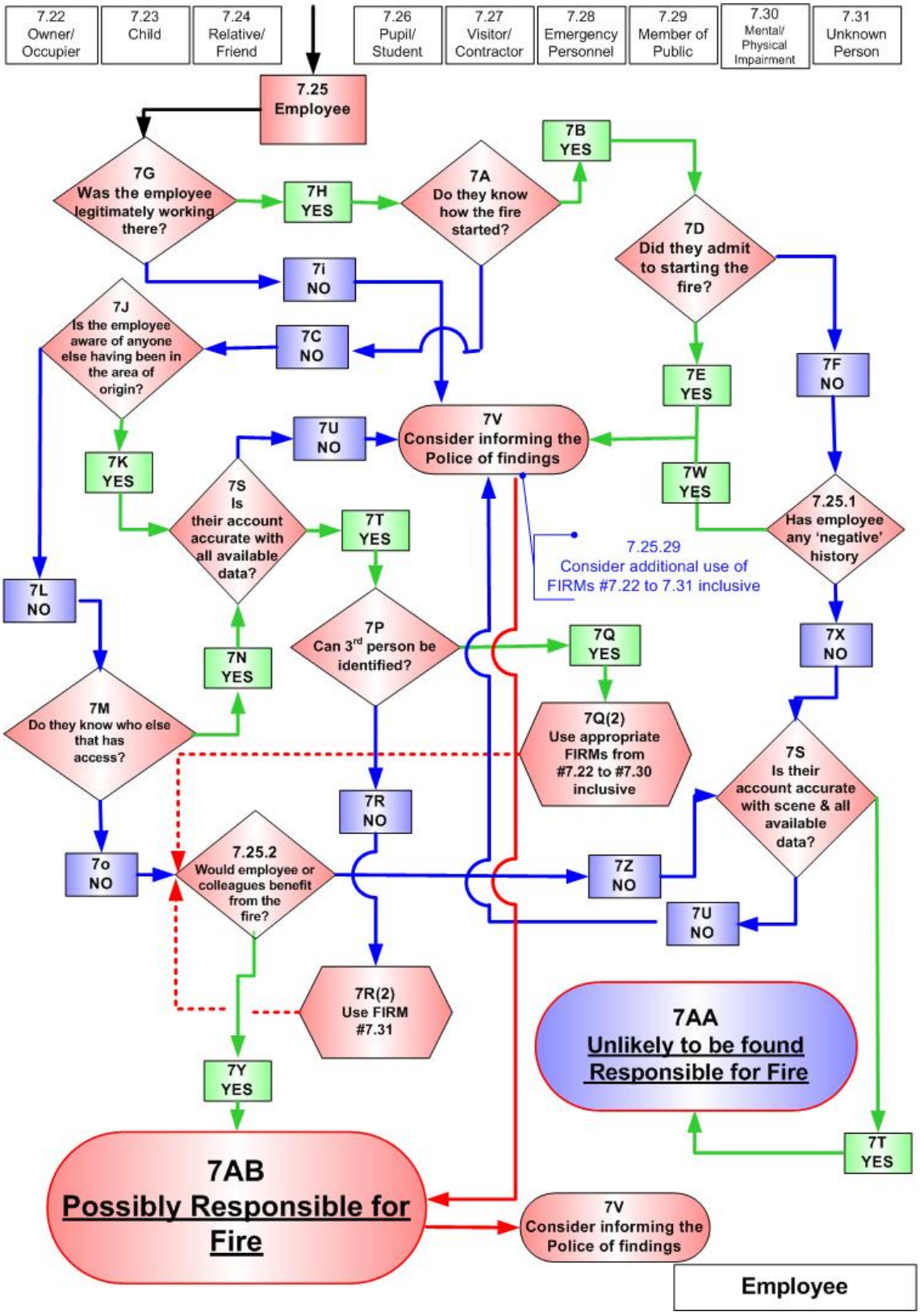
- The investigator should establish if there have been any conflicts between the primary person, immediate family, relatives or friends and any associated violence or threats made.

(d) 'Honour killings' is a term used when Asian family members kill another, predominantly female, family member for dishonouring the family. The 'offence' may appear to some cultures to be trivial, such as a teenage female family member becoming smitten with a male from another religion; buying lipstick and make-up to wear to college or simply going against an arranged marriage. The family believes their honour will only be restored if the female family member is murdered. This is happening in the UK and has been the subject of several high profile murder enquiries. An example of this is when a father who murdered his15-year-old daughter because of her "Romeo and Juliet" romance with a man from a different branch of Islam was found guilty of her 'honour killing'. More than a decade after Tulay Goren disappeared from the family home in Woodford Green, London her father Mehmet was convicted following his wife's evidence against him in court (Hughes, 2009).

- All 'accidental' fires involving the harming of Asian women should be treated as potential assaults or murders until proven otherwise.

FIRE INVESTIGATION ROAD MAP #7.25

EMPLOYEE



7.25 Employee

This person will be employed, or have recently been employed by another and will include paid or voluntary working personnel, child minders, baby-sitters and any role that involves working for another. It will not include any type of Emergency Personnel (See FIRM #7.28). The individual will have a 'line manager' who has overall responsibility for the area where the incident occurred.

Employees should have an in-depth knowledge of their working environment and its layout and, if they are new, they should have been inducted and assigned a mentor to guide them during their early months with the employer. This would give them technical and safety knowledge, including fire safety training, the need for Personal Protective Equipment and the location and handling of dangerous processes and substances. However, not all employers are compliant with legislation such as the Health and Safety at Work etc Act 1974 (UK) and may not fulfil their commitments or 'duty of care' to their employees.

If an employee is not treated with respect regarding some of the latter issues, then it may follow that they are not treated with respect with other issues, such as hygiene facilities, rest facilities, catering facilities, pay awards, etc. This may lead to resentment amongst the employees who may not be too upset following a fire or explosion at their place of work. What will upset them, however, is the loss of work if they cannot be relocated to another workplace within the organisation.

A problem that the investigator may experience is that some employees are not from the country that they are working in; so may not be able to converse in the local language. The employer may wish to offer a translator to assist, but it may be advisable to solicit the use of a local university languages department, or if necessary, a police translator to maintain impartiality and a truthful translation.

Following many serious fires involving a workplace, important records have been destroyed. If the employer is insured and the investigator is not representing an insurance company, the investigator may wish to work with any commissioned insurance investigator or request assistance from the insurance company directly to

access information that would be available under the conditions of the insurance policy. This would include bank accounts and technical details of the building and its contents.

The investigator must have a full understanding of the company structure, the line management system, recent promotions and failed promotions and any other disciplinary issues. It is important to get a 'feel' for the working relationships in order to identify any underlying problematic issues which may have relevance to the investigation. For instance, if a conflict issue is highlighted between employees or an employee and management, it may be that the area of origin can be associated with those individuals in one way or another and may lead the investigator to focus attention on these 'persons'.

Any employee(s) must be positively excluded from having any involvement with the scene if the application of this FIRM is not to be followed. All employees that were at work on the day of the incident and if necessary, before the day of the incident, should be interviewed.

7.25.1 Has the employee any negative history?

(a) Enquiries should be made as to whether the employee has any history of fire starting, discovering fires, extinguishing fires or being the 'victim' of other incidents where a perpetrator could not be identified. The employee's present and previous employers should be contacted to ascertain any history of all other incidents as well as fires.
    - It may be necessary in order to make these enquiries for the investigator to contact previous employers, the police and the fire department to check the employee's name on their databases.

(b) Employees have been known to start fires so that they can discover them and possibly extinguish them in order to appear to be the 'hero' (Williams, 2005e). This is commonly known to fire investigators as the 'hero syndrome'.
    - The investigator must consider that in what may be boring and low paid jobs, such as security guards, a fire may offer a temporary moment of excitement.
    - Previous employment records or applications should be sought as several arsonists have been known to have been rejected as fire fighters or police

officers and taken up security work to fulfil their 'uniformed' career. Such a situation occurred in the Fleur Lombard case, who was the first female fire fighter in the UK to be killed in action by a security guard arsonist who could not get into the fire service and set a warehouse alight.

- The intentions of such 'heroes' are believed to be to only start a small fire and then put it out; most have no concept of basic fire science or fire dynamics and many of their fires get out of control, such as the Waitrose twenty pump fire in North London in 2003, which the author investigated.

(c) It may also be possible to check whether any records exist of previous fires at the employee's home(s) addresses due to 'special leave' or sickness records.

- Suspicions should be aroused if the employee has experienced a fire at home which has caused an injury to refrain them from work and then experience a fire in their workplace. This is not to say that they could have just been unlucky, but it would be unusual as outlined in (d) below.

(d) The investigator must always consider, if appropriate, to ask the question directly:

- Do you know of, or have you experienced any other fires at your own home or work, or at any other persons' home or work?
  - The reason for this is that most people never personally experience a fire in their life-time. To have experienced two or more would be unusual and may require further investigation.

(e) Consider asking the employer whether the employee has recently been disciplined, refused promotion or any other associated issues which may lead to some resentment.

- As with other categories of the person, revenge is a common motive for arson fires. Even the quietest of people may want to have some retribution for an actual or perceived wrong-doing.
- Any identified employees should be identified to the police and investigated as to their movements, previous fire experiences, etc.

7.25.2 Would the employee or their colleagues benefit from the fire?

(a) Careful consideration should be given as to whether, and how, the employee or any of his or her colleagues could benefit from the fire. The size of the fire may be immaterial at this stage as a small fire could have the same effect, if not more so than the larger fire that may have developed. The investigator should be mindful

that many people who set fires have little, if any understanding of fire dynamics and may not have expected the fire to have grown to the size it did.

(b) Referring to [7.25.10(b)] above, the benefits that the 'hero syndrome' person would gain can be many, with some examples such as:

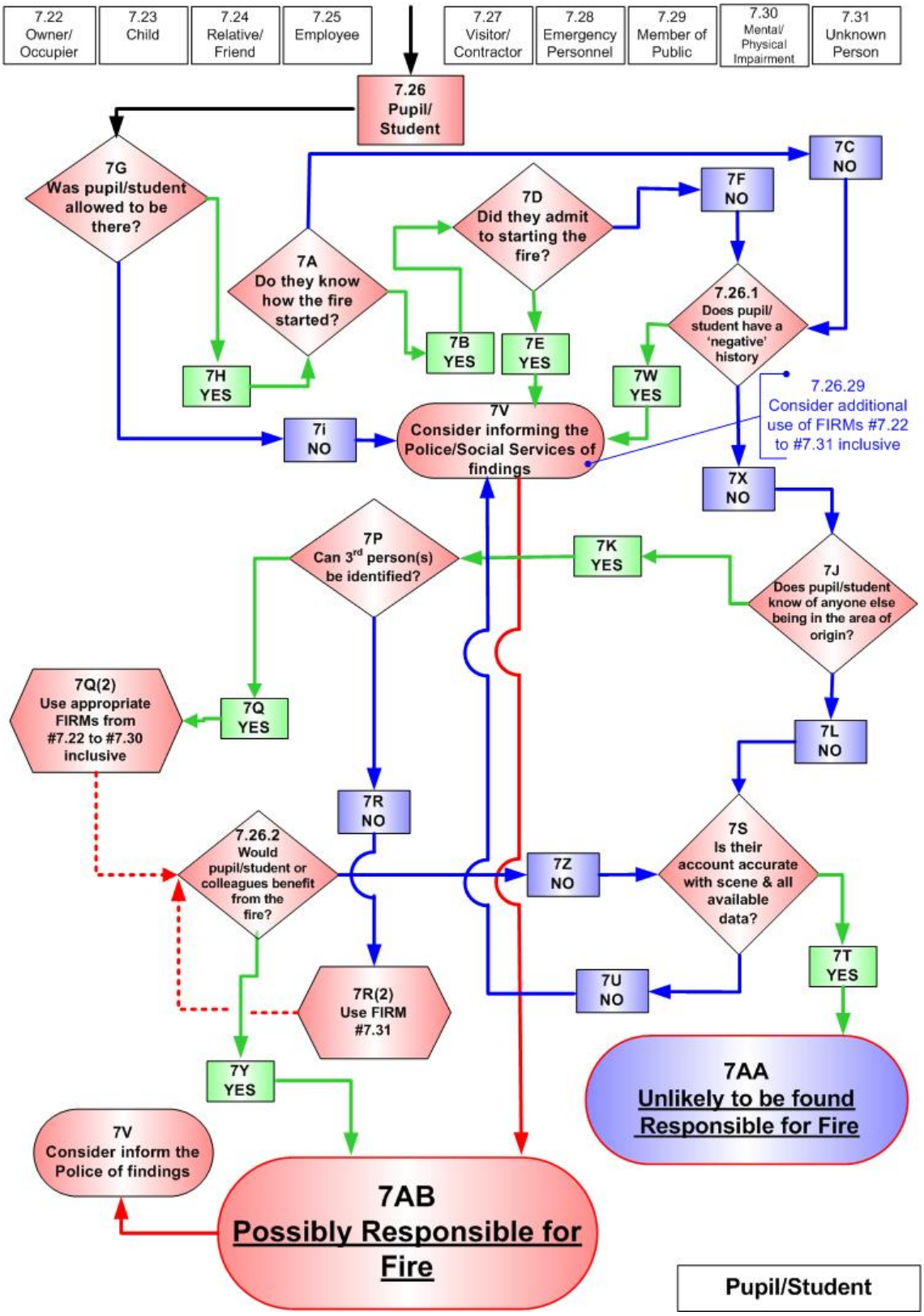
- Being considered a 'good' or 'reliable' employee, particularly in times of cut-backs or redundancies
- Being rewarded with a salary increase as the annual review approaches
- Respect from colleagues if they feel they do not have it already.

(c) Other 'benefits' may be:

- the early closure of the workplace leading up to a holiday;
  - The investigator should establish holiday dates.
- the temporary closure of a work place during a high profile sporting event, such as the world cup.
  - The investigator should record all such events and even consider looking at previous events that may have also followed a small fire in the workplace.
- the discrediting of another (possibly disliked) employee who may receive penalties because of the fire being within an area of their responsibility.
  - The investigator should explore any personality clashes within the employees and/or managers within the area of origin.
- the claiming of compensation for apparent minor injuries, such as minor smoke inhalation.
  - The investigator should explore any claimants for previous personal injury insurance claims, working with the insurance investigators if the investigator is not representing an insurance company.

FIRE INVESTIGATION ROAD MAP #7.26

PUPIL OR STUDENT



7.26 Pupil or Student

This category will include all people who are being taught at an establishment of learning and are, or have been at the scene for lawful educational reasons. The main role of the person in society will not be considered when selecting this FIRM; for example, if a fire-fighter attends evening classes to learn about electronics, he or she will be regarded as a student. However, FIRM #7.28 – Emergency Personnel may be identified as being relevant during the investigation when using this FIRM #7.26, as may other FIRMs, as it is important to have knowledge of the person's skills and knowledge that may have a relevance to the fire. If the pupil is under the age of 18, the investigator should also follow FIRM #7.23-Child.

The investigator should be mindful of the 'fuel available' in places of education, such as in laboratories. These areas contain flammable liquids such as methylated spirits, other solvents and even explosives and although they should be secured, it is possible that a student or pupil with negative intent could secrete some of these materials out of a laboratory whilst in a legitimate lesson. It may be necessary for the investigator to obtain a timetable of lessons and an attendee list from the school office, providing the office has not been affected by fire damage. If it has been, it is worth asking if a remote backup records system exists.

In many such establishments, pupils and students are allocated personal lockers, which can store a myriad of materials and ignition sources. It may be necessary for the investigator to obtain permission to search these lockers but may have to obtain police assistance if the establishment rules do not allow such searches.

Store rooms in educational establishments also contain many flammable materials such as cleaning products and where a swimming pool is available, chlorine. Although these rooms are sometimes fitted externally with appropriate signage, it is possible that the management have decided in their risk assessment not to display the products inside for security reasons. The availability of these products may have been known to anyone who was intent on setting a fire but could not bring fuel in passed the building security, so the investigator should consider this possibility.

Many colleges have areas that are open for study twenty four hours a day and pupils or students may enter into areas that they are not permitted to be. Most educational premises now have entry control systems which may log all personnel movements with times and, where control measures exist such as through restricted areas, the person's travel paths.

Recent international events have led to some student societies and other internal social networking groups to entice young, predominantly male students to construct home-made bombs made from many of the materials available at many higher educational establishments. With information on how to make such devices available in educational libraries and, although supposed to be monitored, on web sites, it would not be difficult for a student with such intentions to start a fire.

Having considered the latter, it is also possible for fires to occur through stupidity or recklessness involving peer pressure and/or immaturity. An example is when an eleven year old boy told his class mates that he would set fire to the toilet rolls for a 'dare'. When encouraged to do so by his 'friends' he eventually could not loose credibility and carried out the deed. On investigating the fire with the appropriate permission and support of the school and associated parents, the friends all informed the author who it was who set the fire and the fact that they did not believe he would do it. The child was entered into the London Fire Brigade's Juvenile Fire Setter Intervention Scheme!

Any pupil(s) or student(s) must be positively excluded from having any involvement with the scene if the application of this FIRM is not to be followed.

7.26.1 Does pupil/student have a 'negative' history?

(a) It may be relatively easy to establish the fire setting history of most habitual fire setting pupils/students by consulting with the educational establishment and/or local fire department.
    - The investigator should ask the establishment about any negative behaviour of their pupils/students.
        - Minor vandalism or previous fire setting may already be known to the teaching staff. It may simply be the incidents have not been

significant enough for them to have called the police or the fire service.

- Consider contacting the local fire service as many run Juvenile Fire Setter Intervention Schemes and maintain a database of juvenile fire setters of all ages.
  - If a juvenile is on a scheme and has set a fire in a school, the investigator must not assume that all agencies involved with that juvenile are communicating the issues effectively; explore the connection with other previously set fires.

(b) The 'disordered coping fire setter', as described by Williams (Williams, 2005b) may not be known to have such fire setting tendencies, which often manifest themselves following anxiety, rage or both in order to return to a state of emotional equilibrium.

- This type of pupil or student can be identified by the investigator as being emotionally dysfunctional with poor relationships with others. It does not automatically make them a fire setter, but the possibility of their involvement should be explored.

(c) Some circumstances however, particularly those described in (b) above, may require the involvement of social services. All investigators must be aware of the limits of their investigations before other agencies, such as social services, must be informed.

(d) The negativity of their history may not solely be connected with fire setting; it may involve violence, theft or other anti-social behaviour.

- It is unlikely that the investigator is a trained and qualified psychiatrist and assumptions should not be made based on a little knowledge of the subject. The investigator should simply be gathering data so that others, if necessary, can later make an informed determination from it.

(e) Many students within universities find it difficult to cope financially with mounting debts and having to maintain part time employment. They are often short of cash unless heavily supported by their family members. This can also result in poor or inadequate accommodation. All of these hygiene and welfare factors can lead to a negative effect within the lives of these individuals.

- It is important that the investigator considers these factors with any student that may be associated with the fire. As previously said, because many

students struggle with financial and welfare issues, it does not make them arsonists. However, it would be prudent to take these factors into account.

7.26.2 Would the pupil/ student or colleagues benefit from the fire?

(a) It could be suggested that most pupils/students would benefit by the educational establishment being closed or partially closed following a fire; this is not the situation when conscientious students are progressing well with their studies or trying to complete project work, for example, for their exams.

- The investigator should consider any significant events that are on the school curriculum, such as mock or real exams and ask the teaching staff to associate any pupil that would not be welcoming that event.
- It should be remembered by the investigator that if a pupil or student is not an 'A' grade star pupil, it does not make them a fire setter. The most academic of students can cause an accidental fire by having a secret cigarette in the store room!

(b) As with all the FIRMs, data should not be taken in isolation and consideration to the key players and their current status within the establishment must be carefully analysed. For example, in the case of a potentially deliberate fire in an art class of 16 year olds preparing for an art exam, the investigator's attention may be focused on the individual(s) that has not achieved satisfactory progress as the exam gets closer, rather than on those that were on target for 'A' grades and have now lost all their project work. Polk and Richmond (Polk and Richmond, 1972) observed that students who did well in their education had lower rates of delinquency than those that did not do well.

- It is critical that the investigator works closely with the teaching staff (remembering that it could be the teaching staff that was the cause of the fire!) as they will know their students' behaviours and characteristics better than can be gleaned from office records and reports.

(c) As with most other FIRMs, the investigator should also consider the following issues, although not exhaustive:

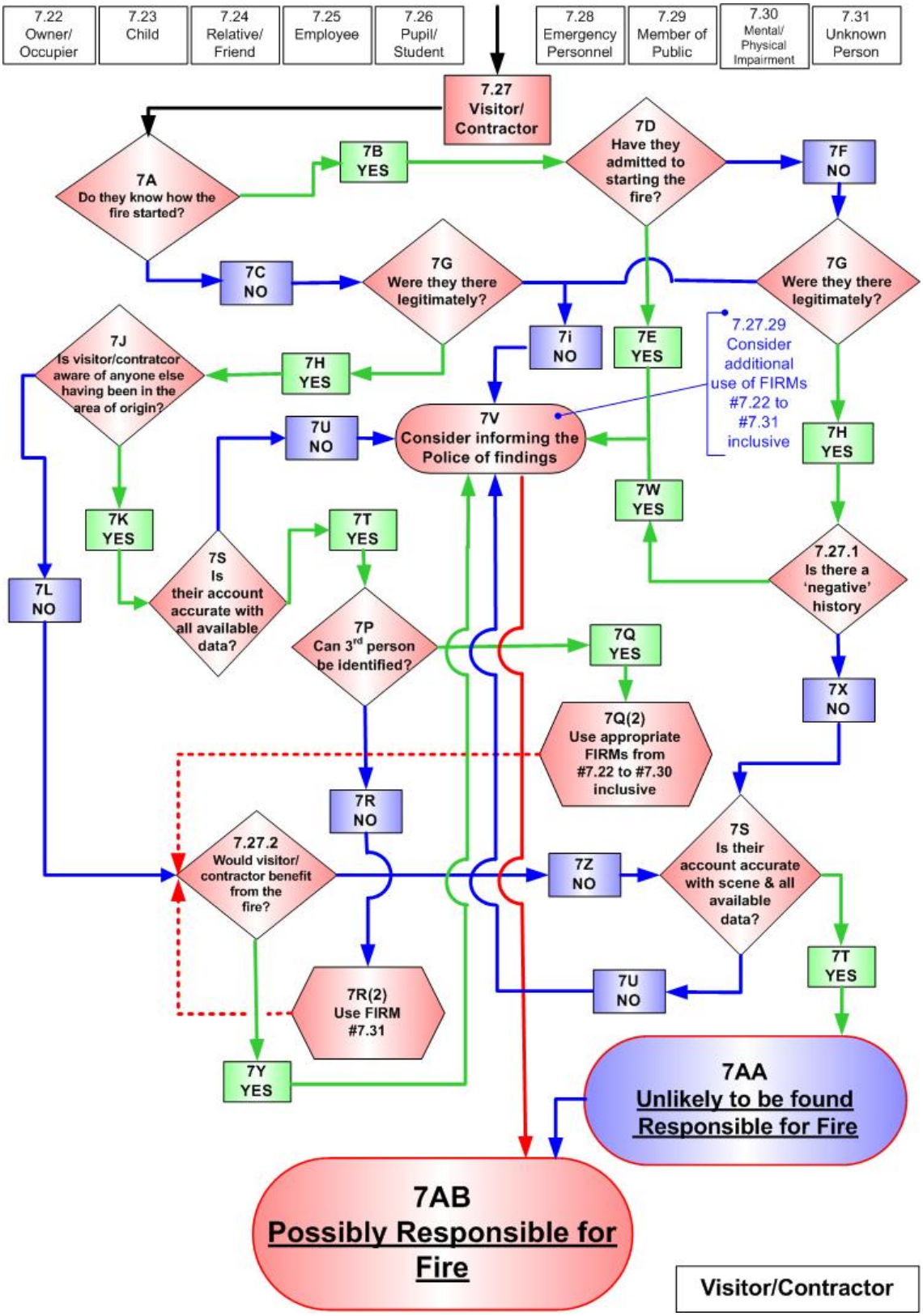
- Disputes between individuals leading to revenge arson attacks, possibly satisfying the perceived injustice to the perpetrator.
  - Again, the teaching staff will most probably be aware of any conflicts between pupils/ students within their establishment.

- The investigator must try to establish any threats that have been made between parties with specific reference to fire, such as ‘you’re gonna burn’. Whilst the threat may have appeared at the time to simply be bravado, any threats involving fire setting should be taken extremely seriously, as it is not a common way to retaliate to a conflict situation.

- Disputes between the pupil/student and the establishment also leading to a revenge attack and satisfaction
  - The investigator should establish any pupils/students that have recently been excluded or disciplined by the establishment. Those individuals will need to account for where they were at the time of the fire and the police may need to be informed.
- Reports of bullying and harassment which may lead to diversionary fire setting and temporary removal of the problem by closing the establishment
  - As previously discussed, the teaching staff may be aware of any situations of bullying and/or harassment and all individuals involved should be considered during the investigation.
- Previous vandalism and damage such as graffiti, broken windows, minor rubbish fire setting, etc.
  - Dates, times and type of damage should be obtained so that some geographical profiling can be carried out which may place any suspects at the scene at the time of the damage. This information can be obtained from the fire service and police databases. Minor damage would not normally be covered by most educational establishment insurance policies as there is normally a large excess payment attached to them.

FIRE INVESTIGATION ROAD MAP #7.27

VISITOR OR CONTRACTOR



7.27 Visitor or Contractor

This person will be, or have been lawfully at the scene of the incident, due to their interest in, or association with that scene. This may involve persons that have not been at the scene for some time but could have some relevant association to the scene, for example a sprinkler pump engineer who services the pumps on a monthly basis. Any visitor(s)/contractor(s) must be positively excluded from having any involvement with the scene if the application of this FIRM is not to be followed. Visitors will only include customers of shops, restaurants and leisure facilities if there is a mechanism of identifying them through entry control systems (such as leisure facility membership systems) or signing in procedures, otherwise refer to FIRM #7.29 – Member of Public.

Visitors and contractors to premises are normally known by someone in the establishment's management, either by appointment or membership. At a multiplex cinema for example, where hundreds of members of the public 'visit' to see films and eat in the restaurants that exist in some complexes, they are not 'booked in', registered or inducted into the establishment's fire safety arrangements as are visitors or contractors. Visitors and contractors would most probably expect to feel safer within their more controlled environment than members of the public in their less controlled environment.

A difference between a contractor and an employee is often familiarisation with their surroundings; contractors are often less familiar and may have less interest or care in their temporary environment as they probably have several customers and locations to share that interest with.

The difference between visitors and members of the public are that visitors are normally made to feel more welcome and are treated more individually by the establishment's management as they are often known to varying degrees by them. A visitor will have reserved a table at a restaurant which requires bookings to be made, giving a name and often a contact number. That visitor's guests are also classified as visitors as they can be identified by the person reserving the table. In opposition to this situation, a person buying food at a fast food or self service eating establishment would be classified as a member of public as they are not identifiable by name by any recording system.

So visitors and contractors can have an array of knowledge, purpose and attitudes to the location where the fire occurred. It is important that the investigator establishes the reason for their attendance and some of their background personal information wherever possible.

7.27.1 Is there a negative history?

(a) Enquiries should be made as to whether the visitor/contractor has any history of fire starting, discovering fires, extinguishing fires or being the 'victim' of other incidents where a perpetrator could not be identified. It is important to remember that some contractors that carry out hot works, may not have had sufficient training in risk assessment and management and may simply be careless and cause a fire without any malicious intent. Such 'carelessness' could however, result in a civil prosecution for damages against the person accidentally starting a fire.

- The investigator should ask to see any hot work permits to see if the works were carried out accordingly, for example, was an extinguisher to hand when jointing a copper pipe with a blow torch?
- Do they have public liability insurance and what are the conditions of that insurance? The investigator should also try to establish any previous claims for fire damage.

(b) People have been known to start fires so that they can discover them and possibly extinguish them in order to appear to be the 'hero'. This is commonly known to fire investigators as the 'hero syndrome'.

- See [7.25.1(b)] above.

(c) It may also be possible to check whether any records exist of previous fires at the visitor/contractor's other work and home addresses.

- This can be done by the investigator liaising with the police, fire service and insurance investigators to access their respective databases.

(d) The investigator must always consider, if appropriate, to ask the question directly: 'Do you know of, or have you experienced any other fires at your own home or other work locations, or at any other persons' home or work?' The reason for this is that most people never personally experience a fire in their life-time. To have experienced two or more would be unusual and may require further investigation, especially if not a contractor that has a hot working practice.

(e) The investigator should assess this person's knowledge regarding the incident's location against that which would normally be expected when considering the amount of times they had previously been to that premises. For example, if a pump engineer visits a site twice a year solely to conduct a one hour test on the sprinkler pumps and control system within the pump room and nowhere else in the building(s), but he or she appears to have extensive knowledge about the area of origin, which may have been some distance from the pump room, questions should be focussed on how the person has acquired such knowledge.

- Occasional visitors and contractors can be problematic in as much as they are less accountable than staff, residents, pupil/students, employees, owner/occupiers, family and friends but are more accountable than Members of Public. The investigator should endeavour to collate the movements and other premises that the visitor/contractor frequents to establish if there are any patterns or trends due to carelessness or malicious intent.

(f) If foul play is suspected, the police should be involved with the investigation, if not already. A check with the Criminal Records Bureau would reveal any previous involvement with deliberate fire setting or other criminal activities.

- If the investigator is not part of law enforcement, then the police must be notified if criminal activity is suspected or previous fire setting identified.

7.27.2 Would the visitor/contractor have benefitted from the fire?

(a) It may be difficult to establish how a visitor or contractor may have benefitted from a fire compared to an owner/occupier, however all motives should be explored.

(b) The investigator may need to establish more detail regarding the relationship between the visitor/contractor and the owner/occupier of the premises that has been damaged by fire. A visitor may have had an issue or altercation with the owner/occupier that has fostered resentment and possible revenge. An example is the customer of a restaurant that has complained about a meal and not received any recompense or apology. Although that customer may be at liberty to frequent the restaurant anytime, that liberty may allow him or her to gain their revenge by setting a fire, possibly with the intention of only causing some disruption to the business.

- As with many other situations, CCTV, records of attendees and witness testimony should be explored to collate movements of all visitors/contractors.

(c) Another common practice, particularly in the building industry, is when a contractor feels as if they are being 'held to ransom' over interim or staged payments, which means that they are being paid sometime after an element of work is completed. However, the commissioning of new work before they have been paid for the last completed work forces them to always be behind with cash-flow and they may become very resentful. When a contractor has a client that puts them in a position which almost forces them to take on additional work due to monies already owed by the client, not only resentment, but anger may manifest itself into fire setting for revenge. Revenge can be an emotive but powerful 'benefit' to someone who feels aggrieved, especially when money is involved.

- The investigator should try to establish working arrangements including payment methods and current workload of both the employer and the contractor.
- Try to identify any conflicts regarding payments and also the stock control payments on the premises, as it may be the contractor that looses out by the fire due to unpaid invoices relating to the stock stored on site.

(d) The investigator should, therefore, not only establish any previous visits or works carried out by the visitor/contractor but also what the direct or indirect agreements or contracts were in place between them and the owner/occupier. A contract can also be in place between a visitor and an owner/occupier, for example, the visitor of a gym would have a contract in the form of a membership agreement.

- The investigator should explore any membership agreements that have lapsed or been revoked causing a dispute between the visitor and the owners. If any individuals are identified, then their location at the time of the fire should be established and the police may need to be informed if not already involved.

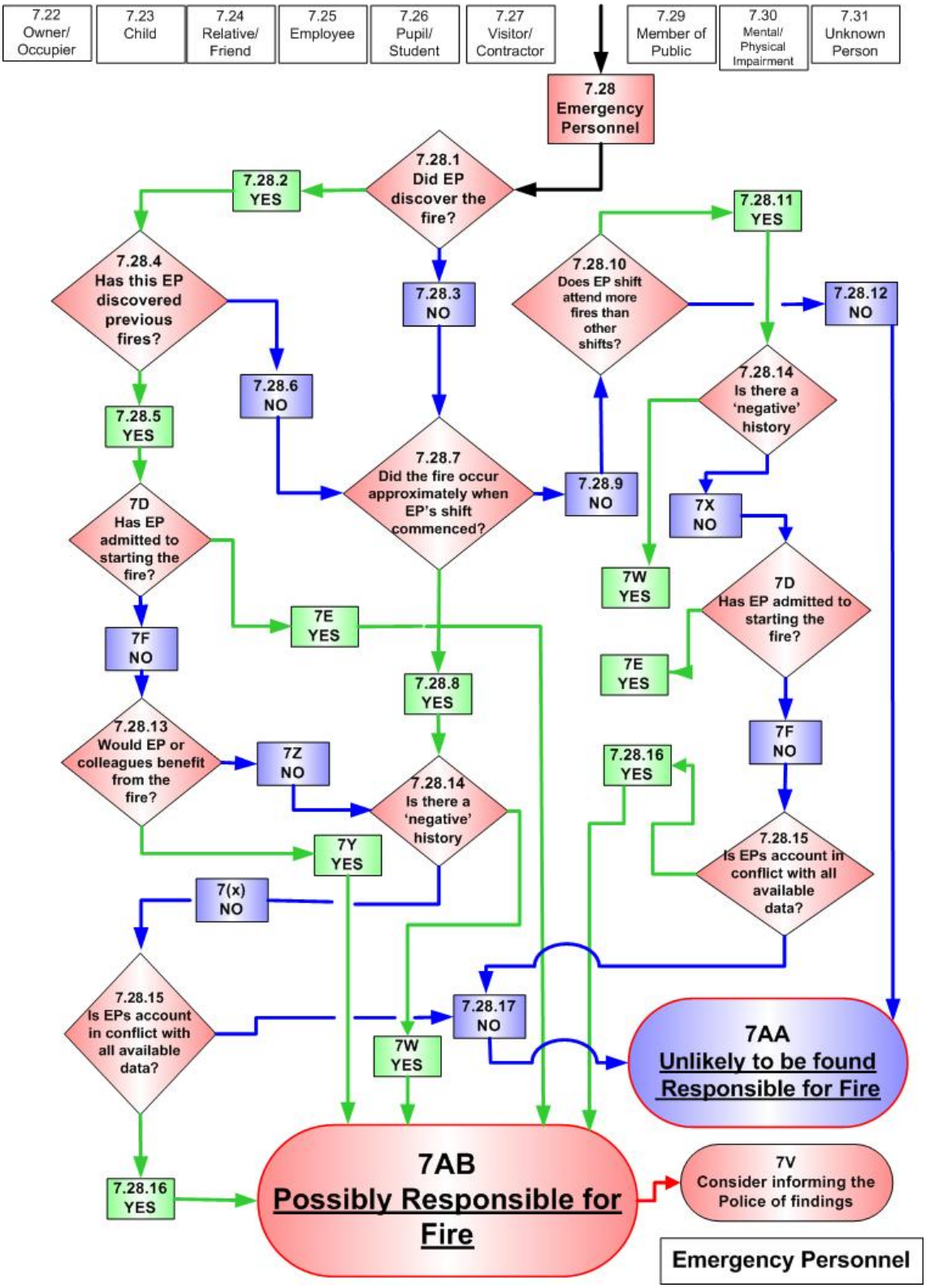
(e) Consideration should also be given to what effect the fire would have on the visitor or contractor; the former may be recompensed if they were hotel guests that had been disrupted by the event, whereas the latter may get additional work from the same fire if it were their remit for repairing the resultant damage. In such

circumstances, the investigator should establish if any similar incidents have occurred during any previous associations with the person in question.

- A hotel chain in the UK offers a money back guarantee if the visitor gets a disturbed sleep; a staged small fire would fulfil that criteria and would allow any visitor that made the claim to be completely reimbursed.
- In situations such as the example above, it may be possible to track the movements of certain visitors where there have been fires in hotels, for example, and place them within the premises each time there has been a fire.

FIRE INVESTIGATION ROAD MAP #7.28

EMERGENCY PERSONNEL



7.28 Emergency Personnel

This applies to employees who, in their role, respond to various types of emergencies and this group will include all personnel commonly regarded as emergency workers and not only the fire, police and paramedic services; it will also include roadside mechanics, voluntary rescue workers, St John Ambulance and other medics, military personnel and anyone that falls within the common perception of this trusted group, including priests, clerics, and other religious/faith officials.

Emergency Personnel receive unique training in the use of specialised equipment, which they routinely practice using, thereby gaining experience and in-depth knowledge regarding their own discipline. This may be very relevant to a fire or explosion investigation involving any Emergency Personnel involvement.

This FIRM may need to be cross-referenced with FIRM #7.25 – Employees and any other FIRM that the emergency personnel is in role at the time of the fire (for example FIRM #7.26 as a student, if going to night class for self-study). Although it is abhorrent to imagine any personnel in this category abusing the trust given by society, many have been known to start fires for a variety of reasons, such as the 'hero syndrome', boredom or financial gain, to mention but a few. Any emergency personnel must be positively excluded from having any involvement with the scene if the application of this FIRM is not to be followed.

7.28.1 Did emergency personnel discover the fire?

(a) It is not unusual for on or off duty emergency personnel to discover fires, probably because they are more aware of danger, are trained in how to respond to them and have the confidence to do so.
(b) As with other 'persons', the investigator needs to ask, what alerted them to the fire?
(c) It is worth clarifying with the emergency personnel why they were in or near the area of origin at the time of the fire. For example, if they state that they were on their way to work, establish where they live and whether this is a route they normally take into work. Consider consulting a map to establish the feasibility of the route.
(d) Ask if there was anyone else with them or in the immediate area when they discovered the fire.

7.28.2 Yes

(a) It has been established that an emergency service personnel discovered the fire and is therefore connected to the fire scene. Whilst emergency personnel may have the confidence to investigate unusual situations and render assistance relevant to their profession, such as smoke issuing from a building or a road traffic collision, it is a reasonably uncommon occurrence. Proceed to [7.28.4].

7.28.3 No

(a) It has been established by the investigator that the emergency service personnel did not discover the fire and at this stage cannot be connected with the fire scene. Proceed to [7.28.7].

7.28.4 Has this particular emergency personnel discovered previous fires?

(a) Although it has been mentioned in [7.28.1(a)] that it is not unusual for on or off duty emergency service personnel to discover fires, probably because they are more aware of danger and are trained in how to respond to them, it is unusual for them to discover two or more in their career, let alone over a short time frame and particularly when off duty.

(b) The investigator should establish from the emergency personnel themselves, from colleagues and from line managers as to any previous fires that he or she may have discovered. It is important that all the information is gathered, including any database information that can provide hard time data such as dates, times and first telephone caller numbers.

(c) Consideration should be given to other exciting ‘discoveries’ apart from just fires; witnessing any dramatic events, preventing ‘disasters’ and other such stories should be taken into account when considering the data being obtained about this fire. It has been known that some emergency service personnel develop the ‘hero syndrome’ (Ahuja, 2009)

(d) Ascertain from their line manager how they have performed in the past; how have their reactions been whilst on duty and have they ever been involved in any ‘heroic’ rescues which may have caused concern.

7.28.5 Yes

(a) It has been verified that the emergency service personnel has discovered at least one other fire, which is reasonably unusual with most emergency personnel. This would therefore link them to at least one other fire. Proceed to [7D]

7.28.6 No

(a) It has been established that the emergency personnel has not discovered another fire apart from this one. This will only link them to this fire. Proceed to [7.28.7].

7.28.7 Did the fire occur approximately when emergency service personnel's shift began or finished?

(a) Careful consideration should be given to the time of the discovery of the fire, the size and condition of the fire when responders arrived and an estimate as to when the fire may have been started in order to develop to the size and condition identified in conjunction with:

- The start time of the emergency personnel's shift or working pattern
- The finish time of the emergency personnel's shift or working pattern
- Any CCTV images from emergency personnel's workplace, perhaps showing personnel movement around the times of the fire.

(b) It may be necessary to obtain attendance records from line managers or human resource departments to ascertain the attendance records of the emergency personnel in association with previous fires. An example may be if the emergency personnel is always on one-days leave when a fire occurs; this may lead the investigator to give that person more attention.

7.28.8 Yes

(a) It has been identified that the fire occurred around the time that the emergency service personnel's shift started or finished. This may give a window of opportunity for a connection between the fire and the person. Proceed to [7.28.14].

7.28.9 No

(a) It has been identified that the fire did not occur around the start or finishing times of the emergency service personnel's shift. This may minimise any potential for a connection between them and the fire. Proceed to [7.28.10].

7.28.10 Does emergency service personnel's shift attend more fires than other shifts?

(a) The investigator should consider studying patterns and trends relative to the emergency service personnel's place of work, whether in urban or rural areas, comparing data such as:

- call rates compared to other shifts (disproportionately higher calls)
- types of calls compared to other shifts (disproportionate amount of fires)
- other emergency service personnel that have discovered fires across all shifts.

7.28.11 Yes

(a) It has been established that the emergency service personnel's shift attends a disproportionately higher amount of fire calls than other shifts at the same unit. Whilst this may be a coincidence, it does highlight the issue of 'coincidence' which will need to be explored. Proceed to [7.28.14].

7.28.12 No

(a) It has been established that the emergency service personnel's shift attends a similar amount of fire calls than other shifts at the same unit. There would therefore be nothing abnormal with these findings.

7.28.13 Would this emergency personnel or colleagues benefit from this fire?

(a) There are many ways in which emergency service personnel, and not just fire fighters, may obtain personal benefit from a fire. These may include:

- Increased self-esteem (the hero syndrome)
  - The investigator may get some indication of personality types from the shift leader, but must be aware that in some areas, the problem is systemic and cultural and the leader may also be part of the problem.
- Acceptance by colleagues (initiation 'ceremonies')
  - This is definitely a systemic and clandestine problem which can only be resolved by working with either external agencies, the organisation's Head Quarters or both.
- Excitement (born out of boredom) (Williams, 2005e)

- The investigator needs to establish a data log of all calls and compare them with the shift patterns that are responding to them to see if any one shift or person can be identified as responding to more fires than others.

- Political gain (if a department or unit is to be shut down or reduced in resources)
  - Most emergency service departments are not gangs of organised criminals and it is not difficult to identify the militant shifts and their locations if this type of fire setting is occurring. Call logs, shift patterns and individual attendees can be formulated into a report to identify such behaviour.
- Financial gain (where responders are retained/volunteers and get paid per call)
  - Although this is not such a problem with full-time emergency personnel, the latter will still get overtime if they go past the end of their shift. To this end, a similar methodology as above can be employed to identify repeat abusers.

7.28.14 Is there a 'negative' history?

(a) If the investigator has not become aware of any negative history with the emergency service personnel, he or she must try to ascertain if there have been any of the following; although this is not exhaustive:

- recent discipline issues
- personal issues
- conflict issues with management or work colleagues
- any history of fire setting

  - The investigator must not take for granted that because the person is now an emergency service personnel, he or she has not previously been involved in fire setting, even as a child (as opposed to 'fire play'). See FIRM [7.29] to explore and Member of Public that may have applied and been rejected for the fire or police department (Shears, 2009).

7.28.15 Is the emergency service personnel's account in conflict with all available data?

(a) The investigator must now compare all the data available to this fire with any account and data that the emergency service personnel have provided. If both data sets appear to be in conflict, the investigator must take every measure to verify the discrepancies.

7.28.16 Yes

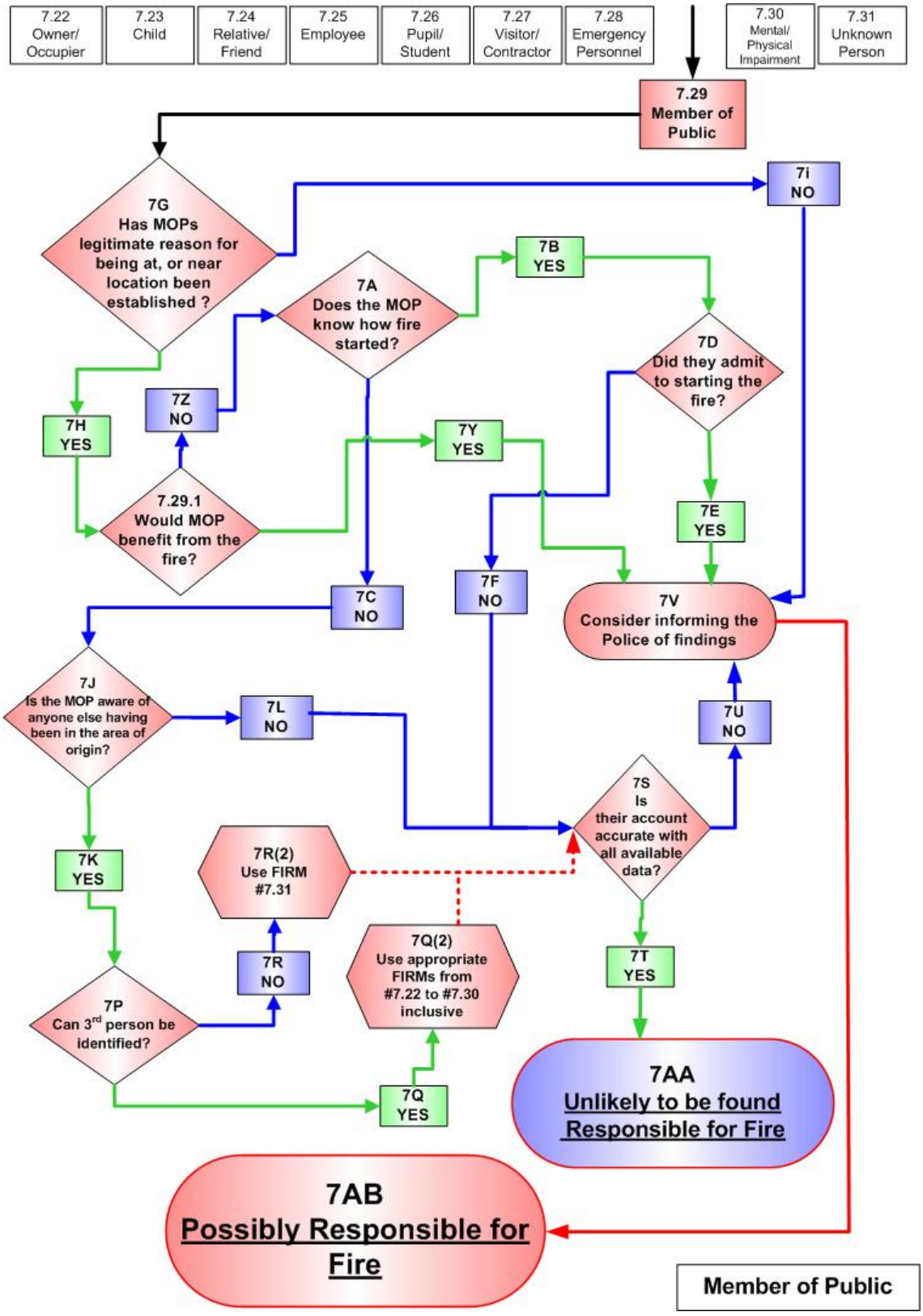
(a) Following careful consideration of all available data, the investigator has identified that there is conflict between the emergency service personnel's account and additional data gathered by the investigator. Proceed to [7.28.19]

7.28.17 No

(a) Following careful consideration of all available data, the investigator has not been able to identify any conflict(s) between the emergency service personnel's account and additional data gathered by the investigator. Proceed to [7.28.18].

FIRE INVESTIGATION ROAD MAP #7.29

MEMBER OF THE PUBLIC



7.29 Member Of The Public

This group will include any person that has no apparent interest in, nor is apparently associated with the scene of the incident. This may include a person that has discovered a fire and called the emergency services, or an identifiable individual observed on CCTV as being in the area at the time of the fire but not associated with it. An example may be a vehicle identified by its registration on CCTV, with a description of the driver obtainable from the images and observed driving near to where a fire had occurred during the early hours of the morning. The vehicle could be traced and the owner identified through normal enquiries. If this person was simply returning from shift work, he or she would be deemed as 'a member of the public'. A member(s) of the public must be positively excluded from having any involvement with the scene if the application of this FIRM is not to be followed.

7.29.1 Would the member of public have benefitted from the fire?

(a) Although it may be difficult for the investigator to see how a member of the public could benefit from a fire, information should be sought and analysed which may connect the member of the public to the fire scene or the owner of the fire scene.

(b) An example to emphasise the latter would be if a member of the public was seen walking his or her dog on a housing estate at various times, which can be linked to a series of rubbish bin room fires in the same location and same times, the member of public should be investigated as to their back ground:

- How long have they lived there?
- How long have the fires been occurring?
- Where did they live before?
- Were there fires at the previous location which may have now stopped when that person relocated?
- Are there any disputes with the landlord or other persons that could also be connected to the fires?

The 'benefits' could be satisfaction from revenge attacks, excitement from the fire and the emergency response, disruption caused to the landlord, etc.

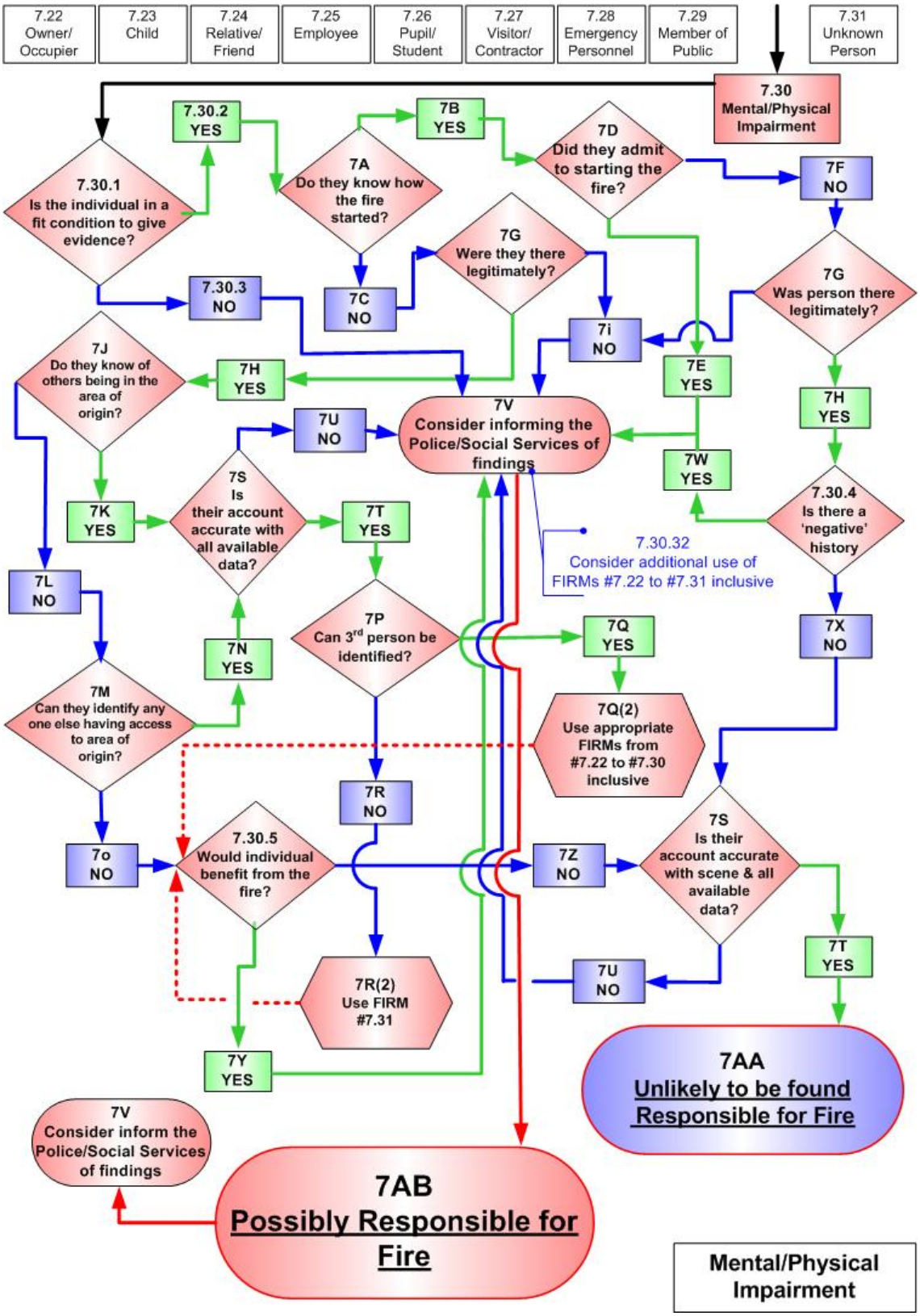
(c) The investigator should try to ascertain if the member of public has ever tried to become a fire fighter or police officer and been refused. It may be that the person has resentment at being refused and will set fires for revenge (Shears, 2009).

(d) The investigator should cross-reference the Member of Public with the other FIRMs as the Member of Public may have an indirect connection with the property that was on fire. For example, if a construction worker worked for an organisation building timber framed buildings and was sacked a week prior to this fire, he or she may have been in the area of one of the company's other sites out of hours, claiming to be returning home from a social evening and may have set the fire in revenge. He or she could be a witness but their indirect connection should not be overlooked.

(e) Another example of cross-referencing this FIRM with other FIRMs is when a Member of Public was attacked and set fire to on his way home from work late one evening. Following an extensive cold case review and investigating his personal role, it was identified that he had set fire to himself, possibly as a diversion for a large debt that was about to be discovered by his wife (Mansi and Carey, 2003).

FIRE INVESTIGATION ROAD MAP #7.30

MENTAL and/or PHYSICAL IMPAIRMENT



7.29 Mental/ Physical Impairment

This group will include any person that has any mental or physical impairment, irrespective of the degree of severity. The elderly should be considered within this FIRM due to their mental and physical decline associated with ageing. This FIRM may be cross-referenced to many of the other FIRMs within the 'Person' group, depending on their role associated with the incident.

Consideration should be given to the abilities of the person's:

- Mobility
- Sensory perceptions
- Memory function (dementia, Alzheimer's, etc)
- Effects of controlled medication and/or substance abuse
- Social behaviours (for example hoarding, Obsessive-Compulsive Disorders (OCD), etc.)

Any person(s) with mental or physical impairment must be positively excluded from having any involvement with the scene if the application of this FIRM is not to be followed.

7.30.1.1 Is the individual in a fit condition to give evidence?

(a) Expert medical advice may need to be sought to determine whether an individual that may have been identified with mental health or physical disability problems is fit enough to give evidence with respect to the fire investigation. Witness testimony is often not the most reliable type of evidence, even given by persons of sound mental status, but anyone recounting pre-, during or post-fire events may have been traumatised by the fire, which may distort their testimony; to interview a person that already has mental conditions that are predisposed to inaccuracies would possibly not assist with the investigation.

(b) As discussed in [6.7(c)] above, older people are at a high risk of injury from fire and their mental and physical capabilities should be carefully considered by the investigator (whilst remaining respectful that many older people are still very mentally and physically capable). In the USA, UK and Japan research has shown that the risk to older people (over 65 years old) becoming injured or killed in a fire

significantly increases compared to all other age groups (NZFSC, 2007). Apart from age-related decline, the investigator should also consider the individual's:

- Mobility
- Medication
- Substance use such as (but not exhaustive)
    - Alcohol
    - Illegal drugs
    - Legal 'highs'
    - Solvent inhalation
- Risky known behaviour (such as careless disposal of smoking materials, unattended cooking, etc)

(c) If the investigator has any doubts about the capability of the person or the severity of their disability with regard to the outcome of interviewing them or the stresses it may cause them, go to [7.30.3]

7.30.2 Yes

(a) The investigator has confirmed that the impaired individual is in a fit enough state to be asked about the fire.

7.30.3 No

(a) The investigator has been given advice, or has made a personal judgement that the impaired individual is not in a fit enough state to be asked about the fire. Proceed to [7.30.37]

7.30.4 Is there a 'negative' history

(a) It is necessary to ask the impaired person or their carer, if they have 'experienced' any previous fires, either at the premises where this fire has occurred, or at any other premises.

- The investigator should establish if there has been any history of minor fire damage, such as burnt handles on cooking utensils, cigarette burns on furniture or carpets, etc, potentially due to their immobility or motor functions.

(b) It may also be prudent to enquire through other agencies, such as the fire service, police or insurance agencies whether there is any history of previous fires on any of their databases, relating to either the property, previously occupied properties by the person or the person themselves.

- People with mental health issues may display fire setting behaviour but, due to their health conditions, are not arrested or treated for that specific behaviour. Barker (1988) identified that sometimes, the only way for them to be treated for fire setting is by arresting them and processing them through the criminal courts.

7.30.5 Would the individual benefit from the fire?

(a) The investigator must consider any circumstances in which the impaired person may benefit from the fire. Although it may be difficult for the investigator to see how an impaired person could benefit from a fire, information should be sought and analysed which may connect the person to the fire scene or the owner of the fire scene.

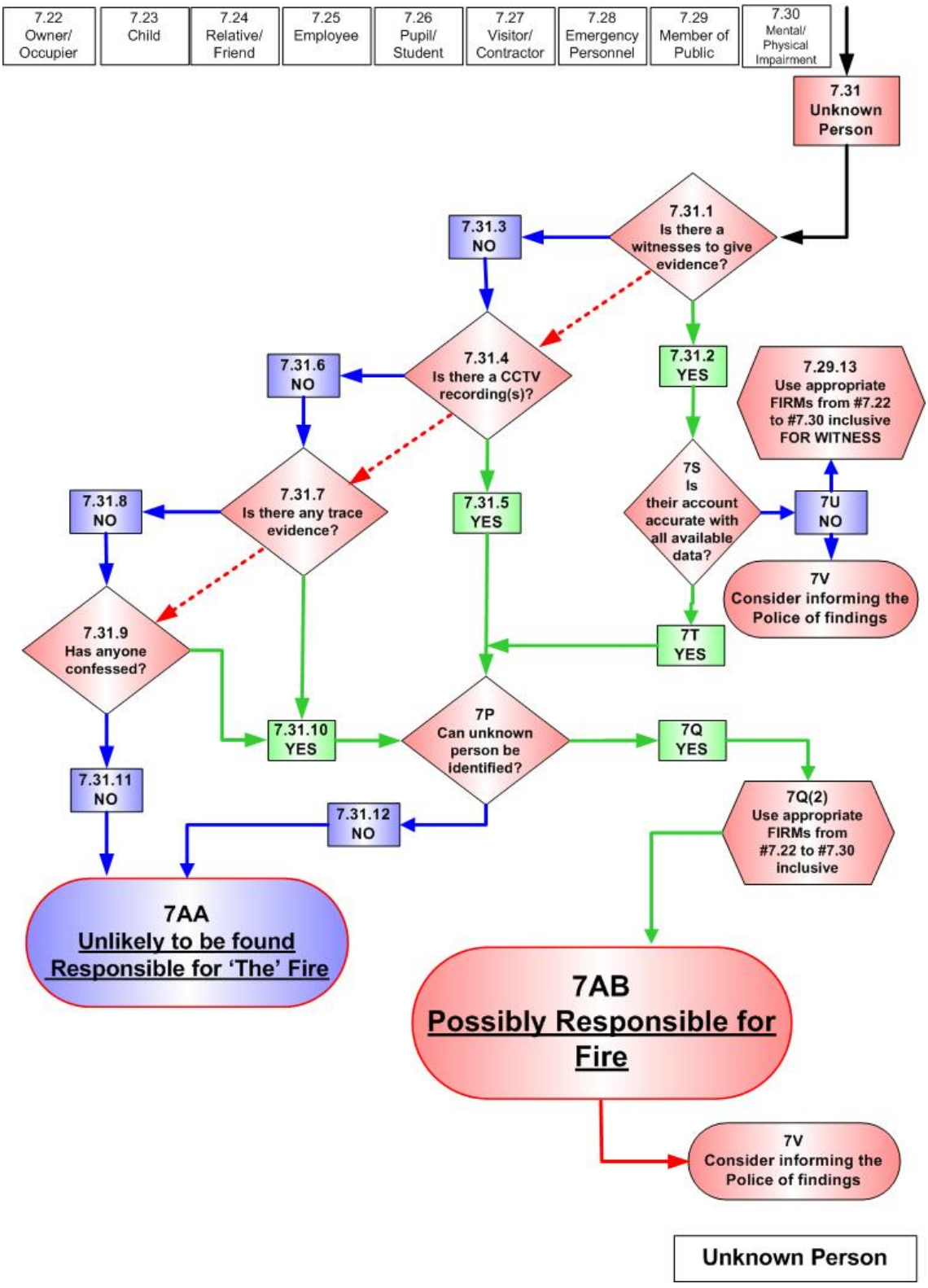
(b) An example to emphasise the latter would be if an impaired person was attending a therapy centre, where there had been previous fires in the same location and at the times of their attendances, the impaired person should be investigated as to their back ground:

- How long have they been attending the centre?
  - Obtain dates when they started, any breaks in treatment and appointment times.
- How long have the fires been occurring?
  - Compare the dates and times of fires to the latter.
- Where did they attend before?
  - Obtain any other centres they may have attended.
- Were there fires at the previous location, which may have now stopped when that person relocated?
  - Compare dates and times of any fires with the latter.
- Are there any disputes with the centre staff or other persons there that could also be connected to the fires?
  - A dispute may exist between one or more staff and this may reflect on that person(s) having property or themselves targeted.

The ‘benefits’ could be satisfaction from revenge attacks, excitement from the fire and the emergency response, disruption caused to the premises’ managers, etc.

FIRE INVESTIGATION ROAD MAP #7.31

UNKNOWN PERSON



7.31 Unknown Person

This is a person that cannot be identified by lawful name. This may include a witness account of an individual seen within the vicinity of the incident or observed on CCTV but that individual is not known to those observers. It may also include evidence of unidentified human agency presence at the time of, or shortly before the incident. Unknown persons must be positively excluded from having any involvement with the scene if the application of this FIRM is not to be followed.

7.31.1 Are there witnesses to give evidence?

(a) The investigator must try to secure any witnesses that may have any information about the fire, no matter how insignificant it may appear to be at the time.

(b) Ensure that all names and contact details are recorded.

(c) It may be necessary to obtain the first caller's number from the mobilising control that despatched the emergency response to ask them what alerted them to the fire and the size of the fire when they made the call.

7.31.2 Yes

(a) It has been confirmed that there is/are witness(es) to the fire.

7.31.3 No

(a) It has been established that there were no witnesses to the fire. Proceed to [7.31.4].

7.31.4 Is there a CCTV recording?

(a) The investigator must survey the area around and leading to the fire for any CCTV cameras, public or private.

(b) If any CCTV cameras are available, the investigator should make every effort to contact the owner to request any recordings specifying:

- The date
- The time frame required
- The exact location

(c) It may be possible to identify individuals who may be responsible for the fire, potential witnesses, vehicles or any other information that may assist in the investigation.

7.31.5 Yes

(a) CCTV has identified a person as being at or near to where the fire occurred. Proceed to [7.31.16] also considering [7.31.7]

7.31.6 No

(a) There was no CCTV in or near the fire that could be used to assist with the investigation process. Proceed to [7.31.17].

7.31.7 Is there any trace evidence?

(a) If the fire is suspected to be a deliberate fire, the police should be requested to attend if not already in attendance. Ensure that all samples have been collected in accordance with police protocols, packaged and labelled appropriately to ensure continuity of evidence.

(b) DNA can be retrieved from items such as disposable lighters, matches, cigarettes, blood.

(c) Shoe marks can be recovered and used to identify the footwear of a suspect, so every effort should be made to approach the scene in an unorthodox approach path to preserve any possible contamination/ destruction of potential evidence.

(d) Finger prints can be recovered from shiny surfaces in fire scenes that are covered in soot using special techniques such as liquid latex removal.

7.31.8 No

(a) Either there is no evidence that can be retrieved from the scene, or the scene has not been secured and has subsequently become contaminated.

7.31.9 Has anyone confessed?

(a) The investigator needs to establish whether anyone has confessed or admitted to starting the fire. This may mean contacting the first responders, witnesses or, if a suspected deliberate fire, Crimestoppers.

7.31.10 Yes

(a) Either someone has confessed or admitted to causing the fire or there has been trace evidence discovered at the scene. Proceed to [7.31.16].

7.31.11 No

(a) No one has confessed or admitted to causing the fire.

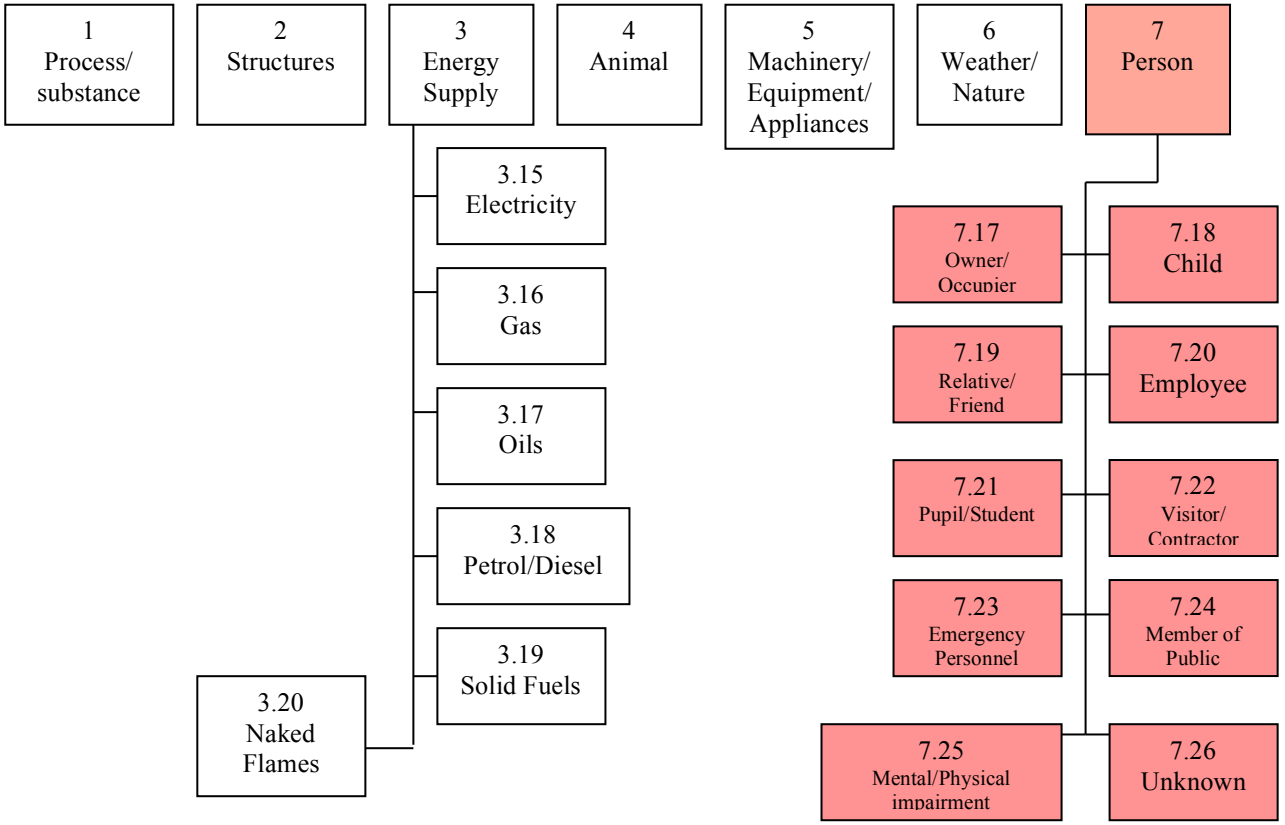
7.31.12 No

(a) It has not been possible to make a positive identification of the third party.

7.31.13 Use appropriate FIRM #7.22 to #7.30 for witness 'role' at the scene

(a) As there are discrepancies with the witness testimony and the data that the investigator has gathered so far, it will now be necessary to establish the role of the witness and follow the appropriate FIRMs # 7.22 to #7.30.

Appendix One



Titles of Fire Investigation Road Maps (FIRMs)

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