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An Examination of Fire Flow Determination Methods for Possible Use by Rock Springs

Carl Blanksvard

Rock Springs Fire Department, Rock Springs, Wyoming

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CERTIFICATION STATEMENT

I hereby certify that this paper constitutes my own product, that where the language of others is

set forth, quotation marks so indicate, and that appropriate credit is given where I have used the

language, ideas, expressions, or writings of another.

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Abstract

Several recognized methods could be used to determine the fire flow required for a building. The problem was Rock Springs had not examined the recognized methods for determining fire flow. This could affect system costs, insurance costs, water quality, and the availability of water for fire extinguishment. The purpose of the research was to compare and contrast the recognized methods for determining fire flow and determine if Rock Springs should select one method for use over the others. An evaluative research method was used to answer the research questions: (a) What recognized methods were available for determining fire flow? (b) What inputs were required for each of the identified fire flow methods? (c) For each identified fire flow method, what were the fire flow requirements for common residential and commercial construction projects within Rock Springs? (d) Why would Rock Springs select one fire flow method over the others? Fire flow determination methods and their required input factors were identified. Using each determination method the required fire flow was determined for several construction projects. The construction projects were a single family building, a multifamily apartment building, a single story commercial building, and a single story industrial building with an attached two story office. The required fire flow for each determination method was examined. The reason each fire flow method should or should not be utilized was examined. Recommendations were made on use of the fire flow determination methods.

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An Examination of Fire Flow Determination Methods for Possible Use by Rock Springs

Introduction

Adequate fire flow is critical for the effective extinguishment of a fire (Barr, Bennett, Brunacini, Coleman, & Eversole, 2003; International Association of Fire Chiefs [IAFC], 2009). Fire flow could be defined as the rate of water flow needed to control a fire (American Water Works Association [AWWA], 2008).

Several recognized methods could be used to determine the required fire flow for a building (Cote, Grant, Hall, Powell, & Solomon, 2008). Determining the correct fire flow is vital. If the fire flow is over calculated, there could be a negative impact on the water distribution system. If the fire flow is under calculated, a fire may result in the loss of the building or lives.

The problem is Rock Springs has not examined the recognized methods for determining fire flow. This could have a negative impact on system costs, insurance costs, water quality, and the availability of water for fire extinguishment.

The purpose of this research is to compare and contrast the recognized methods for determining fire flow and determine if Rock Springs should select one method for use over the others. An evaluative research method will be used to answer the research questions: (a) What recognized methods are available for determining fire flow? (b) What inputs are required for each of the identified fire flow methods? (c) For each identified fire flow method, what are the fire flow requirements for common residential and commercial construction projects within Rock Springs? (d) Why would Rock Springs select one fire flow method over the others?

Background and Significance

Water is the primary fire extinguishing agent used by fire departments throughout the country (Barr, et al., 2003; IAFC, 2009). In most communities the water is supplied by the public

water distribution system. By using storage tanks, piping, pumps, and hydrants water can be made available at or near a fire.

While using water to extinguish fires is vital, the primary purpose of the public water distribution system is to supply potable water to consumers (AWWA, 2003; Clark, et al., 2002; Lauer, 2005; Wieder, 2005). Potable water is considered water that is safe for drinking (Potable, 2009). This is essential in a public water distribution system but not in a water system used purely for fire extinguishment (AWWA, 2003; Clark, et al., 2002; Lauer, 2005).

The use of the public water distribution system to provide fire flow has a large impact (AWWA, 2003; Clark, et al., 2002; Lauer, 2005). Fire flow demands are usually much higher than the daily consumer demands. The higher fire flow demands are typically the determining factor in the amount of water storage, pipe size, distribution pressure, and water volume.

Increasing the size of a water distribution system for fire flow needs could have several negative impacts (AWWA, 2003; Clark, et al., 2002; Lauer, 2005; Trifunovic, 2006). The first is in water quality. An increase in pipe sizes may lead to lower water velocities throughout the system. This may result in a situation where it may take longer to move water through the distribution system. This creates possible water quality issues. Water may sit and become stagnant within the distribution system lowering the water quality.

Another issue that results from the increase in size of a water distribution system is an overall increase in cost (AWWA, 2003; Clark, et al., 2002; Lauer, 2005; Trifunovic, 2006). Larger pipes and fittings raises construction costs. Additional hydrants and piping needed to supply fire flows adds additional costs to the system. The increase in water volume also raises costs. All water in the system must be treated to make it potable. The added treatment needs adds costs. The additional volume of water also requires an increase in the storage capacity.

There are also problems if a water distribution system cannot meet the fire flow needs. A water distribution system may not have enough hydrants or properly sized water mains in an area (AWWA, 2003; Barr, et al., 2003; Clark, et al., 2002; Lauer, 2005). The most obvious concern in an inadequately sized water distribution system is that it will not be able to provide the needed fire flow. This situation could increase loss potential in a community due to the inability to extinguish a fire. In extreme instances an undersized water distribution system may not be able to supply the water needed for maximum daily consumer use (Barr, et al., 2003; Clark, et al., 2002; Lauer, 2005).

As a community grows the capability of the water distribution system to meet the fire flow demands can be outpaced (Clark, et al., 2002; Cote, Grant, Hall, Powell, & Solomon, 2008; IAFC, 2009; Wieder, 2005). Waterlines that were once adequate may no longer be able to handle the increased demand. In addition, a community may not have the funding to develop or maintain the water distribution system. This has been the case in Rock Springs. The history of Rock Springs has been punctuated by periods of rapid growth. The past years have been just such a growth period. Spurred by the demand for oil and natural gas, found in the area, there has been new development and construction throughout the city. New businesses have moved in while old businesses have built new and larger facilities. People moving into the community have required new neighborhoods to be developed.

In some areas Rock Springs was able to keep pace with the need for the increased water demand. In other areas the aged water distribution systems and lack of funding created potential fire flow deficiencies. These conditions created a situation where waterline size, age, and hydrant spacing varies throughout Rock Springs.

In addition to existing water distribution system shortfalls, a water distribution system may need to expand into areas with little or no existing water infrastructure (Cote, et al., 2008; Trifunovic, 2006; Wieder, 2005). Without proper planning the water distribution system may be unable to meet future needs. This has been an issue within Rock Springs. To allow growth to continue Rock Springs has annexed large tracts of undeveloped land. Due to rapid unplanned infrastructure growth many of the areas have limited water availability. There exist several new areas of the city with limitations in the maximum available fire flow.

To prevent a continuation of the limited fire flow situations Rock Springs will need to reevaluate present and future water distribution system development with a focus on fire flow. To do so an accurate and standard fire flow policy is needed. Future water distribution system development must be prepared to meet fire flow requirements (Cote, et al., 2008; Lauer, 2005; Wieder, 2005). This must be balanced against the need for water quality and fiscal responsibility. The need for fire extinguishment must be balanced against the domestic and industrial water needs of Rock Springs.

A goal of the United States Fire Administration (USFA) is to "reduce risk at the local level through prevention and mitigation" (USFA, 2008, p. 3). The research conducted supports this goal by use of multiple USFA strategies.

The first strategy is to "support adoption and enforcement of national consensus construction and prevention codes" (USFA, 2008, p. 5). The research in this paper will allow a greater understanding of the methods for determining fire flow. This increased knowledge will enhance the proper use and interpretation of the codes and standards regulating fire flow.

The next strategy is to "conduct studies and initiatives to enhance fire and life safety" (USFA, 2008, p. 5). The research conducted as part of the Executive Fire Officer Program is in

direct support of this strategy through the program goal of understanding "the value of research and its application to the profession" (USFA, 2009).

In order to achieve change one must be able to speak with credibility (Federal Emergency Management Agency, 2005). The National Fire Academy (NFA) Executive Leadership Course teaches that knowledge and expertise help in developing credibility. Both of the USFA strategies aid in increasing knowledge and expertise and in turn credibility. The research conducted in this paper will allow the user to gain credibility on the recognized methods for determining fire flow. The credibility gained will allow the user to take a leadership role in planning for future fire flow needs and the use of a fire flow policy.

<center>Literature Review</center>

An adequate water distribution system is instrumental in the development of fire flows (AWWA, 2003; 2008; Barr, et al., 2003; Cote, et al., 2008; Wieder, 2005). The water distribution system must be sufficient to provide fires flows along with domestic needs every day of the year (AWWA, 2008; Barr, et al., 2003; Clark, et al., 2002; Insurance Services Office, Inc. [ISO], 2003). It is recommended that a municipal water distribution system provide a minimum of 250 gallons per minute (gpm), at 20 pounds per square inch (psi) pressure, above the domestic needs. This flow should be available for a period of at least two hour.

In locations where an adequate water distribution system is not available fire flow must be provided by other methods (Barr, et al., 2003; Clark, et al., 2002; IAFC, 2009; Wieder, 2005). Methods could include natural sources, private tanks, or vehicle transport of water.

Even in areas served by a water distribution system the supply may not provide adequate fire flows (Barr, et al., 2003; Wieder, 2005). Consideration should be given to augmenting the water system at a fire. This may require the need to develop alternate water sources.

A local water authority typically directs and maintains the public water distribution system (AWWA, 2003; Lauer, 2005; Trifunovic, 2006). In Sweetwater County a joint powers water board (JPWB) manages the water treatment and distribution systems (Water Service, 2009). The JPWB both owns and operates the water system infrastructure.

The fire flow needed for a building is typically determined during initial construction planning (Barr, et al., 2003; Brock, 2000). It is vital that fire flow policies be in place. The policies must ensure that fire flow requirements are consistent and adequate. Fire flow requirements can be controversial due to cost to the building owner and the community.

Fires can increase in size rapidly. Several factors can affect the fire flow needed to extinguish a fire (AWWA, 2008; Barr, et al., 2003; Wieder, 2005). Factors pertaining to the building can affect the fire growth and spread. These factors include construction type, building size, building use, contents, and installed fire protection systems.

External factors can also affect the fire (AWWA, 2008; Barr, et al., 2003; Wieder, 2005) External factors include the proximity of other structures to the fire building. These structures are known as exposures.

While there is little question regarding the need for adequate fire flow several methods exist for determination (AWWA, 2008; Barr, et al., 2003; Wieder, 2005). Different organizations have developed methods to estimate required fire flows. The ISO, the National Fire Protection Association (NFPA), the International Code Council (ICC), and other organizations have developed fire flow determination methods.

The Iowa State University (ISU) fire flow calculation method was first published in 1967 (AWWA, 2008; Barr, et al., 2003; Brock, 2000; Clark, et al., 2002; Cote, et al., 2008; Wieder, 2005). The ISU method is based on the amount of water that would need to turn to steam in order

to extinguish a given fire. The ISU method considers the total volume of the building that must

be filled with steam. For the ISU method to be accurate the total volume of the building

including basements, attics, and void spaces must be taken into account. See *Equation 1* for the

ISU fire flow formula.

$$FF = V \div 100. \tag{1}$$

The Illinois Institute of Technology Research Institute (IITRI) method was developed

from a survey of 134 fires in the Chicago area (AWWA, 2008; Clark, et al., 2002; Cote, et al.,

2008; Wieder, 2005). The IITRI method was based on the rate of water application needed for a

given fire area.

The IITRI method was actually two different formulas (AWWA, 2008; Clark, et al.,

2002; Cote, et al., 2008; Wieder, 2005). One formula was used for residential buildings, the other

formula for all other buildings. See *Equation 2* for the IITRI residential fire flow formula. See

Equation 3 for IITRI nonresidential fire flow formula.

$$FF = (9 \times 10^{-5} \times A^2) + (50 \times 10^{-2} \times A). \tag{2}$$

$$FF = (-1.3 \times 10^{-5} \times A^2) + (42 \times 10^{-2} \times A). \tag{3}$$

The NFA method was developed as a way of estimating needed fire flow (AWWA, 2008;

Brock, 2000; Hannig & Mahoney, 2009; Wieder, 2005). The original intent was to approximate

the fire flow needed at a fire scene. The NFA method determined fire flow based on the square

footage of the fire floor. If more than one floor was involved the total number of floors was calculated into the fire flow. The NFA method was only considered accurate up to four floors.

If there were exposures to the building on fire the NFA method allowed for calculation of the exposure fire flow needs (AWWA, 2008; Brock, 2000; Hannig & Mahoney, 2009; Wieder, 2005). An exposure for the NFA method was considered a building within 30 feet of the fire building. Each exposure was considered to require 25% of the fire flow needed for the fire building. See *Equation 4* for the NFA fire flow formula.

$$FF = (A \div 3 \text{ x } F) + [E \text{ x } (A \div 3) \text{ x } 0.25]. \tag{4}$$

The ISO provided fire and risk information to insurance companies (Barr, et al., 2003; Cote, et al., 2008; Diamantes, 2005; Dickson, 2001; ISO, 2008; Wieder, 2005). Insurance companies used the information to help establish insurance costs within a community.

The ISO Public Protection Classification (PPC) program evaluated a community's fire protection information and ability to extinguish a fire (Barr, et al., 2003; Cote, et al., 2008; Diamantes, 2005; Dickson, 2001; ISO, 2008; Wieder, 2005). One of the areas the PPC examined was the water system. This included an evaluation of the available water versus the water needed to extinguish a fire. The water system accounted for 40% of the PPC.

To be recognized by the ISO a water system needed to be capable of delivering a minimum of 250 gpm for a two hours period (AWWA, 2008; Barr, et al., 2003; Cote, et al., 2008; ISO, 2008; Wieder, 2005). This minimum flow was in addition to any daily consumer use. If the community provided fire flow through an alternative source, water had to be available

within five minutes of the arrival of the fire department. Afterwards the required fire flow had to

be maintained for a minimum of two hours.

For one and two family buildings, not exceeding two stories in height, the ISO

determined the needed fire flow by considering the distance between buildings (AWWA, 2008;

Barr, et al., 2003; Brock, 2000; Clark, et al., 2002; Cote, et al., 2008; ISO, 2008; Wieder, 2005).

See *Table 1* for the ISO residential fire flow requirements.

Table 1

ISO Residential Fire Flow

Dwelling Separation Distance	Needed Fire Flow
Greater than 100 feet	500 gpm
31 to 100 feet	750 gpm
11 to 30 feet	1,000 gpm
Less than 11 feet	1,500 gpm

Note. From *Guide for Determination of Needed Fire Flow* (p. 23), by Insurance Service Office,

Inc., 2008, Jersey City, NJ: Author. Copyright 2008 by Insurance Service Office, Inc. Adapted

with permission.

For other buildings, the ISO calculated the needed fire flow based on the modified

building area, construction type, building use, and exposures (AWWA, 2008; Barr, et al., 2003;

Brock, 2000; Clark, et al., 2002; Cote, et al., 2008; ISO, 2008; Wieder, 2005). The needed fire

flow for buildings ranged from a minimum of 500 gpm to a maximum of 12,000 gpm.

To estimate the fire flow needed in other buildings the ISO used a calculation formula

(AWWA, 2008; Barr, et al., 2003; Brock, 2000; Clark, et al., 2002; Cote, et al., 2008; Dickson,

2001; ISO, 2008; Wieder, 2005). The ISO method took the building and external inputs and

relates them to predetermined values. These values were then used in the fire flow calculation.

See *Equation 5* for the ISO fire flow formula.

$$FF = [18 \times F \times (A)^{0.5}] \times O \times [1.0 + (X + P)] \tag{5}$$

The ISO required the water supply to deliver the required fire flow for a specified period

of time (AWWA, 2008; Barr, et al., 2003; Brock, 2000; Clark, et al., 2002; Cote, et al., 2008;

ISO, 2008; Wieder, 2005). The minimum fire flow duration ranged from two hours to four hour.

Buildings protected by an approved sprinkler system were not calculated using the ISO

fire flow formula (AWWA, 2008; Barr, et al., 2003; Brock, 2000; Clark, et al., 2002; Cote, et al.,

2008; ISO, 2008; Wieder, 2005). *NFPA 13: Standard for the Installation of Sprinkler Systems

(NFPA 13)* or *NFPA 13R: Standard for the Installation of Sprinkler Systems in Residential

Occupancies up to and Including Four Stories in Height* requirements would be used to

determine if a sprinkler system was classified as approved.

The NFPA (Barr, et al., 2003; Burke, 2008) had several standards that applied to fire flow

requirements. The *Uniform Fire Code* (*UFC*) was one of the standards (Curtis & Sawyer, 2006;

2009). The *UFC* guided fire and life safety requirements in new and existing buildings.

The fire flow requirements in the fourth edition of the *UFC* were contained in *Annex H*

(Curtis & Sawyer, 2006; NFPA, 2006). The requirements of a *UFC* annex only applied if the

annex was specifically adopted. In the fifth edition the fire flow requirements were moved into

the body of the *UFC* (Curtis & Sawyer, 2009; NFPA, 2009). This made the fire flow

requirements applicable upon adoption of the fifth edition of the *UFC*.

The fourth edition of the *UFC* set the minimum fire flow for one and two family buildings, less than 3,600 square feet (sq ft), at 1,000 gpm (Curtis & Sawyer, 2006; NFPA, 2006). In the fifth edition the size was raised to 5,000 sq ft (Curtis & Sawyer, 2009; NFPA, 2009). In several instances the fire flow could be reduced. If the building was separated from others by a minimum of 30 feet, the fire flow could be reduced by up to 25%. If the building had an approved sprinkler system, the fire flow could be reduced by up to 50% (Curtis & Sawyer, 2006; 2009; NFPA, 2006; 2009). In no case could the fire flow be reduced to less than 500 gpm. The minimum duration for the fire flow was one hour.

Fire flow for other buildings, or one and two family buildings larger than the maximum area, was determined by used of a minimum fire flow table (Brock, 2000; Curtis & Sawyer, 2006; 2009; NFPA, 2006; 2009). The table was based on the square footage of the building as well as the construction type. Certain construction types only included the three largest successive floors in the fire flow area. Fire flows ranged from a low of 1,500 gpm to over 8,000 gpm. The fire flow duration ranged from a minimum of two to four hours. If the building was equipped with an approved sprinkler system the fire flow could be reduced by up to 75%. If the sprinkler heads were quick response type fire flow could be reduced to a minimum of 600 gpm. All other types of sprinkler heads limited the reduced fire flow to 1,000 gpm. In either case if the reduced fire flow was less than the required sprinkler flow the required sprinkler flow was considered the minimum fire flow.

The ICC was another developer of fire and life safety requirements. The ICC publication that regulated fire flow was the *International Fire Code* (*IFC*). The *IFC* required an approved water source capable of supplying the fire flow be provided (ICC, 2006a; 2006b; 2009a; 2009b). The means by which the fire flow was supplied was left to the policies of the jurisdiction.

A jurisdiction could utilize *Appendix B* of the *IFC* to guide fire flow determination. *Appendix B* contained the *IFC* method to determine fire flow and fire flow duration (ICC, 2006a; 2006b; 2009a; 2009b). The appendixes of the *IFC* were not considered part of the code unless specifically adopted.

The *IFC* fire flow method focused on the fire flow calculation area of the building (ICC, 2006a; 2006b; 2009a; 2009b). The fire flow calculation area was the total sq ft of all floors. Some construction types used only the three largest consecutive floors towards the fire flow calculation area. A building fire flow calculation area could only be reduced by a firewall with no openings or penetrations.

The minimum fire flow for one and two family buildings that did not exceed 3,600 sq ft was 1,000 gpm (ICC, 2006a; 2006b; 2009a; 2009b). Fire flow and flow duration for buildings with an area larger than 3,600 sq ft was calculated the same as other buildings.

The minimum fire flow and flow duration for buildings other than one and two family buildings not exceeding 3,600 sq ft was specified by a minimum fire flow table in *Appendix B* (ICC, 2006a; 2006b; 2009a; 2009b). The minimum fire flow ranged from 1,500 gpm to over 8,000 gpm. The duration ranged from a minimum of two hours to four hours. As the fire flow increased the required flow duration increased.

A reduction in fire flow was authorized, by the *IFC*, under certain conditions (ICC, 2006a; 2006b; 2009a; 2009b). One was when it was determined the code required fire flow was impractical to obtain. Another time a reduction in fire flow was allowed was when the building was equipped with an approved sprinkler system. For one or two family buildings not exceeding 3,600 sq ft the reduction allowed was 50%. For other buildings equipped with an approved

sprinkler system a reduction in fire flow of up to 75% was allowed. The reduced fire flow for those buildings could not be less than 1,500 gpm for a minimum duration of two hours.

Both the *IFC* and *UFC* allowed fire flow requirements to be increased (Curtis & Sawyer, 2006; 2009; ICC, 2006a; 2006b; 2009a; 2009b; NFPA, 2006; 2009). When there was a possibility of multiple or large fires the fire flow could be increased. The maximum increase was limited to twice the normally required fire flow.

Where an adequate water supply was not available alternative methods could be used to provide the needed fire flow (Clark, et al., 2002; Cote, et al., 2008; IAFC, 2009; Wieder, 2005). It was recommended that a policy be in place to guide alternative fire flow methods.

NFPA 1141: Standard for Fire Protection in Planned Building Groups (*NFPA 1141*) applied to groups of buildings that had a limited water supply or other fire protection limitations (NFPA, 2008). The purpose of the standard was to reduce the impact of a fire in a group of buildings in suburban or rural areas. The required fire flow was based on the available water supply. For areas with a municipal water distribution system, the adopted fire flow calculation method would be used. For areas without a municipal water distribution system *NFPA 1142: Standard on Water Supplies for Suburban and Rural Fire Fighting* (*NFPA 1142*) would be applied. Under no circumstance was the fire flow allowed to be less than 250 gpm.

When the minimum required fire flow exceeded 1,500 gpm and there was a municipal water distribution system, the fire flow duration was a minimum of two hours (NFPA, 2008). For all other situations the duration was a minimum of one hour.

NFPA 1142 provided an alternative method to calculate fire flow needs (Barr, et al., 2003; Burke, 2008; Clark, et al., 2002). The standard was typically used in situations where the fire flow was supplied by an alternative water source. *NFPA 1142* also provided guidance for the

design of the water source needed to support the fire flow. The options presented were typically

used in areas without an approved water distribution system.

NFPA 1142 examined several building factors to determine the minimum fire flow

needed (Burke, 2008; NFPA, 2007b). Factors included building occupancy, construction type,

and building area. In addition, several external factors were also examined. The external factors

included the ability to supply and maintain the required fire flow as well as exposures to the

building. An exposure was considered a structure, with an area 100 sq ft or larger, within 50 feet

of the fire flow building. The minimum allowed fire flow was 250 gpm. The maximum required

fire flow was 1,000 gpm.

The ICC developed the *International Wildland-Urban Interface Code* (*IWUIC*) to be

used in areas where there was no reliable water system (ICC, 2006b; 2009c). The *IWUIC* gave

alternatives to providing the needed fire flow. The alternatives included restrictions on

construction type and defensible spaces around a building. The *IWUIC* also provided information

on alternative water sources.

The *IWUIC* set rural fire flow for one and two family buildings that did not exceed 3,600

sq ft, at 1,000 gpm for a minimum of 30 minutes (ICC, 2009c). The minimum fire flow for one

and two family buildings that exceeded 3,600 sq ft was 1,500 gpm for the same minimum

duration. The required fire flow could be reduced by 50% if the building was equipped with an

approved sprinkler system.

The fire flow for other buildings could not be less than 1,500 gpm for a two hour duration

(ICC, 2009c). The required fire flow could be reduced by up to 75% if the building was equipped

with an approved sprinkler system. The reduced fire flow could not be less than 1,500 gpm.

Many fire flow methods did not determine how the fire flow was delivered but only the fire flow needed. Hydrants were the primary means for fire departments to access the needed fire flow (AWWA, 2006; IAFC, 2009; Lauer, 2005). Without proper hydrant placement the needed fire flow could be diminished or unattainable.

The ISO adjusted the maximum available fire flow based on hydrant placement (Barr, et al., 2003; Cote, et al., 2008). The ISO limited fire flow based on the number of hydrants and the available hydrant outlets within 1,000 feet of a building. This distance was measured along an approved route, as a fire apparatus would lay hose. As hydrant distant from a building increased the maximum fire flow dropped. Hydrants greater than 1,000 feet from a building did not provide fire flow. Hydrants within 300 feet allowed the maximum fire flow of 1,000 gpm. The presence of a large hydrant outlet, called a pumper outlet, also allowed the hydrant to provide 1,000 gpm. Different outlet arrangements reduced the hydrant maximum fire flow. The ISO limited the maximum fire flow available from a hydrant to the lower of the distance limit or available outlet limit.

The water pressure available at a hydrant was another factor that affected fire flow. The AWWA recommended that the water pressure at a hydrant, not providing fire flow, be a minimum of 35 psi (AWWA, 2003; Trifunovic, 2006). This pressure was called the static pressure. For many jurisdictions a minimum static pressure was not a major concern since fire apparatus could increase the pressure as needed. The greater concern was the pressure remaining when a hydrant was supplying fire flow. It was recommended that the residual pressure be maintained at a minimum of 20 psi (AWWA, 2003; Clark, et al., 2002; Cote, et al., 2008; Trifunovic, 2006). The minimum residual pressure would prevent a fire apparatus from creating

a negative pressure in the water distribution system resulting in system damage. For this reason, the maximum available fire flow was typically calculated at a residual pressure of 20 psi.

In Wyoming a local community must adopt the same fire code, for enforcement, as the state (Department of Fire Prevention and Electrical Safety, 2008). The local community could amend the fire code to be more stringent than the state but not less. Wyoming adopted the *IFC* 2006 edition for enforcement (Department of Fire Prevention and Electrical Safety, 2008). Wyoming adopted the entire body of the code as well as *Appendixes D, E, F,* and *G*. The other appendixes were not considered part of the adopted code.

Rock Springs zoning requirements set the minimum separation distances between buildings (Zone District Regulations, 2009). The zoning requirements require all hydrants to have a minimum of one pumper outlet and two hose outlets.

In summary, there were several recognized fire flow calculation methods. Methods have been developed by organizations such as ISU, IITRI, NFA, ISO, NFPA, and ICC (Barr, et al., 2003; Cote, et al., 2008). While each method utilized input factors to determine fire flow the factors vary by the method. Factors could include both those associated with the building as well as external to the building.

Adequate fire flows are vital to the fire protection of a community (Barr, et al., 2003; Brock, 2000). A community should have a policy and method to calculate the needed fire flow.

<div align="center">Procedures</div>

The research procedure was designed to answer the research questions. First the fire flow determination methods were identified. The inputs required for each of the determination methods were identified next. Fire flows calculations were then completed with each of the fire

flow determination methods. This allowed each of the fire flow determination methods to be evaluated for use by Rock Springs.

 The research began with a literature review of water distribution system design and operation. The literature review included books, journals, and other written as well as Internet sources. The literature review focused on the requirements for a water distribution system to provide fire flow.

To address local water distribution issues and requirements the author conducted an interview with B. Seppie of the JPWB. At the beginning of the interview the author stated the purpose of the interview and the research being conducted. During the interview the JPWB representative was presented with the research questions and allowed to comment freely. The JPWB representative was asked to explain the policies and operation of the JPWB. Specific inquiry was made on how the JPWB planned and provided fire flow. A limitation in the interview process was the lack of other agencies interviewed. The only other agency identified in Rock Springs, which influenced fire flow requirements, was the Rock Springs Fire Department. The author represents this organization.

The first research area examined was identification of the commonly recognized methods for determining fire flow. The author examined literature pertaining to both water authorities and fire departments. The author attempted to identify the most widely recognized fire flow methods.

A limitation in the research is the possibility that some methods for determining fire flow were not identified. It is possible other methods or less widely know methods exist. One method of determining fire flow that was omitted from the research was electronic fire modeling. This technology was not presently available to Rock Springs or the author.

After identifying the fire flow methods the author began the examination of each method. Particular attention was paid to the input factors each method utilized to determine fire flow. The input factor information for each method was gathered into a table for evaluation. See *Appendix A* for input factor information.

The author next began the process of selecting construction projects to evaluate. The selection of construction projects allowed the research to identify common fire flow needs in Rock Springs. The procedure for selecting construction projects began with a review of common construction in Rock Springs over the past five years. To aid in the selection process the author consulted M. Bider and J. Tuttle of the Rock Springs Building Department. The construction review gave the author the ability to select projects representative of construction uses, types, and sizes typical in Rock Springs. Due to time constraints only a limited number of construction projects could be examined. In the end the author settled on four common construction projects.

The first construction project determined was a single family building. See *Appendix B* for project information. The next construction project was a multifamily apartment building. See *Appendix C* for project information. The third construction project was a single story commercial store and warehouse. See *Appendix D* for project information. The final construction project determined was an industrial warehouse and repair garage with an attached office. See *Appendix E* for project information. All of the projects were typical of construction in Rock Springs.

The selected construction projects set several limits in the research. Although modeled on construction in Rock Springs the projects were not intended to be actual buildings. The use of construction projects was to allow examination of the fire flow methods. A further limitation was that the construction information might not be applicable to other jurisdictions.

After the construction projects were identified, the author addressed the input factors needed to determine fire flow. The input factors were developed for each construction project to allow the fire flow calculations to take place. The consultation with the building department aided in the validation of the input factors. A limitation was that some input information was not readily identifiable. Input information such as exposures or sprinkler systems had to be examined in multiple ways. See *Appendix A* for input factor information.

The author then performed fire flow calculations for each of the construction projects utilizing the identified fire flow determination methods. Some methods identified several possible fire flows. This was due to the multiple input factors previously identified. See *Appendixes B, C, D,* and *E* for the fire flow calculations.

A limitation in the fire flow examination was the omission of the rural or alternative fire flow methods. While identified in the first step of the research these methods were omitted from the calculations. The omission was based on the availability of a municipal water system.

The final research area examined the determined fire flows and fire flow methods. Possible fire flow reductions were also examined. The author attempted to identify reasons each fire flow method should or should not be utilized by Rock Springs.

A limitation in the research is the fact that only fire flow requirements were addressed. Some fire flow methods are part of larger fire protection and safety code. The code may have other requirements including construction and use limits. The research only examined the water supply and fire flow requirements not other code related issues.

A draft of the research paper was submitted to the ISO. This step was taken to allow review and legal authorization for use of ISO material. Changes were made as recommended or required by the ISO.

Results

The first research question examined the recognized methods for determining fire flow. Several methods were identified. The ISU, IITRI, NFA, and ISO all had calculation methods. The *IFC* and *UFC* had fire flow tables to determine the required fire flow.

The second research question examined the inputs required for each of the identified fire flow determination methods. The input factors included both building factors as well as external factors. See *Appendix A* for input factor information.

All of the examined fire flow determination methods utilized the building size to determine fire flow (AWWA, 2008; Barr, et al., 2003; Brock, 2000; Clark, et al., 2002; Cote, et al., 2008; Wieder, 2005). The IITRI method utilized the total volume of the building (AWWA, 2008; Barr, et al., 2003; Clark, et al., 2002; Wieder, 2005). The other fire flow determination methods utilized the area of the building (AWWA, 2008; Barr, et al., 2003; Brock, 2000; Clark, et al., 2002; Cote, et al., 2008; Wieder, 2005). The total number of building floors was also considered in the building area. The NFA method was only considered accurate up to four floors (AWWA, 2008; Brock, 2000; Wieder, 2005).

The ISU method did not examine building use (AWWA, 2008; Barr, et al.e, 2003; Clark, et al., 2002; Cote, et al., 2008; Wieder, 2005). The IITRI method considered building use in a limited fashion (AWWA, 2008; Barr, et al., 2003; Clark, et al., 2002). The IITRI method utilized a separate calculation method for residential buildings (Clark, et al., 2002; Cote, et al., 2008). The ISO, *UFC*, and *IFC* also had different methods to determine fire flow for some residential buildings (AWWA, 2008; Barr, et al., 2003; Clark, et al., 2002; Cote, et al., 2008; Wieder, 2005). These methods limited the utilization based on the size and type of the building. All were particular to one and two family buildings. The ISO method limited height to two floors. The

UFC fifth edition limited size to 5,000 sq ft (Curtis & Sawyer, 2009; NFPA, 2009). The *IFC* and

fourth edition of the *UFC* limited size to 3,500 sq ft (Curtis & Sawyer, 2006; ICC, 2006a; 2006b;

2009a; 2009b; NFPA, 2006). If the building exceeded the limit then the general fire flow

determination method, for other buildings, was used.

The ISO method utilized an occupancy factor based on the building use (AWWA, 2008;

Barr, et al., 2003; Brock, 2000; Clark, et al., 2002; Cote, et al., 2008; Dickson, 2001; Wieder,

2005). The occupancy factor was a way to address the general fire hazards of the building use.

As the general fire hazards increased the occupancy factor size increased.

The ISU, IITRI, and NFA fire flow calculation methods did not consider the construction

type of the building (AWWA, 2008; Barr, et al., 2003; Clark, et al., 2002; Cote, et al., 2008;

Hannig & Mahoney, 2009; Wieder, 2005). The *IFC* and *UFC* methods utilized the building

construction type as a factor in determining fire flow (Curtis & Sawyer, 2006; 2009; ICC, 2006a;

2006b; 2009a; 2009b; NFPA, 2006; 2009). For both the *IFC* and *UFC* methods as the relative

combustibility of the construction increased the required fire flow increased. The ISO method

also utilized a construction factor to calculate fire flow (AWWA, 2008; Barr, et al., 2003;

Dickson, 2001; Wieder, 2005). As the relative combustibility of the building increased the

construction factor increased.

The NFA and ISO methods both examined possible exposures to the fire building

(AWWA, 2008; Barr, et al., 2003; Clark, et al., 2002; Cote, et al., 2008; Hannig & Mahoney,

2009; Wieder, 2005). In the case of the NFA method the exposure fire flow was considered 25%

of the fire building fire flow (AWWA, 2008; Brock, 2000; Wieder, 2005). Exposures for the

NFA method were considered structures within 30 feet of the fire building.

The ISO method determined the exposure factor based on several variables (AWWA, 2008; Barr, et al., 2003; Brock, 2000; Clark, et al., 2002; Cote, et al., 2008; Dickson, 2001; Wieder, 2005). One variable was the distance to the exposure. As the distance increased the exposure factor decreased. The ISO method considered exposures up to 100 feet in the exposure factor. The ISO exposure factor was also affected by the size of the exposure. As the area of the exposure wall increased the exposure factor increased. The construction of the exposure also affected the exposure factor.

The ISO method also examined a communication factor for the fire building (AWWA, 2008; Barr, et al., 2003; Brock, 2000; Clark, et al., 2002; Cote, et al., 2008; Dickson, 2001; Wieder, 2005). The communication factor evaluated the possibility of fire spread due to openings in the fire building.

The presence of a fire protection system could affect the needed fire flow. In particular the presence of an approved sprinkler system could lower the needed fire flow (Barr, et al., 2003; Cote, et al., 2008; Wieder, 2005). The *IFC* and *UFC* methods allowed a reduction in the needed fire flow based on the presence of an approved sprinkler system (Curtis & Sawyer, 2006; 2009; ICC, 2006a; 2006b; 2009a; 2009b; NFPA, 2006; 2009). In both cases the reduction was limited to a minimum required fire flow. The ISO method set fire flow at the required sprinkler demand plus any hose stream requirement (ISO, 2008). For residential buildings, a higher predetermined fire flow could be required.

In Rock Springs the JPWB did not calculate fire flow based on building factors. According to an interview with B. Seppie of the JPWB, fire flow was based on the maximum water available to an area. Hydraulic computer modeling determined the maximum. The fire flow for the area was examined in a worst case scenario. Factors such as low water tank levels,

loss of pumping stations, and shut isolation valves were all considered. In some cases the

requirement to keep the minimum residual pressure above 20 psi determined the maximum fire

flow for the area.

The availability of hydrants also affected the needed fire flow. The ISO method

specifically limited fire flow by the type and distance to a hydrant (Barr, et al., 2003; Cote, et al.,

2008). The *IFC* and *UFC* required the number and spacing of hydrants based on the needed fire

flow (Curtis & Sawyer, 2006; 2009; ICC, 2006a; 2006b; 2009a; 2009b; NFPA, 2006; 2009).

To summarize the second research question there were several input factors that could

affect the fire flow determination (AWWA, 2008; Barr, et al., 2003; Brock, 2000; Clark, et al.,

2002; Cote, et al., 2008; Wieder, 2005). Some factors were related to the building. The most

common was the building size. All identified fire flow determination methods utilized the

building size in some manner. Other factors included construction, use, and sprinkler system

installation. In the case of some fire flow determination methods factors external to the building

were examined. The most common was the presence of building exposures.

The third research question examined the fire flow requirements for common

construction projects within Rock Springs. The first construction project examined was a 2,000

sq ft single family building. Rock Springs zoning requirements determined the minimum

distances to exposures (Zone District Regulations, 2009). The minimum separation distance to

exposures was 16 feet. See *Appendix B* for the first construction project results.

The fire flow required for the single family building, without sprinklers, was the same for

the *IFC* and fourth edition of the *UFC*. The fire flow required for the building without sprinklers

but with exposures, was the same for both editions of the *UFC*. If the single family building was

equipped with an approved sprinkler system the fire flow for the *IFC* and *UFC* was reduced. The

reduced fire flow was the same for both determination methods. In all cases the ISU method had the lowest required fire flow. The IITRI method had the highest required fire flow for all methods examined.

The second construction project examined was an apartment building three stories in height. Rock Springs zoning requirements determined the minimum separation distance, for exposures, to be 40 feet (Zone District Regulations, 2009). The *IFC* building construction type was determined to be VB (ICC, 2006a; 2009a). The *UFC* construction type was determined to be V(000) (NFPA, 2006; 2009). See *Appendix C* for the second construction project results.

The IITRI calculation method might consider this a residential structure (AWWA, 2008; Clark, et al., 2002; Cote, et al., 2008; Wieder, 2005). This resulted in the highest required fire flow. If the building did not have sprinklers the *IFC* and *UFC* methods had the same required fire flow. The lowest required fire flow for the building without sprinklers was the ISU method. If the building was equipped with quick response sprinkler heads the *UFC* method resulted in the lowest required fire flow.

The third construction project examined was a single story commercial store and warehouse. The construction type was metal frame without rated interior walls. The building was considered IIB construction under the *IFC* and II(000) under the *UFC*. The ISO construction factor class and occupancy factor class were both 3. The zoning requirements identified the minimum separation distance at 30 feet (Zone District Regulations, 2009). Any exposures were considered to be the same construction and use as the fire flow building. See *Appendix D* for the third construction project results.

The *IFC* and *UFC* determination methods gave the same results for a building without a sprinkler system. The ISO method required the lowest fire flow for the same building. The NFA

method required the highest fire flow for all building situations. A review of *NFPA 13* indicated

quick response sprinkler heads could not be used (NFPA, 2007a). This resulted in the *IFC* and

UFC methods requiring the same fire flows for the building with a sprinkler system.

The final construction project examined was a single story industrial building, conducting

storage and vehicle maintenance. The building had an attached two story office. The *IFC*

construction was IIB. The *UFC* construction was II(000). The ISO construction factor class and

occupancy factor class were 3. The zoning requirements identified the minimum separation

distance, to other buildings, at 30 feet (Zone District Regulations, 2009). See *Appendix E* for the

fourth construction project results.

The *IFC* and *UFC* methods gave the same results for the building without a sprinkler

system. The ISO required fire flow was the lowest. The NFA method resulted in the highest

required fire flow. A review of *NFPA 13* indicated quick response sprinkler heads were not

allowed (NFPA, 2007a). This resulted in the *IFC* and *UFC* methods having the same fire flow if

the building was equipped with an approved sprinkler system.

The fourth research question examined why Rock Springs would select one fire flow

method over the others. The interview with the JPWB indicated that multifamily, commercial,

and industrial fire flow requirements were not determined by the JPWB. The JPWB required fire

flows to be determined and approved by the local fire department. The minimum allowed fire

flow for residential developments was 1,000 gpm. Fire flows for large residential developments

could be required to be higher.

Cost and installation of new water system infrastructure in Rock Springs was borne by

the developer. The public sections of the water system were turned over to the JPWB for

ownership. The cost of system maintenance was paid by Rock Springs. Water system

infrastructure developed on private property was maintained by the property owner.

Several sources indicated that a jurisdiction should have a policy to determine fire flow in

place (Barr, et al., 2003; Brock, 2000). This policy could help minimize water system costs and

maintain water quality.

<div align="center">Discussion</div>

There were several accepted methods to determine fire flow for a building (AWWA,

2008; Barr, et al., 2003; Brock, 2000; Clark, et al., 2002; Cote, et al., 2008; Wieder, 2005). Each

method examined input factors to determine the required fire flow. The input factors could be

related to the building or external to the building.

Each of the fire flow determination methods had variations in how they calculated fire

flow (AWWA, 2008; Barr, et al., & Eversole, 2003; Brock, 2000; Clark, et al., 2002; Cote, et al.,

2008; Wieder, 2005). The variations resulted in different fire flow requirements from each

method. This brings to question the accuracy of the fire flow methods due to the differences in

the resulting fire flows. It is highly probable that some methods over calculated the needed fire

flow. It is also possible that some methods under calculated the needed fire flow. It is important

to attempt to remove both of these groups of calculation methods from consideration for use.

Over calculated fire flows could create economic and water quality hardships. Under calculated

fire flows could cost lives and property. One issue that must be considered is that fire flows are

an estimate of the water needed to extinguish a fire. In the case of a large fire, the minimum

determined fire flow may not be sufficient to extinguish the fire.

The ISU method was based on the effective use of a fog stream to extinguish a fire

(AWWA, 2008; Barr, et al., 2003; Brock, 2000; Clark, et al., 2002; Cote, et al., 2008; Wieder,

2005). The use of other firefighting techniques would make the calculation method inaccurate. Effective and efficient use of a fog stream was required by the ISU fire flow method. The Rock Springs Fire Department typically utilized a fog stream for fire extinguishment. The question that would need to be examined was if the fog stream use was effective. Another issue with the ISU method was the requirement to utilize the total building volume. Due to variations in building design it could be difficult to determine the total building volume. The ISU fire flow calculation could be inaccurate. The inaccuracy could be from the failure to remove internal structural members or account for architectural features. This could have an impact on the calculated fire flow. The volume of the building was the only factor examined by the ISU method.

The IITRI method had the benefit of examining residential fire flow needs independently from other buildings (AWWA, 2008; Barr, et al., 2003; Clark, et al., 2002; Cote, et al., 2008; Wieder, 2005). In the case of the second construction project this gave an inflated fire flow requirement. The use of the other IITRI formula gave a required fire flow of 3,375 gpm. This fire flow was much closer to the other required fire flows. This brings into question at what point the use of the residential formula was incorrect.

A shortcoming of the IITRI method was the fact that the building size was the only factor examined (AWWA, 2008; Barr, et al., 2003; Clark, et al., 2002; Cote, et al., 2008; Wieder, 2005). An interesting fact was the lower fire flow required for the 24,000 sq ft building than the 10,000 sq ft building. This brings to question the accuracy of the method.

The NFA method was designed for use as a rapid fire flow calculation at a fire scene (AWWA, 2008; Brock, 2000; Hannig & Mahoney, 2009; Wieder, 2005). The accuracy for use calculating a 100% fire involvement could be questioned. The NFA method was only considered accurate for up to four floors. This was not a major concern in Rock Springs where the tallest

buildings were four floors. A strength of the NFA method was the ability to examine building exposures when determining fire flow needs. The NFA method did not examine the fire building construction or the exposure construction. If the IITRI residential formula results were discounted, the NFA method consistently gave some of the highest required fire flows.

The ISU, IITRI, and NFA methods did not adjust fire flow based on the presence or lack of a sprinkler system (AWWA, 2008; Barr, et al., 2003; Brock, 2000; Clark, et al., 2002; Cote, et al., 2008; Hannig & Mahoney, 2009; Wieder, 2005). The effectiveness of a properly installed sprinkler system has been well documented (Barr, et al., 2003; Cote, et al., 2008; Diamantes, 2005). For a building with an installed sprinkler systems these methods could require a higher fire flow than other methods.

The ISO method utilized the greatest number and types of input factors to determine fire flow (AWWA, 2008; Barr, et al., 2003; Brock, 2000; Clark, et al., 2002; Cote, et al., 2008; Wieder, 2005). This was both the methods strength and weakness. Some indicated that the ISO method was overly complex for the results it provided (Barr, et al., 2003; ICC, 2006b; 2009b). Even the ISO recommended the use of a fire protection engineer to calculate the needed fire flow (ISO, 2008). Another issue with the ISO calculation method was the requirement to round fire flow to the nearest 250 gpm. If the fire flow was rounded incorrectly the resulting fire flow could be wrong.

The ISO provided information to insurance companies to help establish insurance costs (AWWA, 2008; Barr, et al., 2003; Cote, et al., 2008; Diamantes, 2005). The inability to meet the ISO required fire flow could have a negative impact on a community.

The *IFC* and the *UFC* took a similar approach in the method to determine fire flow (Curtis & Sawyer, 2006; 2009; ICC, 2006a; 2006b; 2009a; 2009b; NFPA, 2006; 2009). The

literature indicated that both the methods utilized charts developed from the ISO method (Curtis

& Sawyer, 2006; 2009; ICC, 2006b; 2009b). For residential fire flow use, the *IFC* method

limited the size of one and two family buildings to a smaller area than the fifth edition of the

UFC. The *UFC* also examined the separation distance for residential structures. Between the two

the *IFC* appeared to require a possible higher fire flow for residential buildings. The *UFC*

allowed larger reductions in the required fire flow for all types of buildings.

The *IFC* was the adopted fire code in Wyoming (Department of Fire Prevention and

Electrical Safety, 2008). This made the *IFC* mandatory for use in the state. The appendix used to

determine fire flow was not part of the state adoption. A local community could adopt these

requirements if they wanted.

The ISO, *IFC*, and *UFC* methods all determined fire flow requirements for one and two

family buildings based on certain limits (Curtis & Sawyer, 2006; 2009; ICC, 2006a; 2006b;

2009a; 2009b; NFPA, 2006; 2009). When planning fire flow requirements for a residential

development or neighborhood this could be problematic. It could be difficult to predetermine the

size or type of buildings that could be built. Buildings that did not meet the residential

requirements could require higher fire flows. Careful planning would be needed to ensure the

proper water infrastructure was available to the area.

During the planning for new construction it could be difficult to determine exposures or

separation distances for nonexistent buildings. The only available guide to separation presently

provided was the Rock Springs zoning requirements. Zoning requirements provided information

on the minimum distances between buildings (Zone District Regulations, 2009). The

requirements did not indication the possible size or construction type of the exposure. If

buildings were built further apart than the minimum set by the zoning requirements the

determined fire flow could be higher than needed.

The *IWUIC*, *NFPA 1141*, and *NFPA 1142* all determine how to provide fire flow in areas

with a limited water supply (Barr, et al, 2003; Clark, et al., 2002). Rock Springs was served by a

municipal water distribution system. In areas served by a municipal water distribution system the

rural fire flow methods were not considered appropriate.

The JPWB determined the maximum fire flow available in an area. The JPWB developed

standards for the supply and delivery of water. The maximum fire flow available in Rock Springs

could be limited. The JPWB could meet the water demand for a typical sprinkler system. The fire

flow demand needed for buildings without a sprinkler system could be more difficult to meet in

some areas. The large storage and distribution system required to maintain fire flows was

considered counterproductive to water quality and costs.

Recently the JPWB had begun to examine the water distribution system infrastructure

based on the potential fire risk of the existing and possible buildings in an area. In the past a lack

of planning led to areas unable to develop fire flows. Over the past few years rapid growth and

the inability to update water modeling information hampered fire flow planning. The JPWB

identified the need to plan future growth and water system development based on the potential

future growth.

The JPWB indicated it was not in the best interest of the water distribution system to

allow developers to dictate the fire flow needed for a building. B. Seppie indicated that it could

be more appropriate for the water system to set the maximum fire flow and require the developer

to plan the building accordingly. The goal of the JPWB was to balance the fire flow needs

against the requirement to maintain water quality and consumer capacity.

In summary an adequate water supply capable of providing the needed fire flow could

save property, lower costs, and save lives (AWWA, 2003; Barr, et al., 2003; Clark, et al., 2002;

Cote, et al., 2008; Diamantes, 2005; IAFC, 2009; Wieder, 2005). Firefighters and the community

need to be confident that the water supply is reliable and adequate. Yet the fire flow needs must

not be detrimental to water quality or system cost. All of the fire flow determination methods had

strengths. All of the methods had weaknesses as well. The decision to use one fire flow

determination method over the others must be carefully weighed. Points to consider included the

input factors examined and the ease to determine the required fire flow. The appropriateness of

the fire flow method, to the community, must also be considered.

Recommendations

The JPWB recommended that a maximum available fire flow be set for areas of Rock

Springs. The recommendation does not remove the need for determining fire flow. In fact the

recommendation strengthens the need to determine the needed fire flow as early in the building

planning process as possible. Alternatives such as a sprinkler system may be required to keep the

needed fire flow below the maximum available. Due to the increased possibility for the need of a

sprinkler system, the author recommends the removal of fire flow determinations methods that

do not examine sprinkler system presence.

Not meeting the ISO required fire flow could have a negative impact on insurance cost

and the PPC rating. However, use of the ISO fire flow method presented difficulties. The greatest

was the complexity of the calculation method.

The *IFC* and *UFC* fire flow determination methods were developed using the ISO

method. The methods were much easier to use since information was placed in a table. In the

buildings without a sprinkler system both methods consistently met or exceeded the ISO required

fire flow. For these reasons the author recommends the use of either the *IFC* or *UFC* fire flow determination methods.

The *IFC* is mandated for code enforcement in Wyoming. In the case of Rock Springs the use of the *IFC* fire flow determination method seems the most appropriate. The author recommends the use of the *IFC* fire flow determination method in Rock Springs. The down side is the potentially higher fire flow needed than some of the other fire flow determination methods.

To meet fire flow requirements, yet provide the highest levels of water service at the lowest cost, the author supports the recommendation of the JPWB. Specifically, as Rock Springs plans future growth maximum fire flow availability must be determined throughout the area. Appropriate construction methods could then be used to ensure the needed fire flow was maintained below the maximum available. This would help ensure water quality is maintained and costs are kept low for all parties involved.

Firefighters can have the mindset that more fire flow is better (IAFC, 2009). That the greater the water capacity, pressures, and hydrants available the better off the community. The author recommends a new understanding of water systems must be examined. Many of the detrimental problems a water system faces are from the need to provide fire flows. The more is better philosophy may be detrimental to a community in water quality and costs. While adequate fire flow is essential for fire extinguishment it is not the primary role of a community water system. The author recommends that fire departments and jurisdictions reexamine their water system design philosophy to ensure they are in the best interest of the community.

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Appendix A

Fire Flow Determination Method Input Factors

Inputs	Fire Flow Method						
	IFC	IITRI	ISO	ISU	NFA	NFPA 1142	UFC
Building area	X	X	X		X	X	X
Building volume				X			
Construction type	X		X			X	X
Building use	Note 1	Note 1					Note 1
Exposures			X		X	X	Note 2
Sprinkler system	X		Note 3			X	X

Note 1. The determination method considers residential structures separately.

Note 2. The 5th edition considers exposures to residential structures.

Note 3. The determination method uses sprinkler system demand or a default fire flow for

buildings with an approved sprinkler system.

Appendix B

Construction Project 1

Description

Input Factor	Value
Building use	Single family residential
Size (A)	2,000 sq ft
Height (H)	22 feet
Stories (S)	1
Rock Springs zoning	Residential
Exposure distance side	16 feet
Exposure distance rear	40 feet
Exposures (E)	2

IFC method

Appendix B sets the minimum fire flow.

IITRI method

$$FF = [9 \times 10^{-5} \times (A)^2] + (50 \times 10^{-2} \times A)$$

$$FF = [9 \times 10^{-5} \times (2,000)^2] + (50 \times 10^{-2} \times 2,000)$$

ISO method

Exposures would be between 11 and 30 feet. See *Table 1* for the fire flow requirements.

A default fire flow would be used if an approved sprinkler system were present.

ISU method

$$FF = (A \times H) \div 100$$

$$FF = (2,000 \times 22) \div 100$$

NFA method

Exposures would be considered within 30 feet.

Without exposures.

FF = [(A ÷ 3) x S] + [E x (A ÷ 3) x 0.25]

FF = [(2,000 ÷ 3) x 1] + [0 x (2,000 ÷ 3) x 0.25]

With exposures.

FF = [(A ÷ 3) x F] + [E x (A ÷ 3) x 0.25]

FF = [(2,000 ÷ 3) x 1] + [2 x (2,000 ÷ 3) x 0.25]

UFC method

The fourth edition of the *UFC* would use *Annex H*.

The fifth edition of the *UFC* would utilize Chapter 18.

Fire Flow (gpm)

Factors	IFC	IITRI	ISO	ISU	NFA	UFC (4th ed.)	UFC (5th ed.)
No sprinkler							
No exposure	1,000	1,360	500	440	667	1,000	750
Exposures	1,000	1,360	1,000	440	1,000	1,000	1,000
Sprinkler							
No exposure	500	1,360	500	440	667	500	500
Exposures	500	1,360	500	440	1,000	500	500

Appendix C

Construction Project 2

Description

Input Factor	Value
Building use	Apartment
Size (A)	5,000 sq ft
Height (H)	35 feet
Stories (S)	3
Rock Springs zoning	Heavy residential
Exposure distance side	40 feet
Exposure distance rear	50 feet
Construction	Wood frame
IFC construction type	VB
UFC construction type	V(000)
Construction Factor (F)	1.5
Occupancy factor (O)	0.85
Exposure Factor (X)	0.12
Potential factor (P)	0
Exposures (E)	0

IFC method

Appendix B sets the minimum fire flow.

IITRI method

Residential calculation.

$$FF = [9 \times 10^{-5} \times (A)^2] + (50 \times 10^{-2} \times A)$$

$FF = [9 \times 10^{-5} \times (15,000)^2] + (50 \times 10^{-2} \times 15,000)$

Other building type calculation.

$FF = -1.3 \times 10^{-5} \times (A)^2 + 42 \times 10^{-2} \times (A)$

$FF = -1.3 \times 10^{-5} \times (15,000)^2 + 42 \times 10^{-2} \times (15,000)$

ISO method

A default fire flow would be used if an approved sprinkler system were present.

Without exposures.

$FF = [18 \times F \times (A)^{0.5}] \times O \times [1.0 + (X + P)]$

$FF = [18 \times 1.5 \times (10,000)^{0.5}] \times .85$

With exposures.

$FF = [18 \times F \times (A)^{0.5}] \times O \times [1.0 + (X + P)]$

$FF = [18 \times 1.5 \times (10,000)^{0.5}] \times 0.85 \times [1.0 + (0.12 + 0)]$

ISU method

$FF = (A \times H) \div 100$

$FF = (5,000 \times 35) \div 100$

NFA method

Exposures would be considered if within 30 feet. Exposures would exceed 30 feet.

$FF = [(A \div 3) \times S] + [E \times (A \div 3) \times 0.25]$

$FF = [(5,000 \div 3) \times 3] + [0 \times (5,000 \div 3) \times 0.25]$

UFC method

The fourth edition of the *UFC* would use *Annex H*.

The fifth edition of the *UFC* would utilize Chapter 18.

Fire Flow (gpm)

Factors	IFC	IITRI	ISO	ISU	NFA	UFC (4th ed.)	UFC (5th ed.)
No sprinkler							
No exposure	3,250	27,750	2,250	1,750	5,000	3,250	3,250
Exposures	3,250	27,750	2,500	1,750	5,000	3,250	3,250
Sprinkler							
No exposure	1,000	27,750	Note 1	1,750	5,000	813	813
Exposures	1,000	27,750	Note 1	1,750	5,000	813	813

Note 1. For residential buildings up to four stories in height, equipped with an NFPA 13R

compliant sprinkler system, the required fire flow is 1000 gpm or the sprinkler demand plus hose

stream requirement if greater.

Appendix D

Construction Project 3

Description

Input Factor	Value
Building use	Commercial store and warehouse
Size (A)	10,000 sq ft
Height (H)	20 feet
Stories (S)	1
Rock Springs zoning	Commercial
Exposure distance sides	30 feet
Exposure distance rear	65 feet
Construction	Metal frame
IFC construction type	IIB
UFC construction type	II(000)
Construction Factor (F)	0.8
Occupancy factor (O)	1
Exposure Factor (X)	0.17
Potential factor (P)	0
Exposures (E)	0

IFC method

Appendix B sets the minimum fire flow.

IITRI method

$$FF = -1.3 \times 10^{-5} \times (A)^2 + 42 \times 10^{-2} \times (A)$$

$$FF = -1.3 \times 10^{-5} \times (10{,}000)^2 + 42 \times 10^{-2} \times (10{,}000)$$

ISO method

The approved sprinkler system flow requirement would be used as the fire flow.

Without exposures.

$FF = [18 \times F \times (A)^{0.5}] \times O \times [1.0 + (X + P)]$

$FF = [18 \times 0.8 \times (10,000)^{0.5}] \times 1$

With exposures.

$FF = [18 \times F \times (A)^{0.5}] \times O \times [1.0 + (X + P)]$

$FF = [18 \times 0.8 \times (10,000)^{0.5}] \times 1 \times [1.0 + (0.17 + 0)]$

ISU method

$FF = (A \times H) \div 100$

$FF = (10,000 \times 20) \div 100$

NFA method

Exposures would be considered if within 30 feet. Exposures would exceed 30 feet.

$FF = [(A \div 3) \times S] + [E \times (A \div 3) \times 0.25]$

$FF = [(10,000 \div 3) \times 1] + [0 \times (10,000 \div 3) \times 0.25]$

UFC method

The fourth edition of the *UFC* would use *Annex H*.

The fifth edition of the *UFC* would utilize Chapter 18.

Fire Flow (gpm)

Factors	IFC	IITRI	ISO	ISU	NFA	UFC (4th ed.)	UFC (5th ed.)
No sprinkler							
No exposure	2,250	2,900	1,500	2,000	3,333	2,250	2,250
Exposures	2.250	2,900	1,750	2,000	3,333	2,250	2,250

Factors	IFC	IITRI	ISO	ISU	NFA	UFC (4th ed.)	UFC (5th ed.)
Sprinkler							
No exposure	1,000	2,900	Note 1	2,000	3,333	1,000	1,000
Exposures	1,000	2,900	Note 1	2,000	3,333	1,000	1,000

Note 1. For buildings equipped with an NFPA 13 compliant sprinkler system the required fire

flow is the sprinkler demand plus hose stream requirement.

Appendix E

Construction Project 4

Description

Input Factor	Value
Building use	Industrial warehouse, garage, and office
Warehouse size (A_w)	20,000 sq ft
Warehouse height (H_w)	25 feet
Warehouse stories (S_w)	1
Office size (A_o)	2,000 sq ft
Office height (H_o)	20 feet
Office stories (S_o)	2
Total area (A)	24,000 sq ft
Rock Springs zoning	Industrial
Exposure distance	30 feet
Construction	Metal frame
IFC construction type	IIB
UFC construction type	II(000)
Construction Factor (F)	0.8
Occupancy factor (O)	1
Exposure Factor (X)	0.17
Potential factor (P)	0
Exposures (E)	0

IFC method

Appendix B sets the minimum fire flow.

IITRI method

$FF = [-1.3 \text{ x } 10^{-5} \text{ x } (A)^2] + (42 \text{ x } 10^{-2} \text{ x } A)$

$FF = [-1.3 \text{ x } 10^{-5} \text{ x } (24,000)^2] + (42 \text{ x } 10^{-2} \text{ x } 24,000)$

ISO method

The approved sprinkler system flow requirement would be used as the fire flow.

Without exposures.

$FF = [18 \text{ x } F \text{ x } (A)^{0.5}] \text{ x } O \text{ x } [1.0 + (X + P)]$

$FF = [18 \text{ x } F \text{ x } (A_w + A_o)^{0.5}] \text{ x } O \text{ x } [1.0 + (X + P)]$

$FF = \{18 \text{ x } 0.8 \text{ x } [20,000 + (2,000 \text{ x } 1.5)]^{0.5}\} \text{ x } 1$

With exposures.

$FF = [18 \text{ x } F \text{ x } (A_w + A_o)^{0.5}] \text{ x } O \text{ x } [1.0 + (X + P)]$

$FF = \{18 \text{ x } 0.8 \text{ x } [20,000 + (2,000 \text{ x } 1.5)]^{0.5}\} \text{ x } 1 \text{ x } [1.0 + (0.17 + 0)]$

ISU method

$FF = (A \text{ x } H) \div 100$

$FF = [(20,000 \text{ x } 25) + (2,000 \text{ x } 20)] \div 100$

NFA method

Exposures would be considered if within 30 feet. Exposures would exceed 30 feet.

$FF = [(A \div 3) \text{ x } S] + [E \text{ x } (A \div 3) \text{ x } 0.25]$

$FF = [(20,000 \div 3) \text{ x } 1] + [(2,000 \div 3) \text{ x } 2]$

UFC method

The fourth edition of the *UFC* would use *Annex H*.

The fifth edition of the *UFC* would utilize Chapter 18.

Fire Flow (gpm)

Factors	IFC	IITRI	ISO	ISU	NFA	UFC (4th ed.)	UFC (5th ed.)
No sprinkler							
No exposure	3,250	2,592	2,250	5,400	8,000	3,250	3,250
Exposures	3.250	2,592	2,500	5,400	8,000	3,250	3,250
Sprinkler							
No exposure	1,000	2,592	Note 1	5,400	8,000	1,000	1,000
Exposures	1,000	2,592	Note 1	5,400	8,000	1,000	1,000

Note 1. For buildings equipped with an NFPA 13 compliant sprinkler system the required fire

flow is the sprinkler demand plus hose stream requirement.