

Running Head: PREVENTING AND MANAGING ESFR FIRES

Preventing and Managing ESFR Protected Warehouse Distribution Center Fires in Rialto

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Appendices Not Included. Please visit the Learning Resource Center on the Web at <http://www.lrc.dhs.gov/> to learn how to obtain this report in its entirety through Interlibrary Loan.

Abstract

The problem was that Rialto had experienced growth of ESFR warehouses. Community vulnerability was unknown. RFD was missing opportunities for prevention and management of fires. The purpose of this descriptive research project was to identify methods of preventing and managing fires. The research questions addressed were: (a) what community risks existed, (b) what methods of prevention were being utilized, (c) what methods of fire management were being utilized, and (d) what methods for prevention and fire management should RFD utilize. A literature review, feedback instrument and interviews were utilized. Maintenance, commodity monitoring, and obstructions were prevention findings. Safety, defensive strategy, rapid fire growth and large fire flow were fire management findings. The researcher offered pre-event, event and post event recommendations.

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Introduction

Many communities have warehouse distribution centers within their jurisdiction. Jakubowski (2005) and McCafferty (2006) mention that generally, warehouse distribution centers present significant fire prevention and protection challenges for fire departments. Brannigan (1997) considers large, state of the art warehouse distribution centers to be a waiting fire suppression Pearl Harbor. The problem was that Rialto Fire Department (RFD) had experienced rapid growth of early suppression fast response (ESFR) protected warehouse distribution centers within its jurisdiction. RFD had not assessed what vulnerability such warehousing operations presented to the community and its firefighters. RFD was missing opportunities to identify methods for preventing and managing newly constructed ESFR protected warehouse fires that could occur within its jurisdiction.

The research purpose was to identify methods of preventing and managing ESFR protected warehouse fires that may occur in Rialto. A descriptive research method was utilized including a literature review. Best industry methods of preventing and managing ESFR protected warehouse distribution center fires were identified. A feedback instrument was developed and sent to 106 Southern California fire agencies to identify what methods they utilize to prevent and manage ESFR protected warehouse fires in their jurisdiction. Recommendations for RFD to prevent and manage ESFR protected warehouse distribution center fires were identified. Seven personal interviews were conducted with 3 fire marshals, 3 fire protection engineers, and the warehousing operations division head of Target Corporation. This research project included the following questions: (a) what risks to the community of Rialto do ESFR protected warehouse distribution centers pose in the event of an ESFR failure?, (b) what methods are being utilized in Southern California to prevent ESFR sprinkler system failures in warehouse

distribution centers?, (c) what methods are fire agencies in Southern California utilizing to manage ESFR protected warehouse distribution fires should they occur in their community?, and (d) what methods should Rialto Fire Department utilize in preventing and managing fires in ESFR protected warehouse distribution centers within its jurisdiction?

Background and Significance

RFD is a full service fire agency which provides fire suppression, hazardous materials response, fire prevention, paramedic advanced life support (ALS) service and ambulance transport, technical rescue, community risk reduction, arson investigation and other services. The fire jurisdiction covers 23 square miles. Rialto's population is 105,000. RFD has four fire stations and a daily staffing of 22 suppression personnel. Daily shift staffing consists of 5 captains, 5 engineers, 2 fire-fighters, 9 fire-fighter paramedics and 1 shift battalion chief. RFD staffs four fire engines, one ladder truck, three paramedic ambulances, and a battalion chief. Engine and truck staffing is 3 personnel and paramedic ambulance staffing is 2 personnel. Administration consists of the fire chief, deputy fire chief, training battalion chief, 3 shift battalion chiefs, EMS coordinator, fire marshal, fire inspector, executive assistant to the fire chief, two accounting assistants, and a part-time mail clerk. RFD responds to over 11,000 calls annually. It has 600 structure fires annually with approximately 120 working fires per year.

RFD is a participant in the California Master Mutual Aid Agreement and has mutual aid and automatic aid agreements with San Bernardino County FD, San Bernardino City FD, and Colton FD. The city is located in a major fault zone with the San Gabriel fault located to the west, Rialto fault located to the east, San Andreas Fault located to the north and the San Jacinto fault, located to the south (Rialto, 2002). In addition, Rialto (2002) is located in between

wildland-urban interface zones on the north and south ends of the city. This threat is successfully mitigated by a spring and fall weed abatement program.

Environmentally protected lands are identified within and outside of the eastern boundary of Rialto. In addition, protected lands are identified within and outside of the southern boundary near the Agua Mansa area which drains into the Santa Ana River (N. Barajas, personal communication, September 20, 2007). Historically, this area was inundated by a 500 year flood in the 1860's and the town of Agua Mansa was never rebuilt (Rialto, 2002). Flooding threats have been mitigated by county flood control projects.

RFD does not have the resources to manage a major warehouse fire without mutual aid. Rialto has experienced two major warehouse fires in the researcher's 28 year history with RFD and has had to rely heavily on the California Master Mutual Aid agreement to manage those fires. It is important to note that both were protected by conventional fire sprinkler systems and were small in comparison to the huge ESFR warehouse facilities now located in Rialto.

Jakubowski (2005), J. McCafferty (2006) and Brannigan (1997) recognize that major warehouse distribution centers present a significant fire prevention and protection liability for any community. Parlor (2003) points out that during the last 20 years, major changes in how goods are stored and distributed have occurred. Warehousing is big business (Parlor, 2003), business margins are tight, and this has forced a move towards distribution centers to keep costs low. Parlor (2003) points out that in Great Brittan, there are 2500 warehouse fires annually and in the 1990's, Great Brittan experienced 240 very large warehouse fires. Parlor (2003) defines a large loss warehouse fire as exceeding 50,000 pounds. Likewise, Naylis (1999) mentions that retail stores were 10,000 square feet in the past but are now typically 100,000 square feet. Naylis (1999) mentions that warehouses were 100,000 square feet in the past but are now typically

1,000, 000 square feet. The city of Rialto has experienced this growth and change in warehousing distribution centers first hand.

Norma Barajas is the Fire Marshal at Rialto Fire Department. In a personal communication with her on September 20, 2007 she revealed that since 2003, Rialto has had 9 ESFR protected warehouse distribution centers built including: (a) Target Warehouse Distribution center which has two huge separate warehouses, one with 1,554,128 square feet, and the other with 1,767,491 square feet. They store and distribute every commodity available in a Target store. The project cost \$300 million to build and has an inventory that is worth an estimated \$2 billion. It is located near a fireworks factory to the east and a residential neighborhood to the north, east and south. Three hundred and thirty full time employees work at this facility; (b) Solo Cup is an 882, 230 square foot warehouse distribution center that stores and distributes styrofoam, plastic, and paper cups, plates, forks, napkins, etc. The project cost \$70 million to build, has an inventory that is estimated at \$6 million, and employs 70 full time employees; (c) Unilever (South) is a 1, 056,484 square foot warehouse that supplies area stores with laundry detergents, soaps, cosmetics, and aerosols. One unique feature of this building is that it has 88,000 square feet of aerosols, which are separated from the rest of the commodities and covered with a control-mode, in-rack sprinkler system. The rest of the warehouse is protected by an ESFR sprinkler system. The Unilever (South) an \$80 million project, employs 210 full time employees and has an inventory worth \$35 million; (d) Unilever (North) is a 271, 494 square foot complex that warehouses and distributes computers, appliances, and other electrical commodities. The project cost \$20 million to build, has an inventory value of \$10 million, and has 30 full time employees; (e) Sweet Life is a 47,786 square foot cold storage warehouse that stores and distributes ice cream and other cold food items. The project cost \$3.3

million, has an inventory value of \$3 million and has 10 full time employees; (f) Commodity Logistic is a 370,335 square foot warehouse that stores and distributes appliances, microwaves, and computers. The project cost \$26 million to build, will not disclose their inventory value, and has 20 full time employees; (g) MGA is a 435,733 square foot warehouse that stores and distributes plastic toys. The project cost \$35 million, has an inventory worth \$115 million, and employees 35 full time employees and 100 seasonal part time employees; (h) a vacant 55, 916 square foot warehouse that cost \$3.5 million to build (N. Barajas, personal communication, September 20, 2007). The total values are significant with project costs of \$537.8 million, 705 full time employees, 100 part time employees, and inventory costs estimated at \$2 billion, 169 million.

Rialto also has 3 other huge warehouse distribution centers that are protected by control-mode sprinkler systems including: (a) Toys R Us, a 1,000,000 square foot warehouse that supplies Toys R Us retail stores; (b) Staples, a 500,000 square foot warehouse the supplies Staples stores with electronic equipment, office furniture, and stationery products; and (c) Black and Decker, a 700,000 square foot ware house the supplies area stores with Black and Decker tools and equipment (Personal communication with Norma Barajas on September 12, 2007).

The potential for a catastrophic warehouse fire is always present. For example, in 1991, Madison Wisconsin experienced a fire in a cold storage warehouse Cobb, (2000). The fire occurred in high rack storage. This resulted in shelves failing which caused the roof to fail. The fire sprinkler system was over-run and not matched for the high piled stock resulting in a \$100 million loss (Cobb, 2000). Internationally, a huge plastics storage warehouse fire in Nuremberg Germany burned 890 tons of granulated plastic, destroyed the warehouse and resulted in a 3.5

million deutschmarks loss. Over 100 firefighters fought the fire which required a fire flow was 9,000 gallons per minute (Neuhof, 1998).

Bradish, (2006) writes about a fire in a plastics-recycling warehouse. The building was equipped with sprinklers that were not operational. The building had no preplan. Forty fire departments responded from Indiana, Kentucky, and Ohio and was declared under control 27 hours after initial alarm. The fire required 325 firefighters, 60 apparatus including engines, aerials, rescues, foam, hazardous material units, mobile command posts, and ambulances (Bradish, 2006). The fire resulted in a \$4.5 million loss. Three firefighters were injured and one aerial damaged (Bradish, 2006). Shouldis (2001) writes about a warehouse in Philadelphia that lasted 8 days, required 275 firefighters, 57 apparatus, ten alarms and resulted in three injured fire fighters. Shouldis (2001) mentions that warehouse fires are large scale events that will overwhelm local resources, involve many support agencies, and have a negative effect on economic and employment in the community.

For a historical perspective, on December 22, 1910, 21 firefighters were killed at a stockyard and cold storage warehouse in Chicago (Firehouse, 1999). The Worchester cold storage warehouse fire killed six firefighters in 2000 (Eisner, 2000). Fire Engineering (1954) mentioned a warehouse fire in Brooklyn that injured 21 firefighters, five seriously. The fire resulted in a \$3,000,000 loss. Five alarms were sounded requiring fire 40 fire apparatus, 2 fire boats, and a coast guard cutters. Similarly, Fire Engineering (1949) reported a warehouse fire in Rochester New York in 1949 that resulted in 21 fire fighters being injured or overcome by smoke as a result of the night long fire. One engine was seriously damaged. A warehouse fire in Boston (Fire Engineering, 1965) killed 5 firefighters and injured 13 others in 1965.

In more recent history Comeau and Duval (2001) discuss a warehouse fire that occurred in 2000 in Phoenix, Arizona. It was one of the largest fires in Phoenix's history and occurred at the Central Garden and Pet Supply and Cardinal Distributors. The loss is estimated in hundreds of millions. This warehouse was equipped with a modern sprinkler system (Comeau and Duval, 2001).

As previously mentioned, Rialto has experienced 2 serious warehouse fires in the last 28 years that have resulted in conventional sprinkler system failures (N. Barajas, personal communication, September 20, 2007). Both sprinkler systems were operational at the time. One fire occurred in a Georgia Pacific warehouse. The fire started outside of the warehouse in cardboard rubbish. It quickly spread to the warehouse due to strong Santa Ana wind conditions and overwhelmed the sprinkler system. The warehouse had large amounts of plastic and cardboard commodities. Similarly, several years later, RFD experienced a fire in a warehouse that manufactured plastic milk bottles. The fire was caused by an electrical short in a conveyor belt system and quickly overwhelmed the fire sprinklers. Because of the lessons learned in the Georgia Pacific fire, RFD responded its type I foam tender. The fire was extinguished utilizing foam and the warehouse fire was stopped, but not before significant damage was done to storage. Experience in Rialto has demonstrated that once plastics become well involved with fire, water based fire sprinkler systems become less effective (personal communication with Norma Barajas on September 20, 2007).

When considering the future potential for fire loss, job loss, tax base loss, environmental damage, massive fire resources required, and the long term impact on the local economy, it is imperative that RFD take action to avoid the community pain associated with a warehouse fire in Rialto. This applied research project is related to the National Fire Academy (NFA) and

Executive Fire Officer Program (EFOP) course, *Executive Analysis of Fire Service Operations in Emergency Management EAFSOEM-Student Manual, Unit 4:Community Risk/Capability Assessment*, which mentions that: (a) Risk mitigation should keep pace with technological changes in the community related to new business threats locating in the community; and (b) risk management should consider community risk with a pre-event, event, and post-event examination (Federal Emergency Management Agency [FEMA], 2007). In addition, this research project is related to the USFA *Executive Development (R123) Research Self Study Workbook* (FEMA, 2004) operational objectives of: (a) Promoting a comprehensive, multi-hazard risk-reduction plan in the community; and (b) responding to emerging issues in a timely manner.

Finally, this research project is significant because of its regional application. San Bernardino County cities such as Colton, Fontana, San Bernardino, Redlands, Ontario, Victorville, Apple Valley and San Bernardino County Fire Agency's unincorporated areas have experienced similar growth in the warehousing industry. Nationally, the information discovered in this research project is valuable to fire departments that protect Home Depot, Lowe's, Costco, and similar warehouse type stores as well as ESFR warehouses.

Literature Review

Pre-Event: Fire Sprinkler Systems for Warehouse Distribution Centers

Gagnon (2005), and Golinveaux and Hankins (2006), mention two basic functions of fire sprinkler systems: (a) fire control, and (b) fire suppression. Viking Sprinkler Corporation (2001) agrees and mentions that conventional sprinkler systems are control mode sprinklers whereas ESFR sprinklers are suppression mode sprinklers. Welch (2000) adds that suppression mode

sprinklers are engineered so that the first few activated heads provide sufficient water flow to reduce fire to an acceptable level, or extinguish the fire.

Welch (2000) mentions that large drop sprinklers were developed in the 1980's to handle high challenge commodities. However, they are considered to be a control mode sprinkler. ESFR sprinklers were developed in the late 1980's by Factory Mutual and are the first sprinkler system developed that suppresses fire. They (Welch, 2000) produce many large droplets, early in the incipient phase of the fire. Welch (2000) and Viking Sprinkler Corp (2001) state that ESFR sprinkler effectiveness is dependent upon early operation of the system to deliver large amounts of water through the fire plume for the maximum fire expected from the commodities. This is also in agreement with Record (2001), Sprinkler Age (2003), and Fletcher (2001) who add that there is less tolerance for design and installation factors when compared to control mode sprinklers. Record (2001), Sprinkler Age (2003), and Fletcher (2001) emphasize that early, quick operation, directly above fire penetrates the fire plume at a high pressure and is expected to extinguish the fire. Likewise, Fire International (1997) mentions quick fire suppression at point of origin, preventing warehouse collapse. Shultz (2006) adds that ESFR fire flow requirements can be up to four times what is required for a large retail store equipped with ESFR often requiring an onsite water storage tank to meet fire flow requirements.

Fire International (2003) mentions ESFR technology has been widely accepted internationally in the warehouse distribution storage industry in the UK, Germany, France, Ireland, New Zealand, Australia, China, Korea, Japan, Singapore, Thailand, and Taiwan. Fire International (2003) reports that ESFR technology can protect class 1-4 commodities.

Schultz (2006), Welch (2000), Fletcher (2001), and Record (2001) point out that ESFR technology advantages relieve requirements for in-rack sprinklers in buildings with up to 40 feet

of rack storage. Fletcher (2001) mentions greater flexibility in warehouse operations. Sprinkler Age (2003) agrees and, in addition, mentions minimal water damage, a wide protection of commodities, and easier modification of rack configurations as advantages of ESFR technology.

Fire Protection Group, (2007) mentions that ESFR technology costs 30-50% less than conventional in-rack systems. Schultz, (2006) and Fire Protection Group, (2007) state that storage racks can be moved and modified adding to flexibility. Schultz, (2006) adds that ESFR flexibility allows for commodities relocation without concern for automatic sprinklers, piping, and system design. In addition, Schultz, (2006) mentions that forklift drivers don't have to worry about water damage from broken sprinklers.

However, ESFR flexibility does not come without trade-offs. Viking Sprinkler Corporation (2001) mentions stringent rules for installation including: (a) Systems must be properly designed and installed according to testing standards; (b) ceiling slope must not to exceed 170 mm/ m or 2" in 12"; (c) roof construction limitations; (d) installation location; and (e) obstructions to flue spaces and sprinkler heads. Gagnon (2005) and Fletcher (2001) add that there are commodity limitations to consider, especially plastics.

Changes in commodities are a huge issue that can limit ESFR flexibility. Fire International (1997) found that ESFR systems can protect class 1-4 commodities but not flammable liquids or expanded plastics. In contrast, Vincent, Kung, Leblanc and Troup (1998) found that ESFR technology could protect cartoned and un-cartioned flammable liquid storage when combined with large-orifice in-rack sprinklers installed in the longitudinal flue spaces. Vincent et. al. (1998) found that ceiling only ESFR were effective in protecting palletized storage configurations. Likewise, Jakubowski (2005), Fletcher (2001), and Naylis (1999) mention that improperly designed ESFR systems, matched with the wrong commodities, can

result in major failure. James (1999) emphasizes the importance of good project planning, annual code inspections, maintenance, house keeping, checking for obstructions, and assuring the ESFR system is designed to handle occupancy changes is critical for maximum ESFR performance.

Obstructions to ESFR sprinkler systems are commonly mentioned. Sprinkler Age (2003), Viking Sprinkler Corporation (2001), and Fire International (1997), mention that ESFR technology is especially vulnerable to obstructions of joists, girders, braces, plumbing, electrical. Such obstructions can cause splashing and cooling that can delay additional sprinkler activation. All agree that obstructions are the most critical factor in engineering a properly functioning ESFR system.

Automatic smoke and heat venting, combined with ESFR technology is a highly controversial issue discovered by the researcher. Viking Sprinkler Corporation (2001) does not recommend it. In contrast, Schultz, (2006) mentions that the International Building Code 2003 edition requires smoke and heat vents in any moderate-hazard storage occupancy. In discussing this controversy, Schultz, (2006) mentions that NFPA sprinkler protection criteria are based on the assumption that roof vents and draft curtains will not be used. Schultz (2006) states that building owners are faced with conflicting opinions on smoke and heat venting. Sice (2004) adds that automatic smoke and heat venting represents an unresolved controversy in the ESFR protected warehousing industry. ESFR technology is not necessarily designed to work with smoke and heat venting (Sice, 2004). Sice (2004) explains that the primary role of smoke and heat venting is to extract smoke and fumes. Some engineers criticize such systems for feeding oxygen to fuel the fire, and delaying ESFR sprinkler activation by preventing the necessary rise in temperature. Sice (2004) points out that those in favor of smoke and heat venting systems

stress that the biggest threat to the life of firefighters is the smoke produced by a modern warehouse fire.

Sice (2004) points out that the Swedish Fire Research Board recommends manually operated smoke and heat venting with ESFR and high fire load warehouses. Sice (2004) adds that tests in the US and UK show that temperatures in buildings without ventilation can be 3 times as high. Fire Protection-South Africa (2004) adds to this controversial issue by stating that building owners need to especially seek professional advice on smoke and heat ventilation systems.

Prevention and Pre-Event Fire Department Action

Gagnon (2005) feels that fire department involvement in warehouse distribution center maintenance programs is essential. Gagnon (2005) points out that fire pump testing is imperative because they are critical components of an ESFR system and failure is not an option. Gagnon (2005), in agreement with Schultz (2006) recommends NFPA 25, table 8.1 for guidance.

Gagnon (2005) recommends strict adherence to NFPA 13, 2002 Table 8.12.5.1.1 for obstruction management. This is probably the single most important building maintenance issue in ESFR protected warehouses discovered by the researcher. McCafferty (2006) agrees and stresses that the first few ESFR heads must deliver enough water to suppress a growing fire. In addition, McCafferty (2006) points out that water tanks and pumps are essential ESFR components because of huge fire flow demands in modern warehouse distribution centers. McCafferty (2006) points out that building features, lights, ducts, electrical conduits, and cable trays can obstruct ESFR systems.

Whiteley (2006) points out that plastic commodities, once ignited, become burning flammable liquids constituting a severe hazard. Water only systems can provide suppression if

properly engineered. Whiteley (2006) states that tests show carefully engineered foam systems are consistently effective in totally extinguishing such fires whereas water only systems may fail.

Pre-construction coordination amongst all trades to prevent obstructions is essential (Schultz, 2006). He emphasizes that when approving or inspecting racking assure and enforce flue space codes, don't allow solid shelving and refer to NFPA 13 ESFR standards (Schultz, 2006). Schultz (2006) cites problems with NFPA's definition of solid shelving.

Modern warehouses have special considerations. For example, Whiteley (2006) mentions that separate enclosed zones for aerosol storage are essential. Whiteley (2006) cites that the main dangers of aerosols include forklift impacts, dropped pallets, and deterioration of old commodities. Nugent (1998) adds that it is essential to pre-plan and enforce codes for pool chemicals storage. Nugent (1998) mentions that pool chemicals produce chlorine gas in a fire, contamination, and runoff problems. In addition, pool chemicals can react with dry chemical extinguishers resulting in an explosion. Nugent (1998) recommends attacking pool chemical fires with large fire streams and hazardous materials response and make sure these areas are identified in pre-plans.

Nugent (1998) states that the best strategy is defensive combined with pumping to the fire sprinkler system until pool chemical fires die down. Nugent (1998) points out that firefighters need level A or B protection when these chemicals are involved in fire but, level A or B hazardous materials protection does not offer thermal protection necessary for firefighting. Nugent (1998) cites the following points be identified in pre-event training: (a) attack pool chemical fires with large volumes of water, (b) assure rapid intervention is available, (c) evacuation of all personnel is essential if pool chemicals are involved, and (d) ventilate quickly with special attention to SCBA. In addition, Nugent (1998) points out that the danger of

incompatible pool chemical storage is always a fire prevention issue because these chemicals are oxidizers and they react with many compounds such as dry chemical extinguishers, oil, floor cleaning materials other pool chemicals, paints, solvents, metal objects, and organic liquid. Building owners (Nugent, 1998) and fire-fighters must know the signs of reaction including bubbling, smoking, burning, hissing, strong smell. If these conditions exist, evacuate the warehouse (Nugent, 1998).

Warehouse distribution center storage is a challenge to firefighters. High piled storage fires accelerate rapidly, threatening occupants, firefighters, and the building early in the fire (James, 1999). Schultz, (2006) points to the need for continual education of building owners regarding the dangers of commodity changes which may render sprinkler systems ineffective. Fire Departments need to inspect and evaluate systems regularly for commodity changes (Schultz, 2006).

Allen and Molina (2006) state that computer modeling tools are often used in predicting fire development and its effects on fire and smoke generation. They feel modeling techniques have limited applicability to determine sprinkler designs in modern warehouses. Allen & Molina (2006) also mention that many variables including commodity class, packaging, storage configuration, aisle width, storage height, pile stability, and clearance between top of sprinklers must be taken into consideration in maintaining ESFR effectiveness. Golinveaux and Hankins (2006) state that installation cost is often the driving force for warehouse building owner choices of sprinkler system. Meeting the challenges of an ever changing storage industry is a challenge for fire prevention (Golinveaux and Hankins, 2006).

Fire-fighter code knowledge of warehouse distribution centers is problematic. For example, Jarrett (1995) found that 37% of the firefighter's surveyed felt technical competence

would be a problem on inspections and pre-plans. Jarrett (1995) also found that the Decatur Fire Marshal felt engine company inspections should be limited to certain inspections such as repair garages, variety stores, public assemblies not complicated inspections.

McCafferty (2006) recommends that all building materials should give at least 2 hr fire rating in a modern warehouse. In agreement; Zimmerman (2007) mentions that fire sprinklers are not a solo act in protecting buildings. Zimmerman (2007) adds that passive protection systems should include: (a) fire barriers, (b) fire walls, (c) fire doors, (d) fire stops, (e) dampers, and (f) smoke management systems. Brannigan (1997) adds that it is a myth that insurance companies assure that building owners keep up all their various fire protection systems.

Fletcher (2001) mentions that ESFR systems must maintain open racks and shelving. In addition, Fletcher (2001) and Fire International (2003) feel that building owners must understand importance of maintaining flue spaces. Fletcher (2001) stresses that earthquake bracing must be addressed in certain geographic areas.

Davey (2006) feels prevention is the answer to warehousing and is the most important issue. Davey (2006) mentions: (a) Staff training; (b) holistic approach to fire safety with good management and procedures; (c) installed systems such as passive compartmentation and active such as sprinklers; (d) a well trained, fire aware staff; and (e) effective risk management. Davey (2006) also mentions firefighting equipment, means of escape, and strict adherence to aisle widths. Davey (2006) advocates the following preventive actions including: (a) Arson - regular patrols, avoid use of warehouse as general thoroughfare, secure windows, doors, and outside security lighting; (b) electrical- maintain in good condition, avoid temporary wiring, avoidance of portable appliances, or switch off and pull plugs when not using, avoid battery charging in warehouse operations other than in fire-resisting enclosures; (c) heat- avoid open flames, heat

producing activities such as shrink wrapping, welding; (d) housekeeping- keep grass, rubbish, and other combustibles away; and (e) forklift, match with the appropriate storage risk.

Welch (2000) mentions coordinated effort of various disciplines especially for ESFR systems including fire protection, architectural, structural, mechanical, and electrical. Fletcher (2001) also mentions this and stresses periodic meetings and coordination of the various disciplines as well as foremen representing various trades. This point is also stressed by Fire International (1997) mentioning that building owners and contractors must meet all guidelines. Fletcher (2001) emphasizes that reliable water supply is critical. He recommends a booster pump and a secondary water supply in areas subject to earthquakes, regardless of minimum requirements.

Fire Protection-South Africa (2004), similar to Davey (2006) mentions the following common type fires and associate preventive actions including: (a) Arson-regular patrols, restrict access to storage, avoid general thoroughfare; secure windows, doors, security lighting; (b) electrical-maintain wiring, lights over aisles, avoid temporary wiring, avoid portable appliances, avoid battery charging except in fire resisting compartments; (d) open flame and other heat producing operations- avoid portable heaters or incandescent heaters, avoid shrink wrapping using open flames, cutting, welding; (e) smoking not allowed; (f) exposure hazards-keep grass, rubbish, excessive storage of pallets, and other combustibles away; and, (g) check forklift and other vehicles exhaust systems.

Pre-Event: Pre-Planning Warehouse Distribution Center Fires

Jakubowski (2005), Welch (2000) and Shouldis (2001) mention that fire department awareness, knowledge of what is stored and the burning potential, and action planning is important for pre-event management of warehouse fires. Shouldis (2001) and Mark (1999) add

that company level inspections and realistic, hands on proficiency drills, combined with strict code enforcement are essential. Mark (1999) adds that preplanning and inspection programs increase professionalism, knowledge and skills. Naylis (1999) feels that pre incident planning is the most critical and overlooked fire department pre-event function.

The Instructor (2004) states that fire departments need to identify defensive operations buildings on pre-plans. Everton (2002) and Goves (2001) add that sacrificial buildings pose hazards to firefighters. Everton (2002) adds that it is unreasonable for owners and the public good to be expected to watch their 'sacrificial' buildings burn down, damage the economy, and damage the environment. Goves agrees (2001) and adds that the sacrificial building concept does not consider the cost of inter agency liaison dealing with consequences of pollution, evacuation, major incident management, firefighter injuries and litigation costs. In another article, Goves (2003) points out that the Japanese do not accept the concept of a sacrificial building. The sacrificial building concept was controversial in the literature examined by the researcher.

Everton (2002) states that firefighters should pre-plan escape routes, firefighting positions and tactics, and a means for emergency out and off procedures. Germann (1994) recommends training for tenants to include incipient stage extinguishment and evacuation procedures. Likewise, Goves (2003) reports that Japan mandates fire protection managers that have stringent responsibilities including management of private fire brigades and training for all employees in fire prevention, fire fighting, and private fire brigades.

Germann (1994) recommends: (a) identification of safe areas for fire personnel and tenants, (b) extended range breathing apparatus, (c) built-in communication systems of either repeaters or hard wired, (d) alternate forms of ventilation information be included in pre-plans, and, (e) fire suppression systems and automatic alerting systems should be identified.

Parlor (2003) and The Instructor (2004) recommend careful and extensive preplanning by fire brigades. The Instructor (2004) adds that pre-plans should identify a building liaison. Also, The Instructor (2004) adds that pre-planning activities should include practice like you play-hands on training, review, revision and updates to operational procedures, standardized May Day operations and stress training at strategic, tactical, and task level (The Instructor, 2004). Mark (1999) mentioned that company officers who inspect complicated occupancies such as warehouses should be trained to level I and II fire prevention levels in Louisiana to reduce liability. Mark (1999) recommended modifying job descriptions to include pre-fire planning, code enforcement inspections, and adding such to training academy for new recruits.

Miami FD, for decades, has utilized pre-plans for disaster situations. For example, (Fire Engineering, 1965) during Hurricane Cleo, in 1965, Miami FD responded to a warehouse fire. Conditions included 110 mph winds, flying debris, and torrential rains. Miami's pre-planned response and defensive operations prevented this cascading event from spreading to other exposures (Fire Engineering, 1965).

Common Causes of Warehouse Fires

Jakubowski (2005) mentions that fork lift fires commonly spread to warehouse commodities. Jakubowski, (2005) states that electric fork lifts are less hazardous. Pool chemicals (Wolf, 1998) have caused two significant big box store fires, one in Albany Georgia in 1996, and the other in Quincy Massachusetts in 1995. Both fires started in area of oxidizing pool and spa chemicals and spread rapidly (Wolf, 1998). Wolf (1998) mentioned that high piled storage with no in-rack sprinklers and pool chemicals is an extremely dangerous warehouse storage practice. In addition, Wolf (1998) mentioned that pool chemicals are incompatible with flammable liquids, paint, paint thinners, dry chemical extinguishers. Wolf

(1998) also mentioned that Cal hypo, a pool oxidizer, in fire testing creates an extremely fast, hot burning, severe fire, and releases vast amounts of oxygen and noxious gases. Jakubowski (2005) adds that warehouse commodities contribute to exponential fire growth and that rocketing of aerosols can spread fire and create severe hazards for firefighters. Whiteley, (2006) mentions that arson causes 50% of all fires in food storage warehouses.

Event: ESFR Sprinkler System Failures

Gagnon (2005), and Golinveaux and Hankins (2006), mention that anything which could delay activation or interrupt water spray pattern can lead to ESFR failure, because quick penetration and early suppression is essential in an ESFR system. Gagnon (2005), and Golinveaux and Hankins (2006), state that it is very important to consider hazard and commodity classification when a warehouse is protected by an ESFR system to assure the system can extinguish the fire. Golinveaux and Hankins (2006), and Schultz, (2006) point out that ESFR sprinklers are particularly affected by obstructions. They explain that ESFR systems are designed for 12 hydraulically remote sprinkler heads which operate on three lines with 4 sprinklers on each line. This configuration covers an area of 960 square feet. In addition, 2 sprinklers may be positioned below obstructions. Viking Sprinkler Corporation (2001) states that fire suppression with an ESFR is usually accomplished when four sprinklers operate. Schultz (2006) adds that ESFR sprinkler heads typically flow 75- 100 gpm at 75 p.s.i. Viking Sprinkler Corporation (2001) warns that when 12 sprinklers do not suppress the fire, it is unlikely that suppression will ever occur with an ESFR. Such failures are left for the fire service to manage.

Naylis (1999) mentions the following reasons for ESFR failure: (a) miss-matched commodities, (b) sprinkler valves shut off, (c) inoperable pre-action valves, (d) fire doors and shutters blocked, and (e) lack of curbing and decking to stop flammable liquid spread.

Gagnon, (2005) Schultz, (2006) and Viking Sprinkler Corporation (2001) mention that obstructions which interfere with an ESFR design can render them ineffective. Such obstructions can be conduit, bridging, cross bracing, piping, and building features. Viking Sprinkler Corporation (2001) adds that obstructions can block heat from getting to sprinklers preventing early activation. Viking Sprinkler Corporation (2001) mentioned that obstructions can also cause skipping, a phenomenon that causes water from one sprinkler to splash onto and cold solder other sprinklers around it. Golinveaux and Hankins (2006) also mention skipping. Welch (2000) mentions obstructions as a critical factor in ESFR failure and one of the greatest factors to overcome by getting various disciplines, such as fire protection, architectural, structural, mechanical, and electrical disciplines to work together.

The literature warnings about the relation of sprinkler obstructions to ESFR system failure is extensive. Fletcher (2001) mentions obstructions will most likely be caused by equipment added by contractors such as lights, ducts, heaters, cable trays, and conduits, which act like draft curtains, a feature contraindicated with ESFR. Valentine, (2007) adds that the sensitivity of ESFR sprinklers is of utmost importance. Even small obstructions can create spray pattern disruption and interrupt the suppression capability. Valentine (2007) recommends strict adherence to NFPA 13 guidelines. Likewise, Record (2001) mentions to watch for obstructions such as beams, girders, wind bracing and bridging, ducts, heaters, cable trays, piping, and lighting obstructions. Record (2001) also warns not to store open-top combustible containers in rack storage.

ESFR systems function better with high water pressure. Viking Sprinkler Corporation (2001) prefers at least 75 p.s.i. Golinveaux and Hankins (2006) state that ESFR systems are unable to protect very high-challenge occupancies such as rubber tires, lightweight rolled paper

and carpet. Goves (2003) mentioned an ESFR system failure in racked storage 30 meters high caused by obstructions to the system. There was also a 21 minute delay as employees tried to extinguish the fire. Similarly, Vincent (1998) found that ESFR technology could protect cartoned and un-cartoned flammable liquid storage when combined with large-orifice in rack sprinklers installed in the longitudinal flue spaces.

Event Literature: Fire Sprinkler Failure

Lobash (2006) points out that 25% of all fire sprinkler system failures occur in warehouse type occupancies! Harrington, (2006) points out that in 1978, Supermarket General in Edison New Jersey, a large sprinklered warehouse, was destroyed. The fire spread as a result of aerosol rocketing and the sprinkler system was over-ran. In 1981, Schultz (2006) Kmart's distribution warehouse was destroyed. Post fire investigation (Schultz, 2006) noted aerosols breaching the firewalls, an improperly designed system for the commodities, and improperly segregated aerosols. Harrington (2006) also mentioned the Kmart warehouse fire. Schultz, (2006) mentions the Sherman-Williams warehouse fire that spread due to flammable liquids in small plastic containers and also a sprinkler system that was not engineered for the hazards.

Harrington (2006) also mentions the 1996 Lowe's bulk retail store fire which grew out of control and was extinguished after 2 days. Harrington (2006) mentions that the fire started in a rack containing pool chemicals. Harrington, (2006) cites the contributing factors: (a) Sprinkler design must match the fire hazard and, (b) sprinkler and sprinkler water supplies must be maintained. Harrington cited a large fire in New Orleans LA in 1996 that had 2 fires in a single day. The first fire was incendiary in rack storage. The second fire was accidental and was extinguished 6 days later destroying a 930,000 square foot warehouse. The fire sprinklers had been shut down to reduce water damage. Harrington (2006) also cited a 1977 warehouse fire in

Cologne Germany. The fire destroyed an 800,000 square foot warehouse. This was a \$100 million loss at the Ford Parts Depot. The fire pump failed after 10 minutes because the fire burned through the fire pump electrical conduit (Harrington, 2006).

Harrington (2006) emphasized fire detection and notification must not be delayed. Harrington recommends phones, manual pull devices, two way radios, pagers, and quick occupant evacuation. Harrington (2006) mentions that if employee's first actions are to fight fire, unnecessary time delay in notifying the fire department occur. Harrington (2006) stressed that fire defense strategies must consider the environment. On this point, Harrington (2006) cited a 1986 fire in Switzerland where 30 tons of toxic material was washed by the fire department into the Rhine River at the Sandoz Chemical storage facility in Basel Switzerland. The result was wide spread killing of aquatic life which had a lasting effect of over a year. In contrast, Harrington (2006) mentions that the Sherman Williams fire was a success as 1.5 million gallons of paint and paint products were contained and removed preventing aquifer contamination.

Harrington (2006) stressed that fire prevention efforts can be focused. On this point, Harrington (2006) mentions that between 1994 -1998 there were an average of 22,900 fires per year in storage occupancies. The leading cause was arson. Harrington (2006) mentioned other top causes as open flame, embers, torches welding, faulty electrical, and fuel powered forklifts. Harrington (2006) cited a bulk retail storage arson fire in Tempe Arizona which started in a high storage rack of lawn furniture. Harrington (2006) advocates providing and maintaining effective compartmentation. He laments that typical modern warehouse open space can now be close to 1 million square feet (Harrington, 2006).

Lobash (2006) cites the following reasons for fire sprinkler failure; (a) Manual intervention, system shut off before fire extinguished; (b) lack of maintenance; (c) inappropriate

system for fire type; (d) system component damaged by fire; and (e) system shut off for maintenance and never turned back on. Likewise, Harrington (2007) in another article mentions the following common reasons for fire sprinkler systems in warehouse fires: (a) sprinkler design must match the fire hazard, (b) sprinklers and sprinkler water supplies must be maintained, (c) fire detection and notification must not be delayed, (d) occupant fire suppression attempts often fail, (e) fire defense strategies must consider the environment, (f) fire prevention efforts can be focused, and (g) provide and maintain effective compartmentation.

Comeau and Duval (2001) point out that in August 2000, Phoenix experienced one of the largest fires in its history at the Central Garden and Pet Supply and Cardinal Distributors warehouse. The loss is estimated in hundreds of millions. The warehouse was equipped with an automatic sprinkler system (Comeau and Duval, 2001). The fire sprinklers were at the ceiling level. There was no in rack sprinklers. The warehouse supplied area home improvement stores with a wide variety of products such as bird feeders, redwood, batteries, fertilizers, pesticides, and pool chemicals- oxidizers that increase fire intensity (Comeau and Duval, 2001). Five firefighter injuries occurred and 10 area residents were treated for smoke inhalation injuries. The fire is believed to have been caused by incompatible materials mixing with pool chemicals resulting in spontaneous ignition. Glendale Arizona experienced a similar fire in a warehouse in 1988. In addition, a fire in a Home Depot in 1995 in Quincy MA resulted from pool chemicals and oil mixing Comeau and Duval (2001).

Event: Warehouse Fires Kill Firefighters

On December 22, 1910, in one of the most devastating fires in US history, 21 firefighters were killed at a stockyard and cold storage warehouse in Chicago (Firehouse, 1999). A fire in St. Paul Minnesota in a warehouse of the Waldorf Paper Products Company suffered a collapse of a

compartment wall (Fire Engineering, 1949). Ironically, the warehouse had suffered 8 serious fires in the previous 13 years. On May 12, 1938, two firefighters were overcome with smoke in the same warehouse! On June 9, 1949, three St. Paul fire chiefs were killed in a wall collapse during mop up operations.

One of the US's most historic warehouse fires is the 5-11 Waterfront Fire (Ditzel, 1951). This fire resulted in four firefighters being killed in a wall collapse, losses exceeding \$2,000,000, and enormous resources requiring 283 firefighters, 34 engines, 5 ladders, 6 squads, 2 high pressure wagons, 2 water towers, 11 ambulances, 5 chiefs, 2 gasoline wagons, and a firefight that lasted over 24 hours (Ditzel, 1951). This was one of the first warehouse fires to be televised to a vast audience. Over 5 million television viewers saw the fire in audiences as far away as New York (Ditzel, 1951). Another unique aspect of this infamous fire is that it was one of the first fires to utilize newly developed nine pound high frequency Motorola radios (Ditzel, 1951).

Internationally, (NFPA, 2007) a warehouse fire killed 10 firefighters in Rio de Janeiro, Brazil in 1959. A fire in a bonded warehouse explosion killed 19 Glasgow firefighters in 1960. It was rated as the single worst catastrophic fire in modern British history since the great London fire of 1666. Forty other firefighters were hurt in the blaze. (Baird, 1960).

Fire Attack in a Warehouse Distribution Center

Jakubowski (2005), Germann (1994), Fire Protection-South Africa (2004) and McCafferty (2006) stress that early detection is important, that delays in notification and response of fire resources can lead to catastrophic consequences, and that such delays endanger the public and firefighters alike. Numerous fires could be cited and one classic example is the

Kankakee Illinois fire in which the night watchman attempted to extinguish the fire first before notifying the fire department resulting in a 20 minute delay (Fire Engineering, 1951).

Shouldis, (2001) makes the following points when considering fire suppression of a warehouse distribution center fire: (a) Heavy attack and control is required; (b) firefighters must know and understand how built in suppression systems work; (c) ensure sprinkler systems valves are not shut off; (d) ensure fire pumps are operating properly; (e) pump to the affected sprinkler system and augment the system pressure at 150 p.s.i.; (f) pump to the right fire department connection as most modern warehouses have numerous sprinkler systems; (h) strategically utilize firewalls and close any openings; (i) realize that many systems are not designed to extinguish but to control the fire so be prepared to fight fire; (j) don't be surprised if system is not working because of miss-matched commodities; (k) fire protection system designers depend of the fire department to show up and finish job and 1 & ½" lines are too small for the task; (l) if building trusses are involved overhead, direct hoses onto truss supports from a safe location such as, near a fire wall; and, (m) articulating booms are the best aerial apparatus for warehouse fires because they can reach out and over.

The Instructor (2004), in an excellent lesson plan, points out those fire protection systems in warehouse distribution centers will create cold smoke and decreased visibility. Firefighters can expect large quantities of toxic smoke. The Instructor (2004) mentions that ventilation systems can fail and recommends that fire departments consider purchasing a truck or trailer mounted positive pressure fan to mitigate the cold smoke phenomenon. In addition, fire-fighter awareness of overhead items such as HV/AC units, billboards, storage tanks, large bulk storage overhead is essential (The Instructor, 2004). The Instructor (2004) also mentions high fuel loads.

The Instructor (2004) indicates that having a rapid intervention plan is essential in warehouse fires but it is extremely challenging. Tests reveal that rapid intervention in a warehouse requires a minimum of 12 personnel to locate, package, trans-fill, and extricate a downed firefighter (The Instructor, 2004). In addition, a limited means of access and egress due to racking can interfere with rescue efforts (The Instructor, 2004).

Germann (1994) recommends training for tenants to include incipient stage extinguishment and evacuation procedures. Likewise, Goves (2003) reports that Japan mandates fire protection managers that have stringent responsibilities including management of private fire brigades and training for all employees in fire prevention, fire fighting, and private fire brigades. The researcher found that this is one of the more controversial topics considering warehouse distribution centers.

Specialized equipment and supplies are very applicable to fire attack in a warehouse distribution center fire. For example, Jakubowski (2005) recommends the use of compressed air foam systems. We have already discussed specialized, trailer mounted ventilation fans (The Instructor, 2004). Jakubowski (2005) adds that proper ventilation can save millions of dollars. Welch (2000) recommends the use of thermal imaging cameras to locate hot spots and look through cold smoke. This tactic is also recommended by The Instructor (2004) and they add assessment of concealed spaces as an applicable use of thermal imaging cameras. Welch (2000) recommends hazardous materials team response to warehouse fires to deal with the runoff resulting from large attack lines.

Naylis (1999), similar to Shouldis (2001), mentions: (a) Assure sprinkler valves are open and pumping to sprinkler system; (b) assure reliable water supply; (c) expect rapid fire spread; (d) consider building construction features because most modern warehouses have lightweight,

open-web construction features that fail rapidly when exposed to fire; (e) choose a defensive strategy if fire well developed; (f) cool steel roof members from inside; (f) expect a tremendous amount of smoke and have SCBA support; (g) always consider wind conditions, they can hinder or help; (h) ventilation is essential; and (i) a tremendous amount of resources will be required (Naylis, 1999).

Shouldis, (2001) and Welch (2000) mention special considerations related to warehouse distribution fires including the need for multiple tactical frequencies and or hard wired systems. Welch (2000) adds that pressure buildup inside the warehouse exaggerates the effect of heat on structural integrity. Shouldis (2001) mentions the need to activate the Emergency Operations Center (EOC) and a unified command. Shouldis (2001) and The Instructor (2004) also mention the need for implementing a strong incident command system (ICS). Shouldis, (2001) mentions need to keep perspective on priorities including: (a) safety, (b) suppression, (c) hazardous materials containment, (d) evacuations, (f) emergency notifications, (g) public information, (h) cutting off vertical and horizontal spread, and (i) maintaining safe work areas for fire-fighters. Shouldis, (2001) also mentions that master streams do not penetrate partitioned or racked storage deep inside a warehouse fire.

Parlor (2003) mentions that fire spread tests reveal the fire may reach the top of a 40 foot rack in as little as 2 minutes. Parlor states that firefighting reaction time to a warehouse fire is often 20 minutes for the first line to be deployed. Parlor (2003), similar to Shouldis (2001) and The Instructor (2004) mentions that: (a) rapid vertical and horizontal spread is likely to occur, (b) expect difficulty in gaining internal access to the fire, and (c) expect early collapse. Parlor (2003) also offers the following valuable firefighting decision criteria; (a) Occupancy storage; (b) building size and compartmentation; (c) preplan information; (d) construction features; (e)

potential for rapid fire spread and flashover; (f) collapse of racking, falling stock, weakening of structure; (g) nature of building contents, fire load, and hazards; (h) properties of stored materials; (i) high heat and smoke from packaging materials; (j) decision to go offensive or defensive; (k) difficulty in locating fire seat due to large open spaces, racking, and smoke; (l) built-in fire protection features; (m) water supply necessary for large fire flow requirement; (n) use and type of smoke ventilation equipment; (o) internal and external facilities for fire fighting; (p) accessibility, travel distance, and required hose length; (q) rapid loss of visibility due to smoke; (r) communication systems at scene especially in smoky conditions; (s) conditions for switching to defensive; (t) spread to exposures; and, (u) extreme firefighting resource demand. Many of Parlor's (2003) criteria mentioned are similar to Shouldis (2001) and The Instructor (2004).

Hatfield coined the phrase "Wide rise" to describe "warehouse buildings the size of a residential neighborhood" (Hatfield, 2006, p. 1). Hatfield (2006) mentions to expect rapid fire spread along pallets of boxes that are in plastic shrink wrap. As the fire preheats high rack storage, it ignites with the fire sprinklers activating behind it and not containing the rapid fire spread. Hatfield (2006) describes the head of the fire moving ahead of the sprinkler water flow. Hatfield (2006) offers the following points: (a) Locating fire in a building the size of a neighborhood is very difficult; (b) place fire apparatus close to the suspected fire location; (c) expect difficulty in ventilating a building with cold smoke that behaves like a heavy fog. Hatfield (2006) suggests a truck-mounted 80,000 cubic foot smoke blower such as Phoenix fire. As an alternative, Hatfield (2006) suggests opening all bay doors. Likewise, Brunicini (2003) also mentions the problem of cold smoke, which does not rise in a convection current; and (d.) expect communication problems. Hatfield (2006) suggests utilizing 800 MHz direct talk groups.

Hatfield (2006) also suggests: (a) An inside look at building if there is an alarm with no reset, because they are so large and there may be no visual signs of a fire from exterior; (b) enter the building ready to fight fire carrying hose bundles, SCBA, full turnouts, forcible entry tools, lights, and a thermal imaging camera; (c) always stay on the side of the warehouse that has roll-up bay doors; (d) open the roll up bay doors as you travel towards the fire to ventilate; (e) walk the end of the aisles and look down each one until the fire is located; (f) note the bay door number where the fire is located and communicate it as the shortest, and most direct route to the fire; (g) open the dock doors near the fire to allow firefighters access; (h) back an engine to the loading dock and pull a 2 & 1/2" line directly to fire; and (i) never utilize class II standpipes for fire attack.

Firefighter Safety in Warehouse Distribution Fires

Jakubowski (2005) and McCafferty (2006) believe that if serious fire conditions exist involving the structure, strong consideration must be given for a defensive attack. Likewise, The Instructor (2004) mentions that large span lightweight trusses directly exposed to fire represent a no win situation for firefighters. In contrast, Freeman (2000) mentions that limiting firefighters to external operations will inevitably lead to more fire spread, damage, total loss, and increased environmental damage. Freeman, (2000) says it's open to debate as to whether firefighter's lives should be risked and feels their lives should be considered and protected by building stronger building regulations. Shouldis (2001) adds that command should always abort aggressive interior attack if it is suspected that fire is in high piled storage. In addition warehouse distribution fires present many hazards to fire-fighters including size issues, entry beyond the point of no return for firefighters, and SCBA limitations.

Brunacini (2003) warns that maze- like storage arrangements lead to disorientation when trying to egress. Related to this, Brunacini (2003) states that rescue is very difficult to perform in a warehouse. Brunacini (2003) stresses to: (a) never leave the hose line, (b) always have an exit plan, and (c) practice accountability and discipline. Brunacini (2003), like Hatfield (2006), adds that high piled stock collapse and sprinkler caused cold smoke can push smoke down on fire-fighters distorting their vision and block escape routes.

Goves (2001) mentions: (a) Enormous floor areas, (b) multiple mezzanines, (c) risk of early collapse of racking and lightweight construction, and (d) rapid spread of fire unnoticed above fire fighters heads. Goves (2001) also mentions that in a multi-million pound loss fire in Great Brittan, security cameras recorded a flame front accelerating at 100 meters in just over 1 minute! Goves (2001) mentions that fire engineering calculations indicate flashover conditions can be reached in 3-4 minutes in a modern warehouse with a myriad highly flammable storage of plastics and other commodities. Goves (2001) found in his research that fire can reach the top of a 40 foot rack in 2 minutes and such fires are virtually impossible to fight with conventional means. Likewise, Standing, (2000) indicates that modern warehouse building size limits firefighter's ability to fight fire and limits the ability to search. In addition, Standing (2000) mentions that rack heights make it difficult to locate the fire seat, leading to early collapse of racking onto firefighters. Standing (2000) also states that an enormous risk of unseen fire spread exists at high levels above cold smoke and out of sight. Related to the above mentioned safety factors, Standing (2000) mentions that major risk to firefighters exist because warehouse distribution centers are often located remote from fire stations allowing time for fire to grow, completely filling with smoke; rendering an offensive fire attack inappropriate.

Smith (2002) recommends a strong ICS system with an established safety officer. Welch (2000) agrees and recommends a strong accountability system. Smith (2002) recommends that the safety officer must: (a) Wear proper personal protective equipment (PPE) and safety officer vest; (b) obtain a briefing from command; (c) assure that personnel accountability system is operational and adhered to; (d) assess the proper use of PPE; (e) determine incident control perimeters and zones; (f) ensure safe placement of apparatus; (g) assess structural integrity; (h) determine the danger of utilities; (i) evaluate the physical condition of on-scene personnel; (j) investigate all accidents; (k) locate a safe area for VIPs and media; (l) participate in the planning process and IAP; (m) maintain an ICS unit log (ICS 214); (n) be willing to exercise emergency authority; (o) utilize a clear radio identifier; (p) consider sending a safety officer to the roof to monitor high-risk operations such as trench ventilation; and (q) always apply risk-versus gain analysis in decisions.

A warehouse fire in Seattle, (Voice, 1995) resulted in 4 firefighters being killed. Lessons learned included: (a) Fire departments should identify dangerous construction features; (b) fire departments must constantly balance risk versus gain when considering strategy and tactics; (c) fire departments must pre-plan significant occupancies; (d) incident command must assure the flow of critical information is communicated; (e) incident commanders need to recognize and call for command support staff to manage command functions; (f) experience is extremely valuable; (g) accountability is essential; (h) risk versus gain is essential during rescue operations to save lost firefighters; (i) it is extremely difficult to decide to discontinue search and rescue even when there is no hope for success; and (j) warehouse fires require a high level of planning, coordination, and discipline.

The Instructor (2004) mentions the following factors that could lead to a May Day incident: (a) Prolonged burn time; (b) smoke showing through walls; (c) inadequate ventilation leading to rapid fire development; (d) sagging floors, bulging walls, interior collapse; (e) water flowing through bricks; (f) multiple-point building involvement; and (g) unprotected steel with direct flame impingement.

Post Event: Catastrophic Economic Loss of Warehouse Fires

Siphiwe, (2001) mentioned that in 1999, serious warehouse fires in Great Britain resulted in a \$22 million loss. Parlor (2003) mentioned that warehouse fires often result in: (a) a large financial dollar loss, (b) customer loss, (c) high cost to re-stock warehouse, (d) drained company resources, (e) limited investment for growth, (f) business interruption, (g) replacement of specialized equipment and facilities, and (h) corrosive contamination.

In a staff report Fire Engineering (1951) mentioned a warehouse fire in Kankakee, Illinois. The fire resulted in the costliest fire in Kankakee's history. The loss (Fire Engineering, 1951) was in excess of \$3 million and destroyed a 58,000 square foot warehouse. Similarly, Bertalovitz (1969) mentioned a fire in the International Warehousing Corporation complex resulting in 20 buildings being destroyed. Bertalovitz (1969) added that the fire also resulted in a \$5 million contents loss. Likewise, warehouse fires in UK between 1998- 2002 reportedly resulted in a 188,107, 275 pound loss from serious fires (Green, 2004). Green (2004) defined serious fire as those with a loss exceeding 50,000 pounds.

Freeman, (2000), similar to the NFPA, (2007) mentions the following factors related to warehouse fire loss: (a) economic disruption to local business community, (b) job loss, (c) economic impacts such as lost tax revenue, and (d) environmental damage and clean-up costs which may such may dwarf the cost of a properly engineered and maintained

sprinkler system. Likewise, Everton (2002) mentions the hidden cost of warehouse fires related to conflagration including civil litigation and environmental pollution.

Comeau and Duval (2001) mention that in August 2000, Phoenix Arizona experienced one of the largest fires in its history at Central Garden and Pet Supply and Cardinal Distributors. The loss was estimated in hundreds of millions and the warehouse was covered by a state of the art fire sprinkler system. Likewise, the NFPA (2007) mentions the Kmart warehouse fire that resulted in a \$190 million dollar loss to a warehouse in 1982. The Kmart warehouse was also sprinklered. Brannigan (1997) mentions a \$280 million loss in a 930,020 square foot, state of the art warehouse. The warehouse (Brannigan, 1997) had a state of the art sprinkler system. Some portions of the warehouse had in rack sprinklers and other portions had ESFR coverage (Brannigan, 1997). Brannigan (1997) mentioned that the warehouse had 30 different overhead sprinkler systems and 17 in-rack systems. The incendiary fire started in a 21-foot high stack under the ceiling sprinklers (Brannigan, 1997). New Orleans fire department arrived 11 minutes after first sprinkler activation and found fire already showing through roof Brannigan (1997). The fire required a five alarm assignment to extinguish. Brannigan (1997) mentioned that all systems were shut off and facility personnel restored power to conveyors. An electrical short occurred after the conveyors were turned on and arcing ignited combustibles (Brannigan, 1997). Unfortunately, the entire warehouse was destroyed and required six days to extinguish (Brannigan, 1997). Likewise, Brannigan (1997) points out that such fires can seriously harm the economic health of the community.

Post Event: Environmental Consequences of Warehouse Fires

Germann (1994), McCafferty (2006) and Shouldis (2001) mention the runoff threat associated with warehouse fires. Likewise McCafferty (2006) and Shouldis (2001) mention

contamination of internal commodities. McCafferty (2006) mentions that many warehouse distribution centers are located right in the heart of residential areas which adds to environmental life and health threats. Parlor (2003) adds that warehouse fires present a major threat to the local environment related to contaminated run off damage to fauna and flora. In addition Parlor (2003) mentions the liability of such contamination. Likewise, Freeman (2000) and Goves (2001) mention warehouse fire environmental damage related to air and water. Shouldis (2001) mentions the need to contain large quantities of chemicals runoff to other jurisdictional boundaries and the need for hazardous materials response. Standing (2000) mentions that defensive firefighting strategies may lead to enormous environmental air, water, and health concerns. Standing (2000) and Everton (2002) mention hidden costs in pollution, evacuation, long term economic damage.

Litigation

Parlor (2003), Everton (2002), Shouldis (2001), and Standing (2000) mention litigation associated with major warehouse fires. Shouldis advises to expect legal review of: (a) Inspections, (b) SOG's and SOP's, and (c) the presence or absence of a written IAP. Shouldis (2001) says this is highly likely when extensive damage has occurred.

New Technology and Fire Response Practices

Sice (2006) discusses new technology AFFF fire sprinkler systems and their effectiveness. Sice (2006) cites the L 'Oreal warehouse, a giant cosmetics warehouse in France. Cosmetics stored in bulk very hazardous because many contain aerosols, butane, ethanol, dimethyl ether, and natural gas, all flammable with low flashpoints (Sice, 2006). Likewise, Viking Sprinkler Corporation (2001) created a new deluge sprinkler system that uses AFFF designed to provide 97% water and 3% foam. In comparison, Vincent et. al. (1998)

mention that foam water agents in sprinkler systems are extremely effective in protecting flammable liquid storage. However, Vincent et. al. (1998) point out that such systems are costly to install and maintain, require fire pumps and tanks, which they feel increases system unreliability.

Whiteley (2006) mentions that the food industry in the UK lost over 403 million pounds from 1998 to 2006 in warehouse fires. Whiteley (2006) mentions that the main contributing factor are stacks of plastic food trays that when ignited, become a molten flammable liquid that cannot be extinguished with water.

The Japanese (Goves, 2003), utilize a heavy weight attack and assume a worst case scenario on warehouse fire alarms. They (Goves, 2003) utilize specialized apparatus and response innovations such as robotic fire-fighting apparatus, high expansion foam, smoke extraction equipment and massive fire station response. For example (Goves, 2003) in Yokohama City, which has the largest warehouse in Japan, 23 fire apparatus respond on initial response. All are planned to arrive within 35 minutes with pre-established assigned functions.

Summary of Literature

The information examined in the literature review assisted the researcher in developing the feedback instrument and interview questions. The information was separated into pre-event, event, and post event categories. Areas of agreement and differing opinions were found.

Agreement was discovered in the area of ESFR storage issues by Comeau & Duval (2001), Wolf (1998), Schultz (2006), Harrington (2000), Mark (1999), Jarret (1995), Whiteley (2006) and others. Much of the literature reviewed stressed that ESFR obstruction and maintenance of flue spaces was a critical issue including McCafferty (2006), Harrington (2006), Sprinkler Age (2003), Viking Sprinkler Corporation (2001), Fire International (1997),

Golinveaux and Hankins (2006), Fletcher (2001), and Whiteley (2006). Agreement was found in ESFR maintenance by Harrington (2006), Gagnon (2005), McCafferty (2006), and Naylis (1999). Agreement was also found regarding significant economic impact of major warehouse fires by Comeau and Duval (2001), Sipiwe (2001), NFPA (2007), Parlor (2003), Fire Engineering (1951), Bertalovitz (1969), Green (2004), Everton (2002), and Brannigan (1997). Agreement was also found in the area of potential litigation by Parlor (2003), Everton (2002), and Standing (2000). Support for pre-plan development was mentioned by Jakubowski (2005), Welch (2000), Shouldis (2001), Mark (1999), Naylis (1999), The Instructor (2004), Everton (2002), Goves (2003), German (1994), Fire Engineering (1965), Nugent (1998), and Voice (1995).

Controversy was mentioned in the area of ESFR protection and the use of automatic heat and smoke ventilation systems by Viking Sprinkler Corporation (2001), Schultz (2006), Sice (2004), and Fire Protection-South Africa (2004). Tenant firefighting was mentioned favorably by Goves (2003) and Germann (1994). Tenant firefighting was not recommended by Harrington (2006) and Shouldis (2001). Most of the literature regarding fire attack favored early switch to defensive strategy if the fire was well developed including Parlor (2003), Naylis (1999), Jakubowski (2005), McCafferty (2006), and The Instructor (2004). However, Freeman (2000) offered a dissenting opinion on defensive strategy. Everton (2002) and Goves (2001) discussed the controversial issue of sacrificial buildings.

Procedures

A descriptive method was used for this applied research project. Procedures included a literature review, background information, 7 personal interviews, and a 17 question feedback

instrument sent to fire agencies in Southern California. The intent of the research was to identify methods of preventing and managing ESFR protected warehouse fires that may occur in Rialto.

The literature review included 10 visits to the National Fire Academy (NFA) library during the authors' attendance at the NFA in August 2007. The review included published applied research projects by former EFO students, books, and professional journals. The researcher also conducted reviews of internet websites of government, public safety, and private organizations. Additional literature reviewed included searching the RFD library and journals, and the researcher's personal library in September 2007.

On September 20, 2007, a 17 question feedback instrument was sent to 106 fire agencies located in Southern California through the email system. Most agencies in San Bernardino, Ventura, Imperial, Ventura, Santa Barbara, Los Angeles, Riverside, Kern, Orange, and San Luis Obispo counties were sent feedback instruments (See appendix A for the list). Private fire agencies and cities located within a county fire district were excluded and only the lead agency was included. Seven email addresses were undeliverable. In an attempt to increase participation, 13 additional fire departments were added to the list and the feedback instrument was re-sent October 22, 2007 (See appendix B for list). The return rate was 28%, covering an estimated population of 15,000,000 residents.

Each agency was asked to complete the feedback instrument at an attached web link from Survey Monkey included in a cover letter (See appendix C). The researcher utilized *The California Fire Service Directory* (California State Firefighters Association [CSFA], 2007), to identify email addresses. Thirty feedback instruments were completed resulting in a 28% return rate. The researcher subscribed to Survey Monkey which is a website that specializes in survey,

questionnaire, and feedback instruments. The website surveymonkey.com was used as the sole provider for the feedback data collection and statistical analysis.

The literature review assisted the researcher in designing the feedback instrument. To improve reliability, hard copies of the feedback instrument were sent to five RFD command staff members, the fire marshal, and executive secretary for review. Based on their input, all seventeen questions were changed, simplified, edited or revised. The feedback instrument can be viewed in Appendix E.

Personal interviews were conducted by telephone, email or in person with 7 fire service and industry professionals in September and October of 2007. These professionals were selected because of their expertise in ESFR technology. The interview questions were developed to serve as a guide to conduct the interviews (See appendix D). The researcher asked Battalion Chief Mike Peel, who has considerable experience developing interview questions, to review the questions. Based on his input, the introduction was clarified and question 7 was revised. The literature review influenced the development of the interview questions. The 5th edition of the *Publication Manual of the American Psychological Association* (2002) was utilized as the reference source for citations. The following is a list of those interviewed: (a) RFD Fire Marshal Norma Barajas was interviewed at RFD on September 20, 2007. The interview lasted 30 minutes. Barajas is a state certified level I, I, and III fire prevention officer with 30 years experience in fire prevention; (b) Mike Miksich is the Target Corporation's Distribution of Operations division head. He oversees the operations at 30 ESFR protected warehouse distribution centers in the United States. Miksich was interviewed on October 4, 2007 by telephone. The interview lasted 45 minutes; (c) Steve Sutton is a certified fire protection engineer. He contracts with Target Corporation, Nestles, Walgreens, and other corporations for

risk management, engineering of sprinkler systems, sprinkler maintenance, and sprinkler testing. Sutton was interviewed by telephone on October 15, 2007. The interview lasted approximately 45 minutes; (d) Redlands Fire Marshal Leonard Temby is a 30 year veteran, well known in San Bernardino County for his fire prevention expertise. He has extensive experience overseeing development of ESFR protected warehouse distribution centers. Temby was interviewed by telephone on October 3, 2007. The interview lasted 30 minutes; (e) San Bernardino County Fire Department Fire Marshall Mike Horton works for the largest fire department in region. San Bernardino County FD has numerous newly developed ESFR protected warehouses located in the unincorporated areas. Horton was interviewed by telephone on October 3, 2007. The interview lasted 30 minutes; and, (f) Jack Allen is a certified fire protection engineer with over 40 years experience. He has engineered many ESFR warehouses. Allen was interviewed by telephone on October 17, 2007. The interview lasted 30 minutes.

Limitations

Scope: (a) The feedback instrument focused on public fire service providers in Southern California; and (b) while not generalizable to other regions, the results are useful to fire agencies that protect ESFR warehouses.

Limitations: (a) The research was limited to ESFR protected warehouses; (b) only lead county agencies were included, not individual cities within a county fire district; (c) private industrial fire services were excluded because most protect refineries, aircraft manufacturing and not warehouse distribution centers; and (d) since the feedback instrument had a 28% return rate, the research findings can not be generalized to Southern California but only to the respondents.

Assumption: It was assumed that the feedback instrument respondents were knowledgeable about ESFR technology and fire department operations.

Definitions

Sacrificial Building: “Describes a building where a total financial loss is acceptable to the owners or insurance company” (Goves, 2001 p. 23).

Wide rise: “warehouse buildings the size of a residential neighborhood” (Hatfield, 2006 p.1).

Control-mode sprinklers: “Control-mode sprinklers confine a fire by pre-wetting combustibles surrounding the fire area by cooling hot gasses at the ceiling. In an actual warehouse fire, 20 or more control-mode sprinklers may be required for control” (Sprinkler Age, 2003, p. 12).

Suppression mode sprinklers: “Suppression-mode sprinklers, such as early suppression, fast response (ESFR) sprinklers are designed to knock down a fire as fast as possible using an aggressive large-drop spray and a flame-penetrating central core of water. ESFR sprinkler performance depends on open-frame storage that includes enough space for water to penetrate, should fire break out” (Sprinkler Age, 2003, p. 12).

Early Suppression Fast Response (ESFR) sprinkler: “ESFR denotes a special type of fire sprinkler. Early Suppression Fast Response sprinkler heads were developed in the 1980’s to take advantage of the latest fast-response fire sprinkler technology to provide fire suppression to high-challenge fire hazards. The sprinklers are specifically designed to fully suppress a fire that is within the design limits of the piping system. Prior to the introduction of these sprinklers, protection systems were designed to control fires until the arrival of the fire department” (Farlex, 2006, p.1).

Results

Research Question 1:

What risks to the community of Rialto do ESFR protected warehouse distribution centers pose in the event of an ESFR failure?

To answer this question, the researcher searched the literature, interviewed 1 expert, and obtained data from feedback instrument questions.

Significant community risk was found in the literature. Cobb (2000) mentioned a \$100 million loss Madison Wisconsin cold storage warehouse fire. Neuhof (1998) mentioned a 3.5 million deutschmarks loss fire in Nuremberg Germany. Bradish (2006) writes about a fire in a plastics-recycling warehouse requiring resources from 40 fire departments from Indiana, Kentucky, and Ohio. The fire required 325 firefighters, 60 apparatus including engines, aerials, rescues, foam, hazardous material units, mobile command posts, and ambulances (Bradish, 2006). The fire resulted in a \$4.5 million loss. Shouldis (2001) mentioned a warehouse in Philadelphia that lasted 8 days, required 275 firefighters, 57 apparatus, ten alarms and resulted in three injured fire fighters.

Historically, on December 22, 1910, 21 firefighters were killed at a stockyard and cold storage warehouse in Chicago (Firehouse, 1999). The Worcester cold storage warehouse fire killed six firefighters in 2000 (Eisner, 2000). Fire Engineering (1954) mentioned a \$3,000,000 loss warehouse fire that injured 21 firefighters. Fire Engineering (1949) reported a major warehouse fire in Rochester New York in 1949.

Comeau and Duval (2001) and Lobash (2006) discuss a major warehouse fire that occurred at the Central Garden and Pet Supply in Phoenix Arizona in 2000. The loss is estimated in hundreds of millions. The warehouse was equipped with a modern sprinkler system (Comeau

and Duval, 2001). The K Mart fire sprinkler system failure was mentioned by Harrington (2006) and Schultz (2006). Schultz (2006) also mentioned the Sherman-Williams sprinkler failure.

Schultz (2006), Harrington (2006), Comeau and Duval (2001), Wolf (1998) mention the environmental threat associated with pool chemicals. Schultz (2006) and Jakubowski (2005) mention aerosols as a hazardous material threat. Schultz (2006) also mentions the treat of flammable liquid storage. Nugent (1998) mentions incompatible storage, reactions, and potential explosions of pool chemicals when exposed to incompatible chemicals such as dry chemical extinguishers. Comeau and Duval (2001), Siphwe (2001), NFPA (2007), Parlor (2003), Fire Engineering (1951), Bertalovitz (1969) Green (2004), Everton (2002), and Brannigan (1997) all mention financial losses associated with warehouse fires. Parlor (2003) added that such fires drain company resources, investment, and result in customer losses. NFPA (2007) mentions community job losses and tax base loss. Environmental contamination from run-off is mentioned by Parlor (2003), NFPA (2007), Everton (2002), Germann (1994), McCafferty (2006), Shouldis (2001), Freeman (2000), Goves (2001), and Shouldis (2001). McCafferty (2006) and Parlor (2003) mention health threats to residential neighborhoods. Death and injury to civilians and firefighters is mentioned by Firehouse (1999), Fire Engineering (1949), NFPA (2007), Baird (1960), Smith (2002), Bertalovitz (1969), and Voice (1995). Parlor (2003), Everton (2002), and Standing (2000) mention litigation associated with warehouse fires. Brannigan (1997) mentions the enormous requirement of resources.

RFD Fire Marshall Norma Barajas was interviewed on September 20, 2007. Barajas is a California State certified level I, II, and III fire prevention officer and has thirty years experience in fire prevention. She has experience overseeing the development of 9 ESFR protected warehouse distribution centers. Barajas revealed that the total economic impact values of ESFR

protected warehouses in Rialto are significant with project costs of \$537.8 million, 705 full time employees, 100 part time employees, and inventory costs estimated at \$2,169,000,000 (personal communication, September 20, 2007). Barajas feels the most important ESFR issues are maintenance of flue spaces, monitoring storage practices, having an independent on-site water supply, a well maintained functioning fire pump, and an independent inspection program by a fire protection engineer (personal communication, September 20, 2007). Some details of her interview are included in the Background and Significance section.

Feedback Instrument Question 8: A major warehouse fire which overcame an ESFR sprinkler system in my community would result in the following post event consequences.

(check all that are applicable) Choices were;

Community economic losses	(37.9 %) or 11 respondents
Job loss	(44.8%) or 13 respondents
Tax base loss	(34.5%) or 10 respondents
Business disruption	(51.7%) or 15 respondents
Environmental damage	(27.6%) or 8 respondents
Drain on fire suppression resources	(41.4%) or 12 respondents
Litigation	(20.7%) or 6 respondents
All of the above	(44.8%) or 13 respondents
Other	(17.2%) or 5 respondents

One respondent skipped this question.

Comments to Feedback Instrument Question 8 quoted verbatim:

“We do not have these in our jurisdiction but any warehouse fire would create the above mentioned issues”.

“Possible litigation”.

“We currently do not have any ESFR systems”.

“May impact future development by other companies”.

“Political blame game”.

The following feedback instrument questions offered applicable data. This data is reported in more detail, later in the results section. In feedback instrument question 6, 0.0% of the respondents found danger associated with forklift accidents and aerosols. Four percent found danger associated with stored flammable liquids and forklift accidents. In feedback instrument question 11, 50% of the respondents selected a need to establish a safety section early in a warehouse fire. In feedback instrument question 12, 56% of the respondents selected caution when dealing with stored pool chemicals. Thirty-two percent of the respondents selected the need for hazardous materials response, and 48% selected the need for environmental clean-up response. In feedback instrument question 15, 20% of the respondents selected the need for a legal team response, and 56% selected the need for reliance on master mutual aid to manage a warehouse fire.

Research Question 2:

What methods are being utilized in Southern California to prevent ESFR sprinkler system failures in warehouse distribution centers?

To answer this question, the researcher utilized feedback instrument questions, literature review and interviewed 3 experts.

Harrington (2006), Lobash (2006), Naylis (1999), and McCafferty (2006), mentioned preventing valves from being shut off. Harrington (2006), Lobash (2006), McCafferty (2006) Sprinkler Age (2003), Viking Sprinkler Corporation (2001), Fire International (2003),

Golinveaux and Hankins (2006), Valentine (2007), Record (2001) and Fletcher (2001) mentioned obstructions to ESFR systems. Schultz (2006), Harrington (2007), Jakubowski (2005), Comeau and Duval (2001), Wolf (1998), Nugent (1998), Gagnon (2005), Fletcher (2001), Naylis (1999), and Golinveaux and Hankins (2006) mentioned commodities not matching sprinkler design. Arson prevention was mentioned by Brannigan (1997) and Harrington (2006). Shultz (2006) stressed assuring the capability of maintaining large fire flows, up to four times more than a control mode system.

Pre-construction coordination amongst all trades was mentioned by Schultz (2006) Harrington (2006), McCafferty (2006) and Zimmerman (2007) mentioned compartmentation of construction. Fire pump maintenance, maintenance of fire flow, and water tank maintenance was mentioned by Gagnon (2005), McCafferty (2006) Schultz (2006), and Harrington (2006). Strict adherence to stringent design rules was mentioned by Welch (2000), Sprinkler Age (2003), Fletcher (2001), Record (2001), and Viking Sprinkler Corporation (2001).

On October 4, 2005 Mike Miksich, Target Corporations' Distribution of Operations Division head, was interviewed via telephone. Miksich (personal communication, October 4, 2007) stated he did not have enough information to offer an opinion on engine company captain competence to inspect ESFR systems. He (M. Miksich, personal communication, October 3, 2007) stated that in his 16 year history with Target, he has never seen an ESFR sprinkler system over-run in a Target warehouse. Target presently has 30 distribution centers nationally. Miksich (personal communication, October 4, 2007) feels it is possible for an ESFR failure. However, he stated that with annual inspection by a fire protection engineer, strict adherence to fire pump maintenance schedules, and training of Target personnel, such a failure was not likely (M. Miksich, personal communication, October 4, 2007).

Miksich also stated that maintenance of flue spaces was a critical item in ESFR systems (personal communication, October 4, 2007). He emphasized preventative maintenance and due diligence of the owner to maintain fire protection systems. Miksich (personal communication, October 4, 2007) stated that Target utilizes a licensed fire protection engineer to inspect their systems annually, examine life safety procedures and drills, check electrical systems, and test tenant knowledge to address risk management concerns. Such concerns are significant. The Rialto Target warehouse distribution center cost 300 million to build. Each building has a maximum foreseeable loss (MFL) wall. On either side of each wall, there is \$500 million in merchandise. Hence, the Rialto facility has \$2 billion in merchandise (M. Miksich, personal communication, October 4, 2007).

Miksich (personal communication, October 4, 2007) does not favor building tenant fire protection systems such as class II standpipes. Miksich feels tenants should be instructed to quickly leave the warehouse, allow the ESFR system to work, and rely on professional firefighters to mop up and evacuate the smoke. He (M. Miksich personal communication, October 4, 2007) favors class I standpipes at the man doors for firefighters to utilize.

Regarding arson prevention, Miksich stated that Target does not allow any unauthorized personnel into their warehouses. Target (M. Eastman personal communication, October 4, 2007) has a command center that monitors perimeter control. The facility is surrounded by an 8 foot fence with barbed wire at the top. Employees have card access to the employee parking area. If, for some reason, there is a security breach, the command center can activate special security gates locking down the distribution center (M. Miksich personal communication, October 4, 2007).

Target (M. Miksich, personal communication, October 4, 2007), in a fire alarm, evacuates the facility. The buildings have audible PA systems that instruct the evacuation of employees. Personnel on motorized carts drive the warehouse to assure everyone is evacuated (M. Miksich personal communication, October 4, 2007). Target utilizes battery operated fork lifts to minimize a fork lift fire. In addition, they utilize a fire watch within the building, isolate combustibles, and utilize non-flammable blankets to surround an area if they need to weld or repair a rack. Target has an aggressive spill program in case any materials are spilled in the warehouse (M. Miksich personal communication, October 4, 2007).

One unique Target fire protection pre-event activity is their microbiological influenced corrosion (MIC) program (M. Miksich, personal communication, October 4, 2007). Miksich mentioned that Target had a problem, especially in the Sacramento area, with corroding sprinkler risers, main lines and branch lines. They were developing pin holes. Target kept on replacing the pipes but the problem persisted. They researched the issue and discovered that when the systems are flow tested, it introduces oxygen into the system (M. Miksich, personal communication, October 4, 2007). This provides the right environment for bacteria colonies to grow, which, in turn, corrodes the inside of the pipes. Target has retrofitted all of their systems with a chlorine injection system which kills the bacteria (M. Miksich, personal communication, October 4, 2007).

On October 15, the researcher interviewed Steve Sutton, a fire protection engineer who owns a firm that provides risk management and engineering services to Target, Nestles, Walgreens, and other corporations (personal communication, October 15, 2007). Sutton does not feel that engine company captains are knowledgeable enough about ESFR technology to adequately inspect them. Sutton (personal communication, October 15, 2007) attends training

twice a year to keep up with the changing technology. Sutton feels that firefighters and owners need to be re-trained on a regular basis.

Sutton (personal communication, October 15, 2007) did cite an ESFR system failure that occurred in Florida. It is the only ESFR failure he is aware of. He stated the building was lost because of the tactics of the volunteer fire department. The fire department vertically ventilated the roof before the ESFR system extinguished the fire. The vent hole drew heat and smoke away from the fire area and caused sprinklers to activate away from the fire. Sprinkler skipping resulted in depletion of the water supply. The fire spread horizontally and destroyed the warehouse (personal communication, October 15, 2007).

Sutton (personal communication, October 15, 2007) feels the main causes of ESFR failure are blockage or obstructions of ESFR heads caused by construction features such as earthquake bracing, lighting fixtures, etc. Sutton also mentioned the importance of maintaining flue spaces to prevent sprinkler skipping and horizontal fire spread.

Sutton (personal communication, October 15, 2007) stated that Target, Nestles, and Walgreens are very proactive in evaluating their ESFR systems on a bi-annual basis to assure effectiveness. Sutton mentioned that his firm has a risk management emphasis coupled with an emphasis of proper installation and maintenance of ESFR systems. Sutton (personal communication, October 15, 2007), feels that employee and firefighter education is essential to assure proper maintenance. Sutton mentioned that Target, Walgreens, Nestle and Americold, corporations that he has contracts with, have “Highly Protected Risk” (HPR) ratings. This coveted insurance rating, according to Sutton (personal communication, October 15, 2007) translates into lower insurance ratings. For example, Sutton stated that Target’s insurance costs

are 18 cents per \$1,000 of insured inventory, which Sutton (personal communication, October 15, 2007) attributes to their maintenance and inspection program.

Sutton (personal communication, October 15, 2007) mentioned that Target has warehouse cameras and constant monitoring of floor areas to prevent arson. He stated that employee arson is always a concern for big box warehouses. Sutton (personal communication, October 15, 2007) mentioned a warehouse in Woodland California where he designed the ESFR system which had an arson fire. Two disgruntled employees lit flares and placed them under plastic storage at opposite ends of the warehouse in an attempt to burn it down. The ESFR systems activated and extinguished the fire. The employees were videotaped, tried and convicted.

Sutton (personal communication, October 15, 2007) mentioned that Target's SOP for fire alarms includes four employee evacuation points, where all employees are pre-designated to report. Sutton stated that all areas are rapidly swept by Target employees on motor carts to assure evacuation. Two mechanics report to the pump house to assist the fire department and two mechanics report to the gate to meet responding firefighters to assist with fire location. Sutton (personal communication, October 15, 2007) stated that Target does not favor firefighting by building occupants.

Sutton (personal communication, October 15, 2007) feels that controversial issues associated with ESFR technology include the automatic smoke and heat venting issue, occupant firefighting associated with class I and II standpipes, and changing ESFR technology. Sutton (personal communication, October 15, 2007) feels that there are fire protection engineers who have not kept up with the changing ESFR technology. He feels that installers, engineers, occupants, and firefighters all need to be educated and that lack of education with ESFR

technology is dangerous. In addition, he feels that it is critical to coordinate ESFR design with installation. Sutton (personal communication, October 15, 2007) stated that big box structures have forced sprinkler system design to a much higher consideration in construction and that the sprinkler system drives the building design. Sutton (personal communication, October 15, 2007) stated that changes in occupants or commodities is a huge ESFR concern.

Sutton (personal communication, October 15, 2007) mentioned the danger of microbiological influenced corrosion to ESFR systems. He stated that anaerobic and aerobic bacteria feed on any ferrous pipe and that the water in Rialto tests very positive for such bacteria. Sutton stated that he recommends a bleach injection system that injects a 0.5% hypochloric acid solution into the pipes which kills the microbes. Sutton (personal communication, October 15, 2007) mentioned a company named Huguenot Labs that will treat ESFR systems with a foam solution if the condition is bad to restore piping. If the corrosion is allowed to continue, much of the ESFR piping requires replacement (S. Sutton, personal communication, October 15, 2007).

On October 17, 2007 the researcher spoke with Jack Allen, a fire protection engineer who has been in the business for over 40 years. Allen (personal communication, October 17, 2007) stated that he did not feel that engine company captains were knowledgeable enough to adequately inspect ESFR systems. He was not aware of any ESFR system failures. Allen (personal communication, October 17, 2007) feels that an ESFR system failure is entirely possible due to inadequate fire flow, pump failure, mismatched commodities, and obstructions. Allen (personal communication, October 17, 2007) stresses attention to detail in these matters with building owners. Allen did not mention arson prevention. Allen (personal communication, October 17, 2007) mentioned that the automatic smoke removal system issue associated with ESFR systems is controversial. He strongly favors the option and advocates fusible links on

vents that open at 360° F. He cited a recent fire in one of his buildings of 1.4 million square feet that had an ESFR and automatic smoke and heat venting, which extinguished the fire and resulted in minimal damage. Allen (personal communication, October 17, 2007) feels that developers have influenced the code adoption process to cut costs. In addition, Allen favors installation of class II standpipes. Allen (personal communication, October 17, 2007) stated that building owners should have the occupant firefighting option available, especially in California during disaster situations, because the fire service can become overwhelmed and warehouses, presenting low life loss hazards, are not a high priority.

The feedback instrument obtained the following data that are applicable in answering this research question.

Feedback Instrument Question 1: Engine company captains (supervisors) in my fire department know the difference between control-mode (conventional in-rack) fire sprinklers and Early Suppression Fast Response (ESFR) fire sprinklers. (check all that are applicable) Choices available were:

Strongly agree	(0%) or 0 respondents
Agree	(23.3%) or 7 respondents
Disagree	(60.0%) or 18 respondents
Strongly Disagree	(16.7%) or 5 respondents

Zero respondents skipped this question.

Feedback Instrument Question 2: Engine company captains (supervisors in my fire department are knowledgeable about ESFR systems and qualified to inspect such systems on the following issues. (Check all that are applicable) Choices were:

ESFR maintenance	(0.0%) or 0 respondents
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Fire pump maintenance	(3.6%) or 1 respondent
Commodity changes and/or incompatible storage	(0%) or 0 respondents
Obstructions to ESFR systems	(17.9%) or 5 respondents
Lack of maintaining flu spaces	(3.6 %) or 1 respondent
Engine company captains are not qualified to inspect these issues	(67.9%) or 19 respondents
Other	(17.9%) or 5 respondents

Two respondents skipped this question.

Feedback Instrument Question 2 comments quoted verbatim:

“Inspections performed by fire prevention staff. Engine company officers trained in operation only”.

Feedback Instrument Question 7: My fire department participates in the following pre-fire activities to prevent fires from occurring in ESFR protected warehouses. (check all that are applicable) Choices were:

Inspect for incompatible storage	(78.6%) or 22 respondents
Assure sprinkler design matches commodities stored	(71.4%) or 20 respondents
Engine company code enforcement fire prevention inspections	(75.0%) or 21 respondents
Recognition and correction of obstructions	(71.4%) or 20 respondents
Fire pre-plan development	(89.3%) or 25 respondents
Training on ESFR code enforcement	(28.6%) or 8 respondents

Checking for proper ESFR maintenance	(53.6%) or 15 respondents
Coordination of various trades during construction	(32.1%) or 9 respondents
Compartmentation of construction features	(32.1%) or 9 respondents
Education of building owner	(46.4%) or 13 respondents
Other	(21.4%) or 6 respondents
2 respondents skipped this question	

Comments to Feedback Instrument Question 7 quoted verbatim:

“The items checked above are handled by the fire prevention bureau and the engine companies have limited experience in these areas.”

“Performed at the fire prevention unit level”.

“We do not have ESFR sprinklers in our jurisdiction”.

“Annual and semi-annual building inspections by fire prevention and training of engine companies in systems operations”.

“All annual inspections conducted by fire inspectors. HPS reports/plans are required for all high piled storage warehouses”.

“Much more needs to be done”.

Feedback Question 9: The advantages of an ESFR system in a warehouse are. (check all that are applicable) Choices were:

Greater flexibility in relocating commodities	(60.0%) or 18 respondents
Minimizes water damage	(20.0%) or 6 respondents
No in-rack fire sprinklers to	

be knocked off	(53.3%) or 16 respondents
Wide protection of commodities	(56.7%) or 17 respondents
ESFR systems cost less	(13.3%) or 4 respondents
Early fire suppression	(76.7%) or 23 respondents
Internationally accepted technology	(10.0%) or 3 respondents
Unsure	(23.3%) or 7 respondents
Other	(13.3%) or 4 respondents
0 respondents skipped this question	

Feedback Instrument Question 9 comments quoted verbatim:

“ESFR systems cost less depending upon design”.

“ESFR can usually place more water over the protected area than fire department hose-lines in interior attack and promote greater firefighting safety”.

Feedback Instrument Question 10: The disadvantages of an ESFR system in a warehouse are. (check all that are applicable) Choices were:

More stringent design rules	(42.9%) or 12 respondents
Commodity limitations	(14.3%) or 4 respondents
ESFR systems are more sensitive to obstructions	(32.1%) or 9 respondents
ESFR systems are incompatible with automatic smoke and heat venting	(39.3%) or 11 respondents
ESFR systems require more fire-flow	(57.1%) or 16 respondents
Unsure	(25.0%) or 7 respondents
Other	(14.3%) or 4 respondents

2 respondents skipped this question

Feedback Instrument Question 10 comments quoted verbatim:

“Often times eliminates in-rack requirements”.

“Many ESFR require booster pumps which mean more maintenance for the owner and more detailed inspection and testing. Not a bad thing but just more intensive”.

“Lack of maintenance of pump and flu spaces are critical concerns”.

Feedback Instrument Question 13: I favor automatic smoke and heat venting systems in an ESFR protected warehouse. Choices were:

Strongly agree	(24.1%) or 7 respondents
Agree	(13.8%) or 4 respondents
Disagree	(31.0%) or 9 respondents
Strongly disagree	(10.3%) or 3 respondents
Other	(20.7%) or 6 respondents

One respondent skipped this question.

Feedback Instrument Question 13 comments quoted verbatim:

“Automatic is good if heat allows the activation of heads prior to opening. Automatic manual venting is better (see Lowe’s buildings)”.

“Use high temp links on vents”.

“Manual”

“Venting should be controllable by the fire department. Usually it should be shut down while the system does its’ job but may be needed later”.

“Our city utilizes manually controlled smoke and heat venting”.

Feedback Instrument Question 14: Warehouse building tenants should be trained in firefighting tactics to stop a warehouse fire in its incipient phase. Choices were:

Strongly agree	(31.0%) or 9 respondents
Agree	(17.2%) or 5 respondents
Disagree	(24.1%) or 7 respondents
Strongly disagree	(17.2%) or 5 respondent
Unsure	(10.3%) or 3 respondents

One respondent skipped this question.

Feedback Instrument Question 14 comments quoted verbatim:

“Danger to the occupants could occur from personnel turn-over and lack of training”.

“There should be a plan”.

“If it’s sprinklered, get them out!”

“Alarm, control if possible, evacuate the building. Should not put occupants at risk”.

“Only first aid firefighting (extinguishers) should be attempted due to long exit travel distances and smoke dropping when system activates”.

“Tenants and employees should be trained to keep product where it belongs and in the manner in which it is intended to be stored”.

“This is important in earthquake country”.

Research Question 3: What methods are fire agencies in Southern California utilizing to manage ESFR protected warehouse distribution fires should they occur in their community?

To answer this question the researcher utilized a feedback instrument and literature review.

Shouldis (2001), Naylis (1999), Parlor (2003), The Instructor (2004), Hatfield (2006), Goves (2001), Brunacini (2003), and James (1999) all say to expect rapid fire spread, flashover,

and heavy fire attack if the fire overcomes the sprinkler system. Shouldis (2001) mentions the importance of cutting off vertical and horizontal fire spread. In addition, Shouldis (2001) advises to not count on an ESFR to extinguish the fire.

Smith (2002) and Voice (1995) recommend an incident action plan be developed. Shouldis (2001), The Instructor (2004), Smith (2002), Welch (2000), and Voice (1995) add that a strong incident command system is essential. Shouldis (2001) adds that EOC activation should be considered. Goves (2001) and Standing (2000) mention difficulties associated with search and rescue in a big box fire. Parlor (2003) and Hatfield (2006) add there is often difficulty in locating the fire. Welch (2000) Shouldis (2001), The Instructor (2004), Goves (2001) Parlor (2003) Naylis (1999), Jakubowski (2005), McCafferty (2006), Voice (1995), all mention the danger of building collapse and importance of considering a defensive strategy.

Shouldis (2001) and Naylis (1999) mention the importance of assuring fire pump function, open valves, pumping to the right connection, assuring proper water supply, and to strategically utilize firewalls. Shouldis, (2001), Welch (2000), Hatfield (2006) all mention the need for multiple tactical frequencies. In addition, Hatfield (2006) recommends approaching the fire from the roll up door side of the building, to note the bay door number closest to the fire, and communicate it to fire attack, and to open bay doors as you approach the fire. Naylis (1999) and Nugent (1998) mention the importance of ventilation.

One unique big box fire issue is managing cold smoke mentioned by The Instructor (2004), Hatfield (2006), Brunacini (2003), and Standing (2000). The Instructor (2004) and Welch (2000) recommend the use of thermal imaging to peer through cold smoke to determine if fire is spreading above the heads of fire attack crews undetected. Another big box issue of concern is pool chemicals and chlorine gas production mentioned by Nugent (1998), Welch

(2000), and Harrington (2006). The importance of RIC teams was mentioned by Nugent (1999), The Instructor (2004), and Brunacini (2003). Specialized equipment use such as ventilation fans was mentioned by Hatfield (2006) and The Instructor (2004). Sice (2006), Viking Sprinkler Corporation (2001) and Goves (2003) mention AFFF. Goves (2003) mentions robotic fire fighting equipment.

The feedback instrument provided the following information to answer this research question.

Feedback Instrument Question 3. My fire department has experienced a major fire in a warehouse protected by the following sprinkler systems. (check all that are applicable) Choices were:

Control mode (conventional in-rack Sprinklers)	(33.3%) or 10 respondents
ESFR system	(13.3%) or 4 respondents
Deluge system	(3.3%) or 1 respondent
Foam system	(3.3%) or 1 respondent
Un-sprinklered	(46.7%) or 14 respondents
My community has not experienced a serious warehouse fire	(46.7%) or 14 respondents
No respondents skipped this question.	

There were no comments to feedback instrument question 3.

Feedback Instrument Question 5: My department has an SOP or SOG for response to warehouse fires. (check one box)

Yes, my department has an SOP	(20.0%) or 6 respondents
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Yes, my department has an SOG	(16.7%) or 5 respondents
No, my department does not have an SOP or an SOG	(36.7%) or 11 respondents
Unsure	(20.0%) or 6 respondents
Other	(6.7%) or 2 respondents

No respondents skipped this question.

Feedback Instrument Question 5 comments quoted verbatim:

“I have plans to get this procedure started through our operations BC meetings. Big need here”.

“No SOP. However, big boxes are toured by all engine companies and training provided on specific system and hazards”.

Feedback Instrument Question 11: When attacking a fire in an ESFR protected warehouse, the following items are essential to address. (check all that are applicable) Choices were:

Assure a large fire-flow attack. (big fire-big water)	(64.3%) or 18 respondents
Assure sprinkler valves are open	(71.4%) or 20 respondents
Expect rapid fire spread	(25.0%) or 7 respondents
Have a written IAP	(32.1%) or 9 respondents
Initiate a safety section early	(50.0%) or 14 respondents
Utilize thermal imaging cameras to locate the fire	(53.6%) or 15 respondents
Consider lightweight construction collapse and defensive strategy	(60.7%) or 17 respondents

Assure the fire pump is working	(64.3%) or 18 respondents
Cut off vertical and horizontal fire spread	(53.6%) or 15 respondents
Utilize multiple tactical frequencies or direct tactical channels	(42.9%) or 12 respondents
Utilize a Unified Command structure	(46.4%) or 13 respondents
Other	(17.9%) or 5 respondents
Two respondents skipped this question.	

Feedback Instrument Question 11 comments quoted verbatim:

“I appreciate your ops orientation”.

“If the ESFR system is functioning properly, fire spread should be stopped or severely limited resulting in less apparatus being required as opposed to an exterior attack where the entire building is lost”.

“ESFR or not, many listed are uniformly used”.

Feedback Instrument Question 12: When attacking a fire in an ESFR protected warehouse, the following items are essential to address. (check all that are applicable) Choices were:

Activate the EOC	(8.0%) or 2 respondents
Ventilation is essential	(64.0%) or 16 respondents
Utilize a defensive strategy if fire is well developed	(60.0%) or 15 respondents
Be cautious of dangerous pool chemicals	(56.0%) or 14 respondents

Extinguish overhead trusses	
from a safe location	(48.0%) or 12 respondents
Expect cold smoke and fire	
spread unnoticed above the smoke	(56.0%) or 14 respondents
Respond Hazardous Materials units	(44.0%) or 11 respondents
Specialized resources will be needed	(52.0%) or 13 respondents
Performing rescue is extremely	
dangerous in such occupancies	(60.0%) or 15 respondents
Utilize foam to extinguish	
well established fire	(40.0%) or 10 respondents
Other	(24.0%) or 6 respondents

Five respondents skipped this question.

Feedback Instrument Question 12 comments quoted verbatim:

“Haz-mat response, rescue is always first consideration and foam is a nice to have”.

“No ESFR system within city, experience limited”.

“Depends on commodity involved”.

“Rescue can be demanding because of extended travel distances to exits and obstructions; i.e. conveyor belts”.

Feedback Instrument Question 15. What type of specialized resources would your fire department expect to utilize on an ESFR protected warehouse fire? (check all that are applicable)

Choices were:

Trailer mounted ventilation fans	(4.0%) or 1 respondent
Specialized robotic fire	

suppression apparatus	(4.0%) or 1 respondent
Type I Foam Tender	(24.0 %) or 6 respondents
Type I Hazardous Materials Unit	(32.0%) or 8 respondents
Fire Investigation Unit	(76.0%) or 19 respondents
Reliance on master mutual aid	
agreements for resources	(56.0%) or 14 respondents
Cost Recovery	(32.0%) or 8 respondents
Legal Advice Team	(20.0%) or 5 respondents
Environmental clean-up	
personnel and equipment	(48.0%) or 12 respondents
Property conservation personnel	
and equipment	(36.0%) or 9 respondents
Mobile Command Unit	(56.0%) or 14 respondents
Other	(20.8%) or 5 respondents

Five respondents skipped this question.

Feedback Instrument Question 15 comments quoted verbatim:

“Health, haz-mat”

“No ESFR systems in city”.

“Various commodities will require different resources”

Feedback Instrument Question 16: Do you have anything to add?

Seven respondents and 23 respondents skipped this question.

The following comments to feedback instrument question 16 are quoted verbatim.

“Will use portions of this survey as a training and/or information tool; operationally and in our prevention unit. Thanks”.

“We only have 3 conventionally sprinklered warehouses but it would be interesting to know what is out there”.

“A properly designed and maintained ESFR system can apply more water than most fire departments are capable of in an interior attack. We have an 800,000 square foot tire warehouse with ESFR along with several other big box set ups with various classes of commodity. All booster pumps are inspected at least once a year and usually twice a year. The fire department must pay attention to the design of any new system to assure there is adequate fire flow and pressure or they will not function as designed. We have tested various K factor heads and have several different types throughout the city. It is possible to overpressure an ESFR head which changes the droplet pattern and could adversely affect the system operation. Training is essential for all engine companies”.

Research Question 4: What methods should Rialto Fire Department utilize in preventing and managing fires in ESFR protected warehouse distribution centers within its jurisdiction?

To answer this question, the researcher conducted a literature review, utilized a feedback instrument, and interviewed 2 experts.

The literature revealed that RFD should participate in pre-event activities including monitoring of commodity storage Haylis (1999), Golinveaux and Hankins (2006), and Jakubowski (2005). Miss matched commodities was emphasized by Naylis (1999), Golinveaux and Hankins (2006), and Jakubowski (2005). Emphasis should be placed on incompatible pool chemicals (Harrington, 2006), Comeau and Duval (2001, flammable liquids, (Schultz, 2001),

aerosols (Jakubowski, 2005). Arson prevention was mentioned by Brannigan (1997) and Harrington (2006).

Monitoring and preventing obstructions was mentioned by numerous sources including McCafferty (2006), Sprinkler Age (2003), Viking Sprinkler Corp (2001), Fire International (1997), Golinveaux and Hankins (2006), and Fletcher (2001). Prevention of fork lift accidents was mentioned by Whiteley (2006). Training on code enforcement for fire suppression personnel was mentioned by Mark (1999), Schultz (2006), Whiteley and Jarret (1995) with an emphasis on recognizing commodity changes, especially plastics. Education of building owners regarding commodity changes was mentioned by Schultz (2006). Assurance of fire pump maintenance was mentioned by Gagnon (2005) and McCafferty (2006). Pre-planning of buildings was highly recommended by Jakubowski (2005), Welch (2000), Shouldis (2001), Mark (1999), Naylis (1999), The Instructor (2004), Everton (2002), Goves (2001), Goves (2003), Germann (1994), Fire Engineering (1965), Voice (1995), and Nugent (1998). Shouldis (2001), Naylis (1999), Parlor (2003), The Instructor (2004), Hatfield (2006), Goves (2001), Brunacini (2003), and James (1999) all say to expect rapid fire spread, flashover, and heavy fire attack if the fire overcomes the sprinkler system. Shouldis (2001) mentions the importance of cutting off vertical and horizontal fire spread. In addition Shouldis (2001) advises to not count on an ESFR to extinguish the fire.

A strong incident command system is advocated Shouldis (2001), The Instructor (2004), Smith (2002), Welch (2000), and Voice (1995). Smith (2002) and Voice (1995) recommend an incident action planning. EOC activation is mentioned by Shouldis (2001). Difficulty search and rescue is stressed by Goves (2001) and Standing (2000). Early defensive firefighting tactics are mentioned by Parlor (2003), and Hatfield (2006) says to expect difficulty in fire location.

Hatfield (2006) says to approach the fire from the roll up door side of the warehouse, communicate the location of the nearest man door to fire attack, and to open bay doors. Shouldis (2001) and Naylis (1999), mention the importance of assuring fire pump function, open valves, pumping to the right connection, assuring proper water supply, and positioning by firewalls. Shouldis (2001), Welch (2000), Hatfield (2006) all mention the need for multiple tactical frequencies. Ventilation is discussed by Naylis (1999) and Nugent (1998).

The problem of managing cold smoke is discussed by The Instructor (2004), Hatfield (2006), Brunacini (2003), and Standing (2000). The Instructor (2004) and Welch (2000) recommend the use of thermal imaging to see through cold smoke to detect fire spread. Planning for dangerous pool chemical storage was mentioned by Nugent (1998), Welch (2000), and Harrington (2006). RIC teams function was discussed by Nugent (1999), The Instructor (2004), and Brunacini (2003). Specialized equipment was discussed by Hatfield (2006) and The Instructor (2004). Sice (2006), Goves (2003) and Viking Sprinkler Corporation (2001) and mention AFFF usage. Goves (2003) mentioned robotic firefighting equipment.

On October 3, 2007 the researcher spoke with Leonard Temby, the Redlands Fire Marshall. Temby (personal communication, October 3, 2007) feels that engine company captains are capable of inspecting ESFR systems if they are properly trained. Temby feels engine companies should be dispatched on all fire pump activation calls. He emphasizes weekly fire pump testing, assuring commodities match the sprinkler design, and strict adherence to a high piled stock plan (L. Temby personal communication, October 3, 2007).

Temby (personal communication, October 3, 2007) was not aware of an ESFR protected building failure but he cited a Home Depot fire, which had a deluge system similar to an ESFR that failed in Austin Texas. The failure resulted because rocks in the water supply lines destroyed

the fire pump impellers (L. Temby, personal communication, October 3, 2007). The fire was started by a disgruntled employee in the wood working area. Temby (personal communication, October 3, 2007) stated that the main cause of an ESFR system failure would be inadequate water supply, pump failure, or a closed valve.

Temby (personal communication, October 3, 2007) favors the use of battery powered fork lifts. Propane fork lifts should be outfitted with a 5 Lb ABC extinguisher. In addition, to prevent arson, Temby (personal communication, October 3, 2007) states that on site security is a must. Warehouses should also be closed to unauthorized personnel. To prevent accidental fires, Temby (personal communication, October 3, 2007) states that no inside welding should be permitted unless strict rules of emptying the rack, establishing a fire watch, and other preventative measures are taken to prevent a commodity fire. In addition, electrical light fixtures need to be maintained to prevent a high rack fire (L. Temby personal communication, October 3, 2007).

Temby (personal communication, October 3, 2007) feels that the automatic smoke and heat venting issue as it pertains to ESFR systems is very controversial. He stated that the recent International Fire Code (IFC) adoption process going on in San Bernardino County amended the IFC to require manually controlled smoke removal systems, operated by firefighters, from a fire control room. Temby (personal communication, October 3, 2007) does not favor occupant firefighting with the exception of fire extinguisher operation for very small fires. Temby (personal communication, October 3, 2007) does not favor class II standpipes and warehouse occupant firefighting.

Temby (personal communication, October 3, 2007) mentioned that Redlands conducted a ventilation test on a 200,000 square foot warehouse utilizing standard smoke ejectors carried on

their fire engines. The test revealed that they were ineffective in ventilating the buildings. Within two minutes, they caused the smoke to go to floor level, upsetting the thermal balance, and disrupting visibility creating what he described as “tulle” fog (L Temby, personal communication, October 3, 2007). Visibility was reduced to zero and he described the fans as creating a blender effect. Temby (personal communication, October 3, 2007) recommends manually controlled smoke and heat ventilation systems or opening 4-8 warehouse roll up doors for cross ventilation. Redlands does not have a trailer mounted fan.

Temby (personal communication, October 3, 2007) mentioned that all branch lines and bulk feed lines to the ESFR are color coded with reflective tape that can be seen through smoke. This requirement allows firefighter to communicate their position to command in the fire control room. This, in turn, allows firefighters to identify and pump to the correct sprinkler system. Hose valves are color coded with the sprinkler systems so firefighters can identify the correct standpipe, closest to the fire. Temby provided RFD with a copy of Redlands FD’s “Wide-Rise Policy” (Redlands, 2005). (See Appendix F)

On October 3, 2007, the researcher interviewed Mike Horton, the Fire Marshall for San Bernardino County Fire Department (SBCFD). Horton (personal communication, October 3, 2007) stated that he does not feel that engine company fire captains are knowledgeable enough to adequately inspect ESFR systems. SBCFD (M. Horton, personal communication, October 3, 2007) utilizes four fire protection specialists to conduct annual inspections and assure adequate maintenance. Horton stated that he did not feel that engine company personnel are capable of recognizing incompatible commodity storage issues. In fact, Horton stated he expects that warehouses provide a commodity class third party classification that specifies the scope of work, amounts, and percentages of commodities, to determine ESFR compatibility issues. In addition,

Horton feels that maintaining adequate fire flow, incompatible plastics and flammable liquid storage, and obstructions to flu spaces were the most critical items issues that could lead to an ESFR failure (personal communication, October 3, 2007).

Horton (personal communication, on October 3, 2007) mentioned that SBCFD does not have any specific information to provide building owners on how to prevent arson. However, he stressed vigilance and security and stated that it is important to keep unauthorized personnel out of warehouses (M. Horton, personal communication, October 3, 2007).

Horton (personal communication on October 3, 2007) feels that controversial issues surrounding ESFR technology include the automatic smoke and heat venting issue, occupant firefighting, types of stand pipes and commodity classification. Horton (personal communication, October 3, 2007) does not favor automatic smoke and heat venting. He favors manually controlled systems. In addition, Horton (personal communication, October 3, 2007) feels that it's acceptable to train building occupants to utilize fire extinguishers to suppress an incipient fire but he does not approve of class II standpipes. He requires class I standpipes at the man doors.

Horton (personal communication on October 3, 2007) feels that computer modeling is worthwhile to consider if backed up by fire protection engineering acceptance of such but he still requires adherence to the California Fire Code, which is more restrictive. In addition, Horton (personal communication, October 3, 2007) stated that Factory Mutual standards are less restrictive than the California Fire Code, and that he favored stricter adherence.

Research Question 2 has several reported feedback question results that are applicable in answering research question 4 (See Results Section for Research Question 2 data). Feedback instrument questions 1 and 2 explore engine company ESFR knowledge. Feedback instrument

question 7 explores fire prevention and inspection activities. Feedback instrument question 10, explores ESFR warehouse disadvantages, and feedback instrument question 14 explores warehouse occupant firefighting.

Research Question 3 has several reported feedback question results that are applicable in answering research question 4 (See Results Section for Research Question 3 data). Feedback instrument question 3 explores fire department experience of warehouse fires in their jurisdiction. Feedback instrument question 5 explores fire department SOP or SOG development. Feedback instrument questions 11 and 12 explore fire attack in an ESFR warehouse. Feedback instrument questions 11 and 12 explore ESFR warehouse fire attack. Feedback instrument question 15 explores specialized resource use in an ESFR warehouse fire. Feedback instrument question 16 has applicable additional comments.

Feedback Instrument Question 4. The following factors contributed to a major warehouse fire in my fire jurisdiction. (check all that are applicable) Choices were:

Not applicable	(53.6%) or 15 respondents
Occupants attempted to fight fire first	(25.0%) or 7 respondents
Delayed fire department notification	(28.6%) or 8 respondents
Obstructions to fire sprinkler system	(17.9%) or 5 respondents
Lack of maintenance	(7.1 %) or 2 respondents
Pool chemicals	(7.1%) or 2 respondents
Aerosols	(10.7%) or 3 respondents
System design did not match hazard	(28.6%) or 8 respondents
Other	(10.7%) or 3 respondents

Two respondents skipped this question.

Feedback Instrument Question 4 comments quoted verbatim:

“Arson”

“Poor water supply”.

“Modification to electrical system performed without a permit resulted in a serious fire controlled by the high hazard system and fire department attack lines”.

Feedback Instrument Question 6: The most common cause of warehouse fires in my jurisdiction are: (check all that are applicable) Choices were:

My community has not

experienced a warehouse fire (48.0%) or 12 respondents

Arson (24.0%) or 6 respondents

Reacting pool chemicals (4.0%) or 1 respondent

Fork-lift fires spreading to

commodities (8.0%) or 2 respondents

Fork-lift accidents related to

stored aerosols resulting in fire (0.0%) or 0 respondents

Fork-lift accidents related to

stored flammable liquids resulting in fire (4.0%) or 1 respondent

Electrical short (32.0%) or 8 respondents

Welding-related fire inside warehouse

spreading to commodities (16.0 %) or 4 respondents

Other 8 respondents

Five respondents skipped this question.

Feedback Instrument Question 6 comments quoted verbatim:

“We have had very few warehouse fires in our jurisdiction. The ones I can recall were caused by the aforementioned”.

“Flammable liquid spill from a tote”.

Lack of house keeping and mechanical failures”.

“House keeping issues coming in contact with heating appliances”.

“Miss-matched commodities and accidental”.

Feedback Instrument Question 17: Thank you for participating in this survey. Are you interested in seeing the results of this survey?

Yes (20.0%) or 6 respondents

No (46.7%) or 14 respondents

If yes; please write in your email

address in the “other” text box. (0.0%) or 0 respondents

Other (please specify) (33.0%) or 10 respondents

No respondents skipped this question.

Discussion

Research Question 1 Discussion

What risks to the community of Rialto do ESFR protected warehouse distribution centers pose in the event of an ESFR failure?

Clearly, the literature review provided findings that warehouses present significant community risk. Cobb (2000) in agreement with Neuholf (1998) and Bradish (2006) mentioned large loss fires requiring massive resources. There was agreement by Firehouse (1999), Bertalovitz (1969), Voce (1995), Smith (2002), Baird (1960), NFPA (2007), Fire Engineering

(1949) and Eisner (2000) that warehouse fires resulted in multiple firefighter fatalities. Related to this, in feedback question 11, the need to initiate a safety section early on was selected by 50.0% of the respondents. In feedback question 11, 60.7% of the respondents selected the consequence of lightweight construction and early collapse. These findings imply that awareness amongst the respondents of firefighter safety consequences is higher than other areas researched but such awareness could be improved. The implication for RFD, though, is that more awareness is needed because 100% awareness is imperative in the fire service to affect a positive change in ESFR warehouse safety culture. Considering the potential consequences for large life loss fires, firefighter's fatalities could be repeated if attention to detail is not emphasized.

Comeau and Duval (2001) and Lobash (2006) discuss a major warehouse fire that occurred at the Central Garden and Pet Supply in Phoenix Arizona in 2000. The loss was estimated in hundreds of millions. The warehouse was equipped with a modern sprinkler system (Comeau and Duval, 2001). This finding in the literature was similar to The K Mart fire sprinkler system failure was mentioned by Harrington (2006) and Schultz (2006). Schultz (2006) also mentioned the Sherman-Williams sprinkler failure. Likewise, Sphiwe (2001), NFPA (2007), Everton (2002), Parlor (2003), Bertalovitz (1969), Brannigan (1997), Green (2004) and Fire Engineering (1951) point out significant community economic losses associated with major warehouse fires. In feedback instrument question 8, 51.7% of the respondents found that a warehouse fire would result in business disruption. Awareness of community economic losses from a major warehouse fire will improve the motivation for a proactive prevention culture at RFD.

Feedback instrument question 8 revealed that only 35.7% of the respondents selected community economic loss, 37.9% mentioned job loss, and 34.5% mentioned tax base loss as

possible consequences. Likewise, RFD Fire Marshall Norma Barajas revealed that the total economic impact values of ESFR protected warehouses in Rialto was significant with project costs of \$537.8 million, 705 full time employees and 100 part time employees, and inventory costs estimated at \$2,169,000,000 (personal communication, September 12, 2007). The implication is that the literature found more awareness than was discovered in the feedback instrument. These findings relate to Rialto because major warehouse fires do occur in sprinklered warehouses. Such fires negatively impact the local economy and significant resources are required to manage such fires. RFD cannot ignore the significant threat that ESFR protected warehouse fires present to the community in potential financial loss, firefighter loss of life, and resource demand. A culture of complacency is not an option.

Schultz (2006), Harrington (2006), Comeau and Duval (2001), Wolf (1998) and Nugent (1998) mention the environmental threat associated with pool chemicals. Similarly, in question 12 of the feedback instrument, 56.0% of the respondents selected caution as it related to pool chemicals. Likewise, contamination from run-off was mentioned by Parlor (2003), NFPA (2007), Everton (2002), Germann (1994), McCafferty (2006), Shouldis (2001), Freeman (2000), and Goves (2001). Only 27.6% of the respondents to feedback instrument question 8 selected environmental damage. Similarly, in feedback instrument question 15, 32.0% of the respondents mentioned hazardous materials response required, and 48.0% mentioned environmental clean-up personnel and equipment as necessary. McCafferty (2006) and Parlor (2003) mention health threats to residential neighborhoods. The research findings indicate that there is some awareness amongst the respondents regarding the consequences of run-off contamination, the dangers of pool chemicals, and overall environmental threats. Such awareness is not where it

could be. The implication for RFD is that the research found significant community hazardous materials threats related to ESFR protected warehouse fires.

Schultz (2006), Whiteley, and Jakubowski (2005) mention aerosols as a hazardous material threat. However, in feedback question 6, 0.0% of the respondents found forklift accidents related to aerosols punctures was related to warehouse fires. Similarly, Schultz (2006) also mentions the treat of flammable liquid storage. However in feedback question 6, only 4.0% of the respondents found that forklift accidents related to stored flammable liquids were a problem. These findings indicate a lower level of awareness regarding the potential threats mentioned in the literature or perhaps problem resolution in the respondent's respective districts. Since RFD protects a significant aerosol and flammable liquid storage risk, the research findings indicate that these potential consequences exist in Rialto. A more proactive prevention culture is indicated.

Parlor (2003), Everton (2002), and Standing (2000) mention litigation associated with warehouse fires. Feedback instrument question 8 indicated that only 20.7% of the respondents selected this as a consequence and in feedback instrument question 15, only 20.0% of the respondents selected the need for a legal advice team. Hence, the literature searched found some litigation concern and the fire service respondents revealed a similar level of awareness. However, since this issue was not widespread in the findings, the implication is that awareness is not where it could be. Early consideration of litigation in a warehouse fire is an applicable finding for RFD, especially if environmental concerns or fatalities have occurred.

Brannigan (1997) mentions the enormous requirement of resources. In question 8, 41.4% of the respondents selected a drain on fire suppression as a consequence. Likewise in question 12, 44.0% selected the need for haz mat response as a consequence. In question 15, reliance on

master mutual aid was selected by 56.0%, the need for a mobile command unit was mentioned by 56.0% but only 24.0%% mentioned the need for a foam unit. Surprisingly, only 4.0% of the respondents in question 15 mentioned the need for a trailer mounted ventilation fan, whereas the need for a fire investigator unit was mentioned by 76.0% of the respondents. This finding implies that respondent awareness of the enormous resource requirements found in the literature was variable. It is directly applicable to RFD because of the enormous size of ESFR warehouses.

Research Question 2 Discussion:

What methods are being utilized in Southern California to prevent ESFR sprinkler system failures in warehouse distribution centers?

The literature review found a considerable amount of pre-event activity. The problem of closed sprinkler valves is mentioned by Harrington (2006), Lobash (2006), Naylis (1999), and McCafferty (2006). Similarly in feedback instrument question 11, 71.4% of the respondents mentioned this as a priority in fire suppression activities. Allen (personal communication, October 17, 2007) mentioned inadequate fire flow and pump failure.

Managing and preventing obstructions to ESFR systems was mentioned by Harrington (2006), Lobash (2006), McCafferty (2006) Sprinkler Age (2003), Viking Sprinkler Corporation (2001), Fire International (2003), Golinveaux and Hankins (2006), Valentine (2007), Record (2001) and Fletcher (2001). Similarly, Miksich (personal communication, October 3, 2007) stated that maintenance of flue spaces was critical in ESFR systems. Likewise, Sutton (personal communication, October 15, 2007) and Allen (personal communication, October 17, 2007) felt that one of the main potential causes of ESFR failure was obstructions or failure to maintain flue spaces. Likewise, one respondent to feedback instrument question 10 commented that lack of flue space maintenance was a critical concern. However, in feedback instrument question 10,

only 32.1% of the respondents selected the choice that ESFR systems are more sensitive to obstructions. This indicates that there was less awareness of this issue amongst the respondents than the interviewees or the literature. In contrast, RFD Fire Marshal Barajas stressed the importance of the obstruction and flue space maintenance issue (personal communication, September 20, 2007). The findings imply less awareness in the fire service respondents than industry experts or the literature reviewed. One explanation might be that some of the respondents did not have ESFR warehouses in their districts. Any culture of complacency regarding obstructions or flue maintenance is unacceptable at RFD based on these findings.

Only 17.9% of the respondents to feedback instrument question 4 indicated that obstructions contributed to a major warehouse fire in their jurisdiction. In feedback instrument question 7, 71.4% of the respondents indicated their fire departments work to prevent ESFR obstructions. Several comments to feedback instrument question 7 shed light on this inconsistent research finding because they indicate that such duties are performed by trained fire prevention staff and not engine companies. This finding is very significant for RFD because engine companies perform company inspections of ESFR warehouses but they have received minimal training.

Related to the above findings, in feedback instrument question 1, 78.6% of the respondents felt that engine company captains didn't know the difference between control mode and ESFR sprinklers systems. Similarly, in feedback instrument question 2, only 17.9% of the respondents felt that engine company captains were knowledgeable enough to inspect ESFR systems for such obstructions. In contrast, Miksich (personal communication October 4, 2007) offered no opinion on engine company captain qualifications. Sutton (personal communication, October 15, 2007) and Allen (personal communication, October 15, 2007) did not feel that

engine company captains were knowledgeable enough about ESFR technology to inspect them. Sutton (personal communication, October 15, 2007) added that lack of education regarding ESFR systems was a critical issue for building owners, fire protection engineers, employees and firefighters. One comment by a respondent may shed some light on this because it was indicated that their fire department trained firefighters in operation only. Typically, firefighters, including RFD, are more interested in tactics and strategy and less interested in pre-event activity such as fire prevention. However, the findings indicate that a pre-event, preventative culture is beneficial.

The problem of miss-matched commodities relating to ESFR function was mentioned by Schultz (2006), Harrington (2007), Jakubowski (2005), Comeau and Duval (2001), Wolf (1998), Nugent (1998), Gagnon (2005), Fletcher (2001), Naylis (1999), and Golinveaux and Hankins (2006). Related to this topic, Welch (2000), Sprinkler Age (2003), Fletcher (2001), Record (2001), and Viking Sprinkler Corporation (2001) recommended strict compliance with ESFR design rules. Likewise, Allen (personal communication, October 17, 2007) felt that miss-matched commodities could lead to an ESFR failure.

The issue of miss-matched commodities had mixed research findings. In feedback instrument question 2, 0.0% of the respondents selected that they felt engine company personnel were qualified to recognize the miss matched commodity problem in an inspection. This was compounded in feedback instrument question 7, which indicates that 78.6% of the fire departments inspect for incompatible storage and that 71.4 % assure sprinkler design matches stored commodities. Further confusing the issue, feedback instrument question 7 indicated that 75% of the respondents conduct engine company inspections. However, comments to feedback instrument question 7 indicated that such commodity checks are done by qualified inspectors.

This implies that, if fire prevention feels engine companies are not qualified to inspect ESFR warehouses, but fire departments are still having them do so, a significant disconnect exists between knowledge level and actual practice. This conflict does exist at RFD and it has significant implications should a major fire occur. The inevitable after action blame placement, litigation, and political scrutiny of practice, and fire department decision making could be intense. Similarly, litigation issues were mentioned by Parlor (2003), Everton (2002), and Standing (2000).

Arson prevention was mentioned by Brannigan (1997) and Harrington (2006). Similarly, 24% of the respondents mentioned arson as a cause of a major arson fire in their community in feedback instrument question 6. This was second behind electrical shorts. For the most part, the topic of arson prevention was not prevalent in the literature. Conversely, in question 15, 76% of the respondents selected the need for a fire investigation unit on an ESFR protected warehouse fire. Miksich (personal communication, October 3, 2007) mentioned that Target Corporation has perimeter controls, monitoring, restricted access, and special security gates to prevent arson. Likewise, Sutton (personal communication October 15, 2007) stated that employee arson is always a warehouse concern. Sutton (personal communication October 15, 2007) actually cited an arson fire in one of his engineered ESFR warehouses ignited by two disgruntled employees. The implication of these findings is that arson awareness seems to be more prevalent amongst the interviewees than in the literature or the feedback instrument respondents. This finding is applicable to RFD which has numerous warehouses. Fostering a culture of arson awareness amongst firefighters and building owners alike is an applicable finding for RFD.

Shultz (2006) Welch (2000), Viking Sprinkler Corporation (2001), Record (2001), Sprinkler Age (2003), Fletcher (2001), and Fire International (1997) stressed assuring the early

capability of maintaining large fire flows, up to four times more than a control mode system. Similarly, fire pump maintenance, maintenance of fire flow, and water tank maintenance was mentioned by Gagnon (2005), McCafferty (2006) Schultz (2006), and Harrington (2006). Likewise, Miksich (personal communication, October 3, 2007) stressed annual fire pump inspection and strict adherence to fire pump maintenance schedules. Likewise, in feedback instrument question 10, 57.1%, of the respondents felt a disadvantage of an ESFR warehouse was increased fire flow. In addition, feedback instrument question 11 indicates that 71.4% of the respondents would assure that sprinkler valves were open and 64.3% would assure the fire pump was working. Hence, the research findings on this issue are congruent. The implication for RFD is that fire flow is a significant pre-event activity when plan checking an ESFR warehouse. In contrast, only 3.6% of the respondents felt that engine companies were qualified to inspect fire pumps. However, in question 7, 53.6% of the respondents mentioned that they check for proper ESFR maintenance. Such activity might be occurring in fire prevention. If it is being conducted by untrained engine companies, it's a problem for any fire department, including RFD.

Pre-construction coordination between all trades for ESFR warehouses was mentioned by Schultz (2006) Harrington (2006), and McCafferty (2006). Feedback instrument question 7 indicates that 32.1% of the respondents are involved in this pre-event activity. Likewise, pre-construction coordination was also stressed by Sutton (personal communication, October 15, 2007) who indicated that ESFR sprinkler system design drives building design. This issue was not extensively found in the literature and awareness amongst the feedback instrument respondents was relatively low. The researcher cannot assure that such coordination is occurring at RFD. If not, RFD is missing out on significant pre-event activity.

Zimmerman (2007), Harrington (2006), and McCafferty (2006) mentioned compartmentation of construction. Likewise, Miksich (personal communication, October 3, 2007) mentioned that Target Corporation utilizes an MFL wall to limit loss in the event of an ESFR failure. Feedback instrument question 7 indicates that 32.1% of the respondents actively promote the compartmentation in ESFR warehouses. Related to this, in feedback instrument question 12, 48.0% of the respondents recommend extinguishment of overhead trusses from a safe location. The research findings are congruent that there is some awareness of this issue amongst the respondents, interviewees and literature but it is not universal.

The issue of potential ESFR failure was discussed by Miksich (personal communication October 4, 2007). He stated that Target Corporation has 30 ESFR warehouse distribution centers and has never experienced an ESFR system failure. Sutton (personal communication, October 15, 2007) was the only interviewee who mentioned an ESFR failure. He stated it occurred in Florida. He felt improper ventilation tactics by the local fire department caused sprinkler skipping, which resulted depletion of the water supply. Related to this, Sutton (personal communication, October 15, 2007) mentioned that the issue of automatic smoke and heat venting issue is very controversial. Sutton does not support the concept. Allen (personal communication, October 17, 2007) does favor automatic smoke and heat venting. Viking Sprinkler Corporation (2001), Schultz (2006), Sice (2004), and Fire protection South Africa (2004) all mentioned this controversy. Feedback instrument question 13 also confirms this controversy with 40.7% favoring automatic smoke and heat venting and 40.7% not favoring it. Comments to this question were also revealing with some favoring, some not favoring, and some offering a third option of manually controlled smoke and heat venting systems operated by fire fighters. This research finding is very applicable to RFD because of expectations to see the same passionate

feelings communicated in the plan check process by developers weighing in on either side of the issue.

Another controversial issue discovered in the research was the issue of tenant firefighting. Harrington (2006), weighed in against tenant firefighting whereas Goves (2003) and Germann (1994) favored various types. Miksich does not favor tenant firefighting and does not favor class II standpipes (personal communication, October 4, 2007). Sutton (personal communication, October 15, 2007) also did not favor class II standpipes or tenant firefighting. In contrast, Allen (personal communication, October 17, 2007) supports the installation of class II standpipes, especially in California where disasters can overwhelm the fire service. Hence the literature review findings agree with the research findings that this is a controversial issue. These findings are significant for RFD in the pre-event evaluation of ESFR warehouses. In feedback instrument question 14, 48.1% of the respondents favor tenant firefighting and 40.7% do not favor it. Respondent comments indicated conflict also with some favoring first aid firefighting, one mentioning special consideration because of earthquakes, and some not favoring tenant firefighting. Hence, the research finding that tenant firefighting is a controversial issue in warehouse fires is supported by various interviewees, feedback instrument respondents, and the literature. RFD should expect to hear differing opinions from developers on this issue.

One issue mentioned by Miksich (personal communication, October 4, 2007) was MIC influenced corrosion. Sutton (personal communication, October 15, 2007) also mentioned the MIC issue and stated Rialto tests very positive for such activity. This issue was not found elsewhere in the research findings but is a very significant issue for RFD affecting ESFR reliability.

Research Question 3 Discussion: What methods are fire agencies in Southern California utilizing to manage ESFR protected warehouse distribution fires should they occur in their community?

Firefighters were warned to expect rapid fire spread, flashover and a heavy fire attack in the event of an ESFR failure by Shouldis (2001), Naylis (1999), Parlor (2003), The Instructor (2004), Hatfield (2006), Goves (2001), Brunacini (2003), and James (1999). Likewise, feedback instrument question 11 indicated that 64.3% mentioned assurance of a large fire flow and 25.0% indicated to expect a rapid fire spread. One respondent to feedback instrument question 11 mentioned that a properly functioning ESFR would stop the fire limiting apparatus required for exterior attack. The findings indicate that RFD cannot rely on the ESFR system to eliminate the need for advanced, coordinated tactics in such buildings. Trust that the ESFR system will work cannot overcome eventual human failure. A culture of complacency is not an option for RFD.

Shouldis (2001) mentions the importance of cutting off vertical and horizontal fire spread. In feedback instrument question 11, 53.6% of the respondents selected cutting off the vertical and horizontal fire spread as an essential item to address. This is a very significant finding for RFD firefighters because these tactics are much more complicated in an ESFR warehouse than they are in a house fire.

Shouldis (2001) warns firefighters to not expect an ESFR to extinguish the fire. This conflicts with feedback question 9 where 76.7% of the respondents felt that early fire suppression is an advantage of ESFR systems. The researcher feels this discrepancy is attributable to definition of terms where the sprinkler industry has a different understanding of the term suppression than the fire service. The implication for RFD is to understand clear terminology.

Smith (2002) and Voice (1995) recommend an incident action plan be developed. Feedback instrument question 11 reveals that 32.1% of the respondents selected this as an essential function. Related to this, Shouldis (2001), The Instructor (2004), Smith (2002), Welch (2000), and Voice (1995) recommend a strong incident command system in ESFR warehouse fire situations. Likewise, in feedback question 11, 46.4% of the respondents selected the use of a unified command structure. Shouldis (2001) adds that EOC activation should be considered. Only 8.0% of the respondents in feedback question 12 selected EOC activation as essential. These findings indicate various levels of awareness. The implication for RFD is that some experts and other fire service professionals have recognized incident action plans, strong incident command, and opening the EOC as essential functions to address in major warehouse fires.

Goves (2001) The Instructor (2004), Standing (2000) and Brunacini (2003) mention difficulties associated with search and rescue in a big box fire. Likewise, in feedback instrument question 12, 60.0% of the respondents selected rescue as an extremely demanding essential function in ESFR protected warehouse fires. One respondent commented that rescue was complicated by extended travel distances and obstructions such as conveyor belts. The research revealed increased awareness of this issue. This finding is very applicable in Rialto because of limited resources and the large number of ESFR warehouses in the city.

The difficulty in locating a fire in large warehouse distribution centers was mentioned by Parlor (2003) and Hatfield (2006). Similarly, in feedback question 11, 53.6% of the respondents recommended use of a thermal imaging camera for fire location. Related to this issue, in feedback question 12, 56.0% of the respondents indicated to expect cold smoke and unnoticed fire spread above it. Cold smoke was mentioned by The Instructor (2004), Hatfield (2006), Brunacini (2003) and Standing (2000). These research findings indicate that there is some

awareness of these issues in the literature and the respondents. Thermal imaging camera use and cold smoke awareness is a significant finding for RFD. Prior to this study, the use of thermal imaging cameras on warehouse fire alarms was not standard practice.

The danger of early building collapse and need for defensive strategy in such fires was mentioned by Welch (2000) Shouldis (2001), The Instructor (2004), Goves (2001) Parlor (2003) Naylis (1999), Jakubowski (2005), McCafferty (2006), and Voice (1995). In feedback question 11, 60.7% of the respondents selected consideration of lightweight construction and defensive strategy as an essential function. Feedback question 12 indicated that 60.0 % of the respondents recommended use of a defensive strategy if fire is well developed and 48.0% indicated the need to extinguish overhead trusses from a safe location. Since RFD has many ESFR protected warehouses, the potential for all of these factors are very applicable to RFD. Additionally, regionally, San Bernardino County is a warehouse distribution center in Southern California. Hence, this information is useful on a regional basis. Not surprisingly, the fire respondents seemed to be more aware of these tactical and strategic issues when compared with pre-event knowledge levels. This information can foster a positive, pre-event cultural change at RFD.

The importance of assuring fire pump function, open valves, pumping to the right connection, assuring proper water supply, and to strategically utilize firewalls are mentioned by Shouldis (2001) and Naylis (1999). Similarly, in feedback instrument question 11, 71.4% of the respondents selected assurance of open sprinkler valves as essential, and 64.3% selected assurance of a large fire flow. This is an applicable finding for RFD.

The need for multiple tactical frequencies was recommended by Shouldis (2001), Welch (2000), and Hatfield (2006). Likewise, in feedback instrument question 11, 42.9% of the respondents recognized this as an essential function. Communication is always an issue on the

fire ground. RFD can expect major communication issues on a major warehouse fire if not addressed beforehand.

Hatfield (2006) recommends approaching the fire from the roll up door side of the building, to note the bay door number closest to the fire, communicate it to fire attack, and to open bay doors as you approach the fire. The importance of ventilation was mentioned by Naylis (1999) Nugent (1998). The researcher noticed that ventilation in an ESFR protected warehouse is a highly controversial issue with conflicting information. In question 12, 64.0 percent of the respondents selected ventilation as essential in an ESFR protected warehouse fire attack. Related to this, 41.3 % of the respondents in feedback question 13 do not favor automatic smoke and heat venting in ESFR warehouses. In contrast, 37.9% agree that such systems should be installed. Further, 20.7% were unsure. Miksich (personal communication, October 4, 2007), and Sutton (Personal communication October 15, 2007) do not support automatic smoke and heat ventilation systems whereas Allen (personal communication, October 17, 2007) favors them. Specialized ventilation fan use was recommended by Hatfield (2006) and The Instructor (2004). In question 15, only 4.0% of the respondents selected the use of trailer mounted ventilation fans. These results suggest that there is considerable disagreement on issue of ESFR ventilation amongst the experts and within the fire service. The implication for RFD is to expect conflicting advice and recommendations depending upon the orientation of the developer and their fire protection engineers on the issue of ventilation and automatic smoke and heat venting systems in ESFR warehouses. Additionally, this issue may show up on the fire ground with various opinions on how to accomplish ventilation in an ESFR warehouse.

The concern regarding pool chemicals and chlorine gas production was discussed by Nugent (1998), Welch (2000), and Harrington (2006). Likewise, in feedback question 12, 56.0%

selected pool chemicals as a concern in ESFR protected warehouse fires. Only 7.1% of the respondents in feedback instrument question 4 selected pool chemicals as a factor that contributed to a major warehouse fire and in feedback instrument question 6, only 4.0% of the respondents found that reacting pool chemicals caused a warehouse fire in their community. Hence, some of the literature mentioned this issue, but fire respondent knowledge was not at the same level. This research finding is very applicable to RFD and the region.

The importance of RIC teams was mentioned by Nugent (1999), The Instructor (2004), and Brunacini (2003). Similarly, in feedback instrument question 11, 50.0% of the respondents found it essential to initiate a safety ICS section early. Likewise, in feedback instrument question 12, 60.0% of the respondents found that performing rescue is extremely demanding in ESFR protected warehouses. Hence the literature and respondent awareness of these issues seem congruent. RFD cannot depend on 100% ESFR system extinguishment. The inevitable ESFR system failure that results in a major warehouse distribution center fire presents itself as a legitimate rescue issue.

Sice (2006), Viking Sprinkler Corporation (2001) and Goves (2003) mention AFFF. In feedback question 15, only 24.0% of the respondents selected the uses of a type I foam tender in an ESFR warehouse fire. Goves (2003) mentions robotic fire fighting equipment in Japan. Only 4.0% of the respondents in feedback question 15 selected this as an option. The findings indicate that awareness of these issues is lacking in the fire service. RFD, which has a type I foam tender and has utilized this resource on warehouse fires successfully, is perhaps more aware of the value of foam application in a warehouse fire. This particular research finding implies that awareness is below where it should be on the use of foam to suppress warehouse fires.

Discussion of Research Question 4: What methods should Rialto Fire Department utilize in preventing and managing fires in ESFR protected warehouse distribution centers within its jurisdiction?

Haylis (1999), Golinveaux and Hankins (2006), and Jakubowski (2005) recommend pre-event activities including monitoring of commodity storage. Likewise, Naylis (1999), Golinveaux and Hankins (2006), and Jakubowski (2005) recommend monitoring for miss-matched commodities. These recommendations are applicable to RFD. Feedback instrument question 2 found that 0.0% of the respondents felt that engine company captains were knowledgeable enough about ESFR systems to inspect for miss-matched commodities. Contrary to this finding, Temby (personal communication, October 3, 2007) felt engine company captains were capable if properly trained. Temby (personal communication, October 3, 2007) advocates strict adherence to high piled stock plans and assurance that the ESFR system design can adequately cover commodity storage. In contrast, Horton (personal communication, October 3, 2007) does not feel that engine company captains are knowledgeable enough to adequately inspect ESFR systems. Horton utilizes four fire protection specialists to inspect ESFR warehouses.

Related to the issue of commodity storage, 42.9% of the respondents in feedback instrument question 10 felt that ESFR systems have more stringent design rules. In feedback instrument question 7, 78.6% of the respondents indicated they inspect for incompatible storage and 71.4% indicated they assure that the sprinkler design matches stored commodities. The implication of these findings is that differing opinions exist regarding engine company fire prevention inspections of ESFR warehouses. With the majority not favoring such a practice,

this research finding indicates that RFD is out of step with most fire departments in conducting engine company inspections of such complicated systems without specialized training.

Horton (personal communication, October 3, 2007) felt that maintaining fire flow, incompatible plastics storage, flammable liquid storage and obstructions to flue spaces were the most critical items that could lead to failure. Temby (personal communication, October 3, 2007) didn't disagree with Horton but emphasized valves shut off or pump failure as probable causes of failure. These findings are applicable to RFD because of the many ESFR warehouses it protects.

Incompatible pool chemicals mentioned by (Harrington, 2006), Nugent (1998), and Comeau and Duval (2001) are high on their list of commodity storage checks. Feedback question 6 revealed that only 4.0% of the respondents experienced a warehouse fire attributable to pool chemicals. Likewise, feedback instrument question 4 indicated that 7.1% of the respondents chose pool chemicals as a contributing factor of a major warehouse fire in their jurisdiction. The research findings indicate a lack of awareness amongst the feedback instrument respondents. Because of the severe pre-event, event, and post event consequences of pool chemical storage, the researcher feels this is a very significant finding for RFD.

Shultz (2006) emphasized checking for code compliance on flammable liquids storage. Somewhat related to this, feedback instrument question 6 indicated that only 4.0% of the respondents chose forklift accidents related to stored flammable liquids as contributing factors in warehouse fires occurring in their jurisdiction. The lack of literature mention and reported occurrence could indicate that this issue is being handled through stricter code compliance. However, the Prologis South warehouse contains large quantities of cosmetics (N. Barajas, personal communication, September 20, 2007). Hence this finding is applicable to RFD.

Jakubowski (2005), Schultz (2006), and Whiteley (2006) stressed the importance to watch aerosol storage compliance. Related to this, feedback question 6 indicated that 0.0% of the respondents had a warehouse fire that was attributable to forklift related aerosol accidents and only 4.0% had such a fire related to flammable liquids. These issues were found in the literature and appear to be important despite the low incidence of fires caused by such. Since RFD has a major ESFR protected warehouse with a large amount of aerosol storage, this finding is applicable to RFD.

Brannigan (1997) and Harrington (2006) stressed arson prevention. Feedback instrument question 6 indicated that 24.0% of the respondents who experienced a major warehouse fire found arson to be the cause. Likewise, Temby (personal communication, October 3, 2007) mentioned a Home Depot fire that had a deluge system similar to ESFR that failed in Austin. This was an arson fire caused by a disgruntled employee. Temby (personal communication, October 3, 2007) mentioned that warehouses should provide on site security and limit access to warehouses to prevent arson. Similarly, while Horton (personal communication, October 3, 2007) did not have any specific information to provide owners on arson prevention, he stressed vigilance, security and keeping unauthorized personnel out of warehouses. This is a significant finding for ESFR warehouses to be aware of in Rialto.

McCafferty (2006), Sprinkler Age (2003), Viking Sprinkler Corp (2001), Fire International (2003), Golinveaux and Hankins (2006), and Fletcher (2001) all mention monitoring and preventing obstructions. Related to this, in feedback question 2, only 17.9% of the respondents felt that engine company captains were knowledgeable to inspect ESFR systems for such obstructions and only 3.6% felt they were capable for recognizing flue space maintenance problems. However, in feedback question 7, 75% of the respondents indicated they have fire departments conducting code enforcement fire prevention inspections. In feedback question 7, 71.4% of the respondents indicated their fire department seek to recognize and correct obstructions. This finding is significant for RFD because engine companies conduct ESFR warehouse inspections and there appears to be a discrepancy between expertise level and fire department practice.

Mark (1999), Schultz (2006), Whiteley (2006) and Jarret (1995) recommended training on code enforcement for fire suppression personnel emphasizing recognition of commodity

changes. Education of building owners regarding commodity changes was mentioned by Schultz (2006) and Jarret (1995). Likewise, feedback instrument question 7 indicates that 46.4% of the respondents participate in education of building owner activities. Temby (personal communication, October 3, 2007) favors training engine companies on these issues. Temby (personal communication, October 3, 2007) was the only interviewee that discussed prevention of accidental fires related to welding, electrical light fixtures and forklift fires.

Gagnon (2005), Harrington (2006) and McCafferty (2006) stressed the importance fire pump maintenance. Feedback question 2 indicated that only 3.6% of the respondents felt that engine company captains were knowledgeable enough to inspect for proper fire pump maintenance. However, in feedback question 7, 53.6% of the respondents indicated they inspect for such maintenance. Temby (personal communication, October 3, 2007) advocates weekly fire pump testing. In addition, Temby (personal communication, October 3, 2007) mentioned that inadequate water supply, pump failure, or closed valves are the most likely issues to cause an ESFR failure. RFD has several ESFR warehouses that have fire pumps so this finding is significant for RFD.

Many authors recommended pre-plan development including Jakubowski (2005), Welch (2000), Shouldis (2001), Mark (1999), Naylis (1999), The Instructor (2004), Everton (2002), Goves (2001), Goves (2003), Germann (1994), Fire Engineering (1965), Voice (1995), and Nugent (1998). Related to this, 89.3% of the respondents in feedback question 7 indicated their departments participate in fire pre-plan development. Surprisingly, related to this, only 20.0% of the respondents had a warehouse fire SOP and 17.7% had an SOG developed. This seems to be another research finding disconnect. Fire departments, including RFD, develop pre-plans on warehouse fires but they have not taken the time to develop an SOP or SOG. This is

contradictory. In contrast, Temby (personal communication, October 3, 2007) provided RFD with a copy of Redlands Fire Department's Emergency Operations "Wide-rise Policy" (2005). (See Appendix F)

The controversial issue of ESFR technology and automatic smoke and heat ventilation systems surfaced again in researching this question. Horton (personal communication, October 3, 2007) in agreement with Temby (personal communication, October 3, 2007) does not favor automatic smoke and heat ventilation systems. In feedback instrument question 13, 37.9% of the respondents favored the option, and 41.3% opposed it. Twenty-one percent were undecided. Miksich (personal communication, October 4, 2007), and Sutton (Personal communication October 15, 2007) did not support automatic smoke and heat ventilation systems whereas Allen (personal communication, October 17, 2007) favored it. Hence, there was considerable disagreement on the issue of automatic smoke and heat ventilation found in the literature, respondents, and experts. The implication for RFD is to expect conflicting advice and recommendations depending upon the orientation of the developer and their fire protection engineers. Awareness of this issue is very applicable to RFD and the region.

Temby (personal communication, October 3, 2007) and Horton (personal communication, October 3, 2007) offered a different perspective on the controversial automatic smoke and heat ventilation issue. Temby (personal communication, October 3, 2007) and Horton (personal communication, October 3, 2007) recommend a manual mechanical smoke and heat ventilation system, controllable by firefighters. Interestingly, Sice (2004) points out that the Swedish Fire Research Board recommends this option with ESFR systems. Temby (personal communication, October 3, 2007) also mentioned that he recognized this issue was controversial and that he advocated for amending the new IFC to require manually mechanical smoke and heat

ventilation systems in the region. RFD has adopted the requirement for the manual mechanical option as a requirement for new ESFR systems. This solution may strike a balance for fire departments like Rialto who are dealing with rapidly changing ESFR technology and recommendations from developers with opposing views. As an alternative, to manage ventilation in an ESFR warehouse, Temby recommends opening 4-8 roll-up doors and cross ventilation (personal communication, October 3, 2007).

The research findings discovered in answering research question 3 are applicable to answering the second part of research question 4. Shouldis (2001), Naylis (1999), Parlor (2003), The Instructor (2004), Hatfield (2006), Goves (2001), Brunacini (2003), and James (1999) warn firefighters can expect rapid fire spread, flashover the need for heavy fire attack. Research findings in feedback instrument question 11 indicated that only 25% selected the option to expect rapid fire spread in an ESFR warehouse fire. Related to this, the importance of cutting off vertical and horizontal fire spread (Shouldis, 2001) was also found in feedback instrument question with 53.6% of the respondents selecting it. This is a very significant finding for RFD firefighters because these tactics in an ESFR warehouse are much more complicated. RFD has a training culture of applying routine tactics that they are familiar with to non routine incidents. This practice is not an option in a major warehouse fire. Expertise in tactical operations is an expectation of Council, the public, building owners, and firefighters alike.

Shouldis (2001) warns firefighters to not expect an ESFR to extinguish the fire. Feedback instrument question 9 found that 76.7% of the respondents felt that early fire suppression is an advantage of ESFR systems. A discrepancy in definition of terms regarding suppression or extinguishment may contribute to this disconnect. The implication for RFD is to understand clear terminology. In addition, RFD cannot be complacent in trusting ESFR

technology. Things can go wrong and RFD will be expected to manage the consequences. These consequences are apparent in the literature.

Strong incident action planning and incident command is recommended by Smith (2002), Voice (1995), Welch (2000) and The Instructor (2004). In feedback instrument question 11 32.1% of the respondents selected this as an essential function. Likewise, in feedback question 11, 46.4% of the respondents selected the use of a unified command structure. Shouldis (2001) adds that EOC activation should be considered. Only 8.0% of the respondents in feedback question 12 selected EOC activation as essential. These findings indicate various levels of awareness. Perhaps the awareness problem exists in the fire prevention side of the respondents. Experts and other fire service professionals have recognized incident action plans, strong incident command, and opening the EOC as essential functions to address in major warehouse fires. This is very applicable to RFD.

Search and rescue difficulties are addressed by Goves (2001) The Instructor (2004), Standing (2000) and Brunacini (2003) and found in feedback instrument question 12 where 60.0% of the respondents indicated it. One respondent commented that rescue was complicated by extended travel distances and obstructions such as conveyor belts. The research revealed increased awareness of this issue. RFD, and the region surrounding Rialto, can benefit from this finding because of limited resources and the large number of ESFR warehouses in San Bernardino County.

Related to rescue difficulty in ESFR warehouses, RIC team assignment and safety was mentioned by Nugent (1999), The Instructor (2004), and Brunacini (2003). Likewise 50.0% respondents to feedback instrument question 11 found it essential to initiate a safety ICS section

early. The potential for ESFR system failure is an applicable research finding concerning RIC and safety for RFD tactical operations.

Difficult fire location was mentioned by Parlor (2003) and Hatfield (2006). Similarly, in feedback question 11, 53.6% of the respondents recommended use of a thermal imaging camera for fire location. This finding was consistent with the literature recommendations of Welch (2000) and The Instructor (2004). Similarly, in feedback question 12, 56.0% found some respondent expectation of cold smoke and unnoticed fire spread above it. These research findings indicate that there is some degree of research congruence regarding difficult fire location, use of thermal imaging camera usage and cold smoke problems. However, such awareness is not universal. Since RFD will, at some point, have to deal with these issues, these research findings are applicable. A culture of complacency is not an option.

Early building collapse associated with lightweight roof construction was addressed by Welch (2000) Shouldis (2001), The Instructor (2004), Goves (2001) Parlor (2003) Naylis (1999), Jakubowski (2005), McCafferty (2006), and Voice (1995). Hence, awareness in the literature was widespread. Feedback instrument question 11 found that 60.7% of the respondents indicated collapse of lightweight construction as a concern in an ESFR warehouse fire. Likewise, in feedback instrument question 12, 60.0% of the respondents indicated use of a defensive strategy if the fire is well developed. Consequently, there seems to be more research agreement regarding these findings. However, the awareness is not universal and RFD is exposed to ESFR collapse dangers.

Proper pump function, open valves, pumping to the right connection, and assuring adequate water supply, were mentioned by Shouldis (2001) and Naylis (1999). Similarly, 64.3% of the respondents in feedback instrument question 11 selected assurance of fire pump operation

as essential and 71.4% found assurance of open sprinkler valves as essential. This finding was consistent with Temby (personal communication, October 3, 2007) who mentioned pumping to the right connection and fire pump failure as critical issues in ESFR warehouse fires.

The need for multiple tactical frequencies was recommended by Shouldis (2001), Welch (2000), and Hatfield (2006). In feedback instrument question 11, 42.9% of the respondents in thought this was important. The research findings found more agreement between the literature and respondents regarding pump function, open valves and fire flow; and less agreement in the area of multiple tactical frequencies. All of these issues are applicable fire ground findings in Rialto.

The researcher noticed that ventilation in an ESFR protected warehouse is a highly controversial issue with conflicting information. Hatfield (2006) recommended approaching the fire from the roll up door side of the building, to note the bay door number closest to the fire, communicate it to fire attack, and to open bay doors as you approach the fire. The importance of ventilation was mentioned by Naylis (1999) and Nugent (1998). In feedback instrument question 12, 64.0% of the respondents selected ventilation as an essential function in ESFR warehouses. Specialized ventilation fan use was recommended by Hatfield (2006) and The Instructor (2004). In feedback instrument question 15, only 4.0% of the respondents mentioned awareness of this resource. Ventilation in an ESFR warehouse is a critical item. Performing it incorrectly can cause ESFR failure according to Sutton (personal communication, October 15, 2007) who mentioned an ESFR warehouse fire that was lost due to improper firefighter ventilation tactics. This finding is very significant an applicable to RFD.

Dangerous explosive and reactive pool chemicals and chlorine gas production was discussed by Nugent (1998), Welch (2000), and Harrington (2006). Feedback instrument

question 12, found that 56.0 % of the respondents selected this as a concern. Only 7.1% of the respondents in feedback instrument question 4 and 4.0% in question 6 of the respondents in selected pool chemicals as a factor that contributed to a major warehouse fire in their community. Hence, fire respondent knowledge was not where it could be considering the gravity of this finding. This research finding is very applicable to RFD and the region. Any jurisdiction which has a Lowe's or Home Depot can benefit from this discussion.

The usefulness of foam in warehouse fires was mentioned by Sice (2006), Viking Sprinkler Corporation (2001) and Goves (2003). In feedback instrument question 15, only 24% of the respondents selected a type I foam tender response in an ESFR warehouse fire. The findings indicate that awareness of foam use in an ESFR warehouse fire attack is lacking in the fire service and warehouse distribution industry in the USA. RFD, which has a type I foam tender and has utilized this resource on warehouse fires successfully, is perhaps more aware of the value of foam application in a warehouse fire. The reader is encouraged to remember this.

Goves (2003) was the only one found in this research project literature search to mention robotic fire fighting equipment usage. This seems cutting edge. In feedback question 15, only 4.0% of the respondents selected this resource as something they would utilize on an ESFR warehouse fire. Few respondents in feedback question 15 selected this as an option. In light of the previous discussion of rapid flame spread, structural collapse, and firefighter safety, this is a significant new finding for RFD.

Recommendations

- Pre-Event
 - Annual classroom training on ESFR protected warehouses for fire prevention and suppression personnel.

- Monitoring of ESFR maintenance records, especially fire pump maintenance.
- Inspect for miss-matched commodities, obstructions, and maintenance of flue spaces.
- Assure code compliance on pool chemical, aerosol, and flammable liquid storage.
- Examine for electrical shorts, lighting, forklift safety and general house keeping.
- Examine arson prevention procedures.
- Communicate MIC problem to all sprinklered buildings in Rialto.
- Update all pre-plans and establish an ESFR Standard Operating Guideline.
Recommend this be regional, much like the regional High-rise standard.
- Closely monitor tenant changes.
- Coordination of various trades during development of an ESFR warehouse.
- Tactical regional drills much like regional drills for High-rise for ESFR warehouse fires.
- Event
 - Encourage immediate fire department notification; no delays.
 - Expect a large fire flow and rapid fire spread if fire is well developed.
 - Address ICS concerns early establishing unified command, safety section, IAP development, EOC activation, and a communications plan with multiple tactical frequencies.
 - Follow established SOG for ESFR warehouses.
 - Consider a defensive strategy, utilize MFL walls and practice safe tactics if fire is well developed.

- Utilize well thought out ventilation tactics and consider input from the building fire protection engineer regarding proper tactics. This information should be on the pre-plan.
- Deploy multiple RIC teams at strategic locations. Prior training is essential.
- Utilize foam, it works.
- Suggest San Bernardino County Chiefs consider the regional purchase of two trailer mounted ventilation fans; one for the high desert and one for the valley communities.
- Go big early because these incidents require lots of resources.
- Post Event
 - Respond a Type I hazardous materials team early.
 - Respond a regional fire investigation team early.
 - Respond a legal advice team.
 - Establish an economic recovery team.
 - Establish a cost recovery unit.
- Research Recommendations
 - More research is indicated on the use of robotic equipment, ventilation tactics in an ESFR warehouse, and the automatic smoke and heat ventilation systems issue.
- Follow-up
 - Training BC directed to establish an ESFR SOG by June 2008.
 - Fire Marshal directed to establish annual ESFR training starting in February 2008.
 - Fire Marshal directed to examine ESFR prevention inspection practices based on research findings and have recommendations by February 2008.

- Findings will be presented to County Chiefs with recommendations for consideration of trailer mounted ventilation equipment and regional training.
- The San Bernardino County region has already adopted a requirement for manually controlled mechanical smoke and heat ventilation equipment, a diesel powered fire pump, and class I standpipes for all new ESFR systems. Rialto FD actively participated in this process.

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