EVALUATE EXISTING FIRE FLOW CALCULATION FORMULAS FOR ADOPTION IN OUR CITY

EXECUTIVE DEVELOPMENT

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ABSTRACT

This research project analyzed existing fire flow calculation formulas that could be adopted by the Marysville Fire District (MFD) to be utilized during the plan review process and application of the Uniform Fire Code (UFC) requirements. MFD had been using the Insurance Services Office (ISO), "Guide For Determination of Required Fire Flow" since it was referenced in the 1985 Edition of the UFC. At that time other fire flow formulas were not examined. The purpose of the project was to examine the formulas available and recommend a formula for adoption by the MFD.

This research employed historical research by an examination of the literature available, evaluative research to compare the results of each formula for a given scenario, and action research to examine the results of each formula for suitability to the needs of the MFD. The three research methods were used to identify (a) what fire flow formulas are available for use, (b) what factors such as type of construction and use should be included in calculating fire flows, and (c) what alternate methods could be adopted by the MFD to offset deficient fire flows.

The major findings of this research were that the formulas found were designed to offer suppression officers a method of quick and basic fire flow calculations rather than scientific conclusions. These "rule of thumb" formulas have limited use during the plan review process.

Based upon the findings of this research, the recommended formula for adoption by MFD is a combination formula based on Appendix III-A of the 1997 Edition of the UFC, the occupancy and exposure factors from the ISO formula, and some additional requirements that reflect the needs of the MFD.

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INTRODUCTION

The Marysville Fire District (MFD) has been using a method for calculating Needed Fire Flow (NFF) for new construction that was recommended for use in the 1985 Edition of the Uniform Fire Code (UFC). Other existing methods of calculating fire flow were not evaluated and since that time, other methods have been introduced to the fire service.

The impact to the community and the construction industry in added costs and construction time can be significant when it is determined that additional requirements must be employed to comply with the intent of the UFC fire flow requirement.

The purpose of this research project was to evaluate commonly used and available fire flow calculation formulas and identify the formula that best meets the needs of our community and the MFD. The adopted formula should be simple to use and understand so that there is little interpretation necessary. Historical, evaluative and action research methods were employed to answer the following questions:

1. What fire flow calculation formulas are available?
2. What factors, such as type of construction and use, should be included in calculating fire flow?
3. What alternate methods could be adopted by the MFD to offset deficient fire flows?

BACKGROUND AND SIGNIFICANCE

Water is so fundamental to fire fighting that a good water supply is the most important single factor in fire protection. The fire department has responsibility for determining fire flow requirements. It has a stake in all features of the system and should be able to make recommendations on all of them (Municipal Fire Administration, 1968).

Isman (1993) states that when any building is built, consideration must always be given to providing enough water at that building for fire-fighting purposes should a fire occur within the building. Calculating the correct amount of water needed to suppress a fire can be a complex operation that is influenced by variables such as the building size, construction type, occupancy use, and the presence or absence of fire suppression systems. When establishing a fire protection plan, the governing body must first select a well-documented procedure for determining the fire flow requirements (American Water Works Association [AWWA], 1992). Fire flow information can be used to advise the builder of the need to ensure the availability of an adequate water supply (Phelps & McDonald, 1984).

UFC (1985) requires that an approved water supply capable of supplying required fire flow for fire protection shall be provided to all premises upon which buildings or portions of buildings are constructed. In setting the requirements for fire flow, the chief may be guided by the standard published by the Insurance Services Office (ISO), "Guide for Determination of Required Fire Flow." The ISO fire flow formula was adopted for use by the MFD because it was referenced by the UFC and had been adopted by the King County Fire Marshal's Office, the largest county in the state of Washington.

The response area of MFD is provided with a water system operated by the city of Marysville Public Works Department and satisfies the needs of the residential customers but often falls short of satisfying commercial fire flow needs. The reservoir system in place has always provided a storage capacity well in excess of MFD duration needs, but smaller mains in a number of areas supply inadequate volumes. Since there is no legal requirement that a governing body must size its water distribution system to provide fire protection (AWWA, 1992), decisions were made to provide the minimum main size in some of the older sections of the city. R. A. Murdock (personal communication, August 22, 1998), retired fire chief of MFD, stated that it appeared to be an acceptable risk to the community that buildings were destroyed by defensive fire-fighting techniques because there was not enough water available for fire flow. If there is no way of increasing water supply, then a defensive operation is necessary. Protect exposures and hopefully, have some water available to apply to the fire (Sylvia, 1983).

In spite of deficient fire flows, MFD has a commitment to protect all property. Since the adoption of the 1985 UFC, the ISO formula provides a process to require fire flows that provide minimal protection. Excessive requirements increase costs to the point of limiting development and do not necessarily provide added safety.

This research is related to material discussed in the National Fire Academy (NFA) Executive Development course, Unit 10, "Service Quality/Marketing," and Unit 11, "Legal Issues."

LITERATURE REVIEW

Carter (1996) states that fire flow analysis form the basis for determining risk levels in a community. Fire fighters, fire protection engineers, building and municipal officials, and insurance company risk managers generally do not agree on the fire flow requirements for buildings or a section of the city (Milke, 1980). This disagreement is evident by the multitude of published standards or criteria for determining water supply requirements for fire suppression operations (Milke, 1980).

Equations used in the early 1900's related fire flow requirements to the population of the city or town (Milke, 1980; Municipal Fire Administration, 1968; National Fire Protection Association, 1997). Kimball (1966) suggests a very simple way to calculate fire flow requirements is to estimate the number of 2 1/2 inch lines that will be needed both for hand lines and for heavy streams and multiply by 250 gpm. Sylvia (1982), on the other hand, feels that you have to protect exposures and, hopefully, have some water available to apply to the fire. Eventually, the fire will begin to diminish as it runs out of fuel. Sylvia (1982) states that estimating the required fire flow for a building requires judgement based on experience. Phelps & McDonald (1984) add there are three other factors that must be taken into account when doing fire flow calculations for specific buildings and occupancies.

- Occupancy factor
- Exposure charge
- Percentage of involvement

The literature invokes a number of questions, which must be examined to make a fire flow formula acceptable. Comparisons between the various techniques for computing fire flow are not easily made, because each situation to which the fire flow calculation is applied varies greatly (AWWA, 1992). Where some techniques were developed using professional judgement, others were theoretically based. Because the concept of fire flow is not easily resolved, those developed from professional judgement are most widely used and accepted (Milke, 1980).

Another complexity introduced by the literature is the intent of the different fire calculation methods. Determining the amount of water needed to extinguish a fire in a specific building is best accomplished during the pre-planning stages where all factors can be considered (Smith, 1996). Edwards (1992) simply states the more water that can be applied in the initial attack, the less water it takes to darken a fire. When fire flow can absorb heat energy at the same rate at which it is being produced by the fire, there is an equilibrium situation in which the fire can't grow or get hotter. This concept was used prior to the MFD attempts to pre-plan for fire prevention, "Hit it with all you got, and hope for the best," (R. A. Murdock, personal communication, August 22, 1998).

The ISO fire flow requirement, referred to as Needed Fire Flow (NFF), is intended to assess the adequacy of a water system as one element of an insurance rating schedule. It is not intended as a design criterion. However, it has been demonstrated that the NFF coincides, to a reasonable degree, with the actual flow required to suppress a fire in a real-life situation (AWWA, 1992).

Predominately, the intent of the published works appear to be aimed at the suppression officers need to quickly assess needed resources, i.e. fire flow, and assume that available water flow must be known (Smith, 1996). This concept is supported by numerous authors a number of times (Carter, 1996; Edwards, 1992; Kimball, 1966; Phelps & McDonald, 1984; Phelps & McDonald, 1986; Smith, 1996; Sylvia, 1982; Sylvia, 1983). While it is important to calculate needed flows on the scene, there is an additional need to scientifically calculate flows in the pre-fire plan stages. The intent is to anticipate as accurately as possible what may be needed to combat a fire and avoid what DeLay (1994) describes as a 45-minute fire prolonged into a 4- or 5-hour waste of resources because the needed fire flow wasn't adequately pre-planned.

Authors dealing with the issue of NFF focus on four primary formulas attempting to compare their results (AWWA, 1992; Burns & Phelps, 1994; Isman, 1993; Milke, 1980; National Fire Protection Association, 1997; Wiseman, 1993; Wiseman, 1996). These are listed below and described in detail in Appendix A:

- Insurance Services Office Inc. (ISO)
- Illinois Institute of Technology Research Institute (IITRI)
- Iowa State University (ISU)
- National Fire Academy (NFA)

In addition, the International Conference of Building Officials & Western Fire Chiefs Association (1988), publisher of the UFC, authored Appendix III-A, Fire-Flow Requirements for Buildings, which may be included with local jurisdiction's adoption of the UFC. The International Fire Code Institute (1997), publisher of the 1997 Edition of the UFC, modified Appendix III-A. Both documents are referenced to in similar sections of the body of the UFC (Section 10.301 [c] in the 1988 edition and section 903.2 in 1997) where it states that an approved water supply capable of supplying the required fire flow for fire protection shall be provided to all premises upon which facilities, buildings or portions of buildings are hereafter constructed or moved into or within the jurisdiction. This clearly ties the concept of water supply for fire suppression activities to new construction.

Building design and construction methods can be modified such that the NFF requirement can be matched to the available fire flow. A fire resistive wall, either two-hour or four-hour rated, can be utilized to make the fire area smaller. The Uniform Building Code (UBC), published by the International Association of Building Officials

(1997), Section 504.6.1, states that each portion of a building separated by one or more area separation walls may be considered a separate building. The rest of Section 504.6, describes these area separation walls and requires that they be not less than four-hour fire-resistive construction in Types I, II-F. R., III and IV buildings and two-hour rated for Type II One-hour, II-N, or Type V. The UFC Appendix III-A requires a four-hour wall and the ISO formula as used by the MFD allows a two-hour wall (this is a custom used by MFD since the Fire Flow Calculation form was borrowed from the King County Fire Marshals Office). The use of the area separation walls allow the plan reviewer to examine the separated areas of the building as separate buildings, therefore requiring less fire flow, or provide a sprinkler system.

There are allowances in the UBC (1997) that permit the construction of larger buildings than would be basically allowed, if they are protected by a sprinkler system. However, this issue would be dealt with by the Building Official who completes that portion of the plan review prior to it being moved to the MFD for their review of fire related issues.

Consideration should be made for the installation of sprinkler systems installed according to "Installation of Sprinkler Systems" (NFPA, 1996). The Guide for Determination of Required Fire Flow (1974) allows for a reduction of up to 50% of the required fire flow if the structure is completely protected with a sprinkler system and up to 75% for a building of either fire resistive or non-combustible construction. Appendix III-A of the 1997 edition of the UFC allows up to 75% reduction in NFF with an approved sprinkler system, however it requires that a minimum of 1,500 gpm be provided.

In summary, two authors confirm that many jurisdictions have experienced the same dilemma as MFD in selecting an appropriate formula for its use. DeLay (1994) states there are so many different theories for calculating the same needed flows only shows this is not a very exact science. Wiseman (1996) adds that the important lesson to be learned is that each formula is valid for the purpose for which it was intended. There is no one formula that is adequate for all types of fires.

PROCEDURES

Definition of Terms

Fire Area: The floor area, in square feet, used to determine the required fire flow.

Fire Flow Available: Is the amount of water supply available at 20 psi residual, as determined by the city of Marysville Public Works Director.

Needed Fire Flow (NFF): Is the rate of flow, at a residual pressure of 20 psi and for a specified duration considered necessary to control a major fire in a specific building

Required Fire Flow: To be used interchangeably with NFF.

Research Methodology

The desired outcome of this research was to provide a fire flow formula to the MFD for inclusion with the adoption of the 1997 edition of the UFC. The research was historical research in that a literature review was conducted to examine the background and reason each formula was developed. The literature examined consisted of periodicals, textbooks, fire and building code books, National Fire Protection Association documents, and reports. Evaluative research was employed to compare results of each formula for a given fire scenario that was then presented to the fire chief for his evaluation. Ultimately he is responsible for all activities of the various divisions of the

MFD. It was vitally important to obtain his input as to what would be considered a "reasonable" required fire flow prior to being faced with this issue before the public in a hearing for code adoption.

The research was action research in that the information gathered through historical research was applied to an example of current construction methods in the response area of the MFD. (See Appendix B.)

One interview was conducted with a former fire chief of the MFD and on September 30, 1998, a meeting was conducted at the headquarters station of MFD to discuss the results of this research project. In attendance were Greg Corn, MFD Fire Chief, John Dorcas, Building Official for the city of Marysville, and Owen Carter, P. E., City Engineer. After considerable discussion, a consensus was reached that a NFF formula must be relatively easy to use, readily available to all people with a need (i.e. architects, engineers, builders, etc.), preferably a nationally recognized format, reasonably restrictive, will provide a confidence level for MFD command staff that this resource will be adequate for all new construction in the event of a fire, requires a minimum amount of "interpretation," and is a consistent requirement for every project. Appendix C is the result of this consensus.

Assumptions and Limitations

As with most code-related issues, the adoption of a fire flow formula is only a reasonable assumption of what an acceptable level of protection should be. The various formulas examined in this research project provide a range of high and low, and then change with the inclusion of variables such as type of construction, occupancy, weather, abilities of the responding firefighters, etc. A formula must be adopted that gives the most reasonable results as defined by the fire and building professionals, and the political leaders of the jurisdiction affected.

RESULTS

A sample fire flow calculation method, to be presented to the city of Marysville City Council for adoption is shown in Appendix C. This form will then be used during the plan review process as part of the MFD staff review for fire safety concerns.

Each NFF formula examined during this research project is shown in Appendix A and a comparison of the resulting NFF for several scenarios is shown in Appendix B.

Answers to Research Questions

Research Question 1. What fire flow formulas are available? The need to provide water above and beyond the needs of a community's domestic and commercial use was recognized at about the turn of the century. A number of authors document early attempts to provide for the needs of their fire suppression teams. There are four fire flow calculation formulas mentioned in current literature as being of use in modern times. They are the Illinois Institute of Technology Research Institute (IITRI) Method, Insurance Services Office (ISO) Method, Iowa State University (ISU) Method, and the National Fire Academy Field Formula (NFA, 1983). In addition there is Appendix III-A of the UFC. See Appendix A for detail of the NFF formulas.

Research Question 2: What factors, such as type of construction and use should be included in calculating fire flow? The Municipal Fire Administration (1968) states that the number of fire streams needed around groups of buildings of various sizes, heights, and type of construction has been given a great deal of study by fire protection engineers. This statement leads one to believe that "groups of buildings," "various sizes," "heights," and "type of construction" are significant factors to be addressed when considering fire flow requirements. Phelps & McDonald (1984) express concern about "occupancy factor," "exposure charge," and "percentage of involvement." The ISU method addresses the effects of various application rates and techniques. The NFA method considers an exposure charge and percent of involvement whereas the ISU does not consider either. The ISO formula includes factors for type of construction, occupancy, exposure and communication in buildings, or areas of buildings separated by two-hour area separation walls. UFC (1997) Appendix III-A, Section 3.1 and 3.2 state that fire flow requirements may be modified downward or upward by the chief when considering buildings that are in rural areas or where conditions indicate an unusual susceptibility to group fires or conflagrations. The area being considered under the UFC formula can be separated by four-hour area separation walls in a building whose fire flow requirements exceed the available fire flow.

Duration, or the number of hours the required fire flow should be available varies from 2 to 10 hours, is used in both the Appendix III-A and ISO formulas.

This research indicates that the following factors should be included in a NFF calculation method:

- Type of occupancy
- Exposures
- Type of construction

Research Question 3: What alternate methods could be adopted by the MFD to offset deficient fire flows? Besides the controversial issue of not allowing a citizen to build their proposed new building, there are two issues that can be examined during the fire flow calculation process that can mitigate an inadequate NFF.

A fire resistive wall, either two-hour or four-hour rated, can be utilized to make the fire area smaller. The UBC states that each portion of a building separated by one or more area separation walls may be considered a separate building. The UFC Appendix III-A requires a four-hour wall and the ISO formula as used by the MFD allows a two-hour wall. The use of the area separation walls allow the plan reviewer to examine the separated areas of the building as separate buildings, therefore requiring less fire flow, or provide a sprinkler system.

Consideration should be made for the installation of sprinkler systems. The ISO formula allows for a reduction of up to 50% of the required fire flow if the structure is completely protected with a sprinkler system and up to 75% for a building of either fire resistive or non-combustible construction. Appendix III-A of the 1997 edition of the UFC allows up to 75% reduction in NFF with an approved sprinkler system, a minimum of 1,500 gpm is required.

AWWA (1992) states that a building developer who properly designs and installs a fire suppression system can do far more to protect life and property than a fire company can do with any amount of water delivered through the standard hose system. Fire sprinklers drastically reduce the required fire flow for any building (Isman, 1993) and Sylvia (1982) advises that the effectiveness of an automatic sprinkler system in limiting the volume of fire, and therefore the volume of water needed from hose lines, can be used to provide a base for determining the NFF.

There is support by the authors dealing with the concept of NFF, as applied to the issue of planning the construction of buildings with NFF matched to available fire flow, that separation walls and sprinkler systems are valid methods to offset what would otherwise be deficient NFF.

Appendix C reflects the requirement that a four-hour wall designates a fire area and up to a 75% reduction in NFF is available with the provision of a sprinkler system. In areas where there is otherwise inadequate fire flow, these mitigation's allow modifications to the building design that will allow construction to be permitted.

DISCUSSION

The Needed Fire Flow Formula (Appendix C) is the result of this research project's examination of the formulas that are currently recognized by the fire service in the United States. The intent of this research project was to have a formula that can be used by the MFD staff during the plan review process that complies with requirements of the current edition of the UFC. This formula, computed in an office setting without the tension and stress of a fire scene, can be technical in nature such that it should consider any relevant factors and requirements, but not so difficult in nature such that the expertise of a Fire Protection Engineer is required. The literature review revealed a number of discussions centered on the subjects of "Pre-fire planning," "First in officer," "rule of thumb," and "a field formula" (Burns & Phelps, 1994; DeLay, 1994; Phelps & McDonald, 1984; Sylvia, 1982; Wiseman, 1993). These comments were in reference to the ISU, IITRI, and NFA formulas. All were extremely helpful and of use to the suppression fire officers and of invaluable use to the pre-fire planning process of existing buildings.

The ISO formula was referenced by a number of authors (AWWA, 1992; DeLay, 1994; Isman, 1993; Milke, 1980; Wiseman, 1993). They report that this method is used throughout the country by many jurisdictions. It is the result of analysis of the water used on 1,450 actual large-loss fires throughout the country that were plotted on a graph. It then considers adjustments due to construction type, size, use, and exposures to other buildings. This appears to meet the need of the MFD plan review needs.

Appendix III-A of the 1997 edition of the Uniform Fire Code has advantages of being readily available, being an appendix to the fire code used in over half of the United States, and easy to use. It is similar to the ISO formula in that the NFF is based on the fire area and varies according to the type of construction. Examination of the tables in Appendix III-A that give the gpm/square foot NFF and the ISO formula results for a given building of the same size and same construction result in almost identical numbers. The advantage of being readily available to building designers is offset somewhat by the disadvantage of the sections that states that the NFF may be modified upward or downward by the chief for exposures. This ISO formula provides data for types and distances to exposures that can be used by both the chief and the building designer. This helps to reduce the "interpretation" required and eases the burden of the plan reviewer by being able to apply a uniform, consistent code requirement.

Appendix B reveals some of the difficulty in adopting a NFF formula by showing the range of NFF required for an example building in the MFD response area. This example chosen requires a NFF that ranges from 1,800 to 6,250 gpm. The ISO and Appendix C numbers are very close, exceeding the Appendix III-A number because of the consideration of the exposure. With the additional NFF required for the added exposure in the second example, the two formulas show similar results, while the highest number, from the NFA formula, soars to 7,815 gpm. A sprinkler system drops the numbers down to a much more obtainable number of 1,322 gpm for the ISO formula and 1,500 gpm, the bottom of the range, for Appendix III-A and Appendix C.

DeLay (1994) casts a shadow of doubt of the ISU and NFA formulas for the intended use by the MFD when he states:

> The University of Iowa and the National Fire Academy formulas don't consider the type of construction or the occupancy of a structure. At least they don't for each structure as some of the other methods do. I wonder if their "rule of thumb" formulas, which were developed many years ago, are as applicable today with 2" x 4" wood trusses, chipboard "I" beams, and so many synthetic construction and furnishing materials as they were when fewer synthetic construction materials were used and methods more durable. The synthetic materials along with more energy efficient construction (not necessarily durable) produce more heat and the heat is retained in the structure longer. Could this result in more combustion gases and hotter fires?

His concern (Delay, 1994) is that the fire service still gears itself for 95% of the fires that result in 5% of the losses and ignores the 5% fires that are 95% of the dollar loss. "I think this has a lot to do with an understanding of NFF and being able to deliver it."

RECOMMENDATIONS

"I wish there were a simple, accurate, accepted method for predetermining Needed Fire Flow "(DeLay, 1994).

The city of Marysville should, upon the recommendation of the MFD Board of Directors, replace the sentence "In setting the requirements for fire flow, the chief may be guided by Appendix III-A" in Section 903.3, 1997 edition of the Uniform Fire Code, with "In setting the requirements for Needed Fire Flow, the chief shall use the Marysville Fire District 'Standard For Computation of Needed Fire Flow.'"

This formula is based on Appendix III-A but is amended by adding the more descriptive elements of the ISO formula to provide guidance to the plan reviewer of how much additional fire flow to require for exposures and additional or decreased fire flow for types of occupancies. This provides a document based on a nationally recognized formula that has been amended to reflect the needs of the local jurisdiction.

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APPENDIX A

Needed Fire Flow Formulas

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Needed Fire Flow Formulas

Appendix III-A of the 1997 Uniform Fire Code:

Division III

FIRE PROTECTION

APPENDIX III-A

FIRE-FLOW REQUIREMENTS FOR BUILDINGS

(See UFC Section 903.3)

SECTION 1 - SCOPE

The procedure determining fire-flow requirements for buildings or portions of buildings hereafter constructed shall be in accordance with Appendix III-A. Appendix III-A does not apply to structures other than buildings.

SECTION 2 - DEFINITIONS

For the purpose of Appendix III-A, certain terms are defined as follows:

FIRE AREA is the floor area, in square feet, used to determine the required fire flow.

FIRE FLOW is the flow rate of a water supply, measured at 20 psi (137.9 kPa) residual pressure, that is available for firefighting.

SECTION 3 - MODIFICATIONS

3.1 Decreases. Fire-flow requirements may be modified downward by the chief for isolated buildings or a group of buildings in rural areas or small communities where the development of full fire-flow requirements is impractical.

3.2 Increases. Fire flow may be modified upward by the chief where conditions indicate an unusual susceptibility to group fires or conflagrations. An upward modification shall not be more than twice that required for the building under consideration.

SECTION 4 - FIRE AREA

4.1 General. The fire area shall be the total floor area of all floor levels within the exterior walls, and under the horizontal projections of the roof of a building, except as modified in Section 4.

4.2 Area Separation. Portions of buildings which are separated by one or more four-hour area separation walls constructed in accordance with the Building Code, without openings and provided with a 30-inch (762 mm) parapet, are allowed to be considered as separate fire areas.

4.3 Type I and Type II-F.R. Construction. The fire area of buildings constructed of Type I and Type II-F.R. construction shall be the area of the three largest successive floors.

SECTION 5 - FIRE-FLOW REQUIREMENTS FOR BUILDINGS

5.1 One- and Two-Family Dwellings. The minimum fire flow and flow duration requirements for one- and two-family dwellings having a fire area which does not exceed 3,600 square feet (344.5 m^2) shall be 1,000 gallons per minute (3785.4 L/min.). Fire flow and flow duration for dwellings having a fire area in excess of 3,600 square feet (344.5 m^2) shall not be less than that specified in Table A-III-A-1.

> **EXCEPTION:** A reduction in required fire flow of 50 percent, as approved, is allowed when the building is provided with an approved automatic sprinkler system.

5.2 Buildings other than One- and Two-Family Dwellings. The minimum fire flow and flow duration for buildings other than one- and two-family dwellings shall be as specified in Table A-III-A-1.

> **EXCEPTION:** A reduction in required fire flow of up to 75 percent, as approved, is allowed when the building is provided with an approved automatic sprinkler system. The resulting fire flow shall not be less than 1,500 gallons per minute (5677.5 L/min.).

APPENDIX A

Needed Fire Flow Formulas

TABLE A-III-A-1-MINIMUM REQUIRED FIRE FLOW AND FLOW DURATION FOR BUILDINGS

FIRE AREA (square feet) × 0.0929 for m^2					FIRE FLOW (gallons per minute)[2] ´ 3.785 for L/min.	FLOW DURATION (hours)
Type I-F.R. II-F.R.[1]	Type II One-HR. III One-HR.[1]	Type IV-H.T. V-One-HR.[1]	Type II-N III-N[1]	Type V-N[1]		
0-22,700	0-12,700	0-8,200	0-5,900	0-3,600	1,500	
22,701-30,200	12,701-17,000	8,201-10,900	5,901-7,900	3,601-4,800	1,750	
30,201-38,700	17,001-21,800	10,901-12,900	7,901-9,800	4,801-6,200	2,000	
38,701-48,300	21,801-24,200	12,901-17,400	9,801-12,600	6,201-7,700	2,250	2
48,301-59,000	24,201-33,200	17,401-21,300	12,601-15,400	7,701-9,400	2,500	
59,001-70,900	33,201-39,700	21,301-25,500	15,401-18,400	9,401-11,300	2,750	
70,901-83,700	39,701-47,100	25,501-30,100	18,401-21,800	11,301-13,400	3,000	
83,701-97,700	47,101-54,900	30,101-35,200	21,801-25,900	13,401-15,600	3,250	3
97,701-112,700	54,901-63,400	35,201-40,600	25,901-29,300	15,601-18,000	3,500	
112,701-128,700	63,401-72,400	40,601-46,400	29,301-33,500	18,001-20,600	3,750	
128,701-145,900	72,401-82,100	46,401-52,500	33,501-37,900	20,601-23,300	4,000	
145,901-164,200	82,101-92,400	52,501-59,100	37,901-42,700	23,301-26,300	4,250	
164,201-183,400	92,401-103,100	59,101-66,000	42,701-47,700	26,301-29,300	4,500	
183,401-203,700	103,101-114,600	66,001-73,300	47,701-53,000	29,301-32,600	4,750	
203,701-225,200	114,601-126,700	73,301-81,100	53,001-58,600	32,601-36,000	5,000	
225,201-247,700	126,701-139,400	81,101-89,200	58,601-65,400	36,001-39,600	5,250	
247,701-271,200	139,401-152,600	89,201-97,700	65,401-70,600	39,601-43,400	5,500	
271,201-295,900	152,601-166,500	97,701-106,500	70,601-77,000	43,401-47,400	5,750	
295,901-Greater	166,501-Greater	106,501-115,800	77,001-83,700	47,401-51,500	6,000	4
”	”	115,801-125,500	83,701-90,600	51,501-55,700	6,250	
”	”	125,501-135,500	90,601-97,900	55,701-60,200	6,500	
”	”	135,501-145,800	97,901-106,800	60,201-64,800	6,750	
”	”	145,801-156,700	106,801-113,200	64,801-69,600	7,000	
”	”	156,701-167,900	113,201-121,300	69,601-74,600	7,250	
”	”	167,901-179,400	121,301-129,600	74,601-79,800	7,500	
”	”	179,401-191,400	129,601-138,300	79,801-85,100	7,750	
”	”	191,401-Greater	128,301-Greater	85,101-Greater	8,000	

[1]Types of construction are based upon the Building Code.
[2]Measured at 20 psi (137.9 kPa). See Appendix III-A, Section 2.

APPENDIX A

Needed Fire Flow Formulas

Illinois Institute of Technology Research Institute Method

$NFF = -1.3 \times 10^{-5} A^2 + 42 \times 10^{-2} A$

A: the area of the fire in square feet

Discussion: This formula was developed from a survey. Data was collected from 134 fires in several occupancy types in the Chicago area to determine the water application rate needed for control as a function of fire area. Reported fires were of differing levels of magnitude, so not to concentrate solely on large-loss fires. This equation was obtained through a curve-fitting analysis of available data points on a graph. The investigation noted that tactical procedures can influence the application rate of water use greatly, e.g., interior versus exterior attack, leading off with large diameter rather than small diameter hose and similar concerns (American Water Works Association, 1992).

Insurance Services Office Method

$NFF = 18C \sqrt{A}$

A: is the area of the building in square feet

C: is a construction factor that varies from 0.6 for fire resistive construction to 1.5 for wood frame type construction.

The result is increased up to 25% for high fire hazard occupancies or reduced up to 25% or low fire hazard occupancies.

The figure from above may be reduced up to 50% for a complete automatic sprinkler system. Where buildings are either fire resistive or non-combustible construction, and have low fire hazard, the reduction may be up to 75%.

APPENDIX A

Needed Fire Flow Formulas

An exposure factor is then added to the above. This will range from 5% for each side if exposure buildings are from 101' to 150' away or up to 25% if they are within 10'. The total percentage shall be the sum of the percentages from all sides, but shall not exceed 75%. These percentages shall depend upon the height, area, and construction of the building(s) being exposed, the separation, openings in the exposed building(s), the occupancy of the exposed building(s), and if the exposed building(s) are sprinklered.

Discussion: The above is the basic ISO formula. There are more details involved in calculating the NFF according to the ISO "Guide for Determination of Required Fire Flow," but the above gives the reader an accurate idea of the basic requirement.

The basic equation was developed after an analysis of the estimated amount of water used on 1,450 actual large-loss fires. These fires were contained in buildings of ordinary type construction. The date was taken from fire departments throughout the country, thereby accounting for variances in fire suppression tactics. The results were plotted on a graph and the resulting equation developed by a curve-fitting process (Milke, 1980).

Iowa State University Method:

GPM = Cubic Feet/100 or NFF = (L x W x H)/100

Discussion: This method was developed in the early 1950's at Iowa State University College of Engineering (Royer, 1995) during research related to uncontrolled fire behavior in structures. This formula spells out the rate of flow needed to knock down (control) a fire in a single open area when that area is fully involved. It is based on

APPENDIX A

Needed Fire Flow Formulas

scientific fact that one gallon of water will absorb all the heat produced by 200 cubic feet of air and that this gallon will be converted to 200 cubic feet of steam. The Iowa formula has been proven to be valid for flows of up to 1,000 gpm and is used for the NFF for the largest single open area of a building. It does not include the flows required to protect both internal or external exposures.

National Fire Academy Method

NFF = $^{\text{Length x Width}}/_{3}$ for 100% involvement. Add 25% for each exposure.

X 1/2 if building 50% involved.

X 1/4 if building 25% involved.

Discussion: These formulas were derived from data submitted by various fire departments, thus they have a similar origin to the ISO formula. The formula includes exposures as a factor but not occupancy. Because there has been no published justification for the use of the denominator 3, presumable it is arbitrary or empirical in nature (Wiseman, 1996). Phelps & McDonald (1986) explain that this formula can be used for pre-fire planning by accurately measuring the building and presuming certain scenarios rather than using this formula as an estimating tool for the first arriving fire officer. The formula indicates approximate fire flows required for an aggressive interior attack on small and moderate structures, or on large structures with limited involvement.

APPENDIX B

Comparison of Needed Fire Flow Formulas

APPENDIX B

Comparison of Needed Fire Flow Formulas

Using the formulas described in Appendix A, the NFF for a given scenario is shown below.

Example #1: The building being examined is a single story, 12' high, 15,000 sq. ft. building of Type V I-hour construction, no sprinkler system, to be occupied by a mercantile store. Thirty feet away from this building is a three story mercantile building of masonry construction with open communications of combustible construction. This is a very typical commercial building in the MFD response area.

Needed Fire Flow:

UFC Appendix III-A:	2,250 gpm
IITRI:	3,375 gpm
ISO:	2,645 gpm
ISU:	1,800 gpm
NFA:	6,250 gpm
Appendix C:	2,700 gpm

APPENDIX B

Comparison of Needed Fire Flow Formulas

Example #2: The same building but with an additional exposure building similar to the one above, but 90' away.

UFC Appendix III-A:	2,250 gpm
IITRI:	3,375 gpm
ISO:	2,909 gpm
ISU:	1,800 gpm
NFA:	7,815 gpm
Appendix C:	2,970 gpm

Example #3: Example #1 with the building provided with and approved sprinkler system:

UFC Appendix III-A:	1,500 gpm (1,500 gpm minimum is required)
IITRI:	3,375 gpm
ISO:	1322 gpm (50 % reduction for sprinkler system)
ISU:	1,800 gpm
NFA:	6,250 gpm
Appendix C:	1,500 gpm (1,500 gpm minimum is required)

APPENDIX C

Recommended Marysville Fire District "Standard For Computation of Needed Fire Flow"

APPENDIX C

Recommended Marysville Fire District "Standard For Computation of Needed Fire Flow"

Based on Appendix III-A of the 1997 Uniform Fire Code and the Insurance Services Office "Guide For Determination of Required Fire Flow."

Section 1 - Scope

The procedure determining fire flow requirements for buildings or portions of buildings hereafter constructed shall be in accordance with that standard. This standard shall apply to newly constructed buildings and existing buildings being remodeled, when due to the extent of that remodel the Building Official determines that all current code requirements shall be met.

Section 2 - Definitions

For the purpose of this standard, certain terms are defined as follows:

Fire Area: is the floor area, in square feet, used to determine the required fire flow.

Needed Fire Flow: is the flow rate of a water supply, measured at 20 psi residual pressure, that is available for firefighting.

Fire Flow Available: is the amount of water supply available at 20 psi residual, as determined by the city of Marysville Public Works Director.

Section 3 - Modifications

3.1 Type of occupancy.

It is expected that in commercial buildings no percentage increase or decrease for occupancy will be applied in most of the fire flow determinations.

APPENDIX C

Recommended Marysville Fire District "Standard For Computation of Needed Fire Flow"

Fire flow requirements may be modified downward by the chief for low hazard occupancies, see Table B. Up to 25% of the required fire flow may be deducted for occupancies such as apartments and dormitories, 20% for hospitals and elementary schools, and 15% for junior and senior high schools. Judgement should be used when examining the entire occupancy. For example, special consideration might be given to laboratory and shop areas of a junior or senior high school.

Fire flow requirements may be modified up-ward by the chief for high hazard occupancies, see Table B. Up to 25% of the required fire flow may by increased for occupancies that store, use, and handle flammable liquids, or other hazardous materials.

3.2 Exposures

Additional fire flow shall be added for structures exposed within 150' of the fire area under consideration. This percentage shall depend upon the height, area, and construction of the building(s) being exposed, the separation, openings in the exposed building(s), the length of exposure, the provision of automatic sprinklers, and the occupancy of the exposed building(s).

The percentage for any one side generally should not exceed the following limits for the separation shown.

Separation	Percentage
0-10 feet	25%
11-30 feet	20%
31-60 feet	15%
61-100 feet	10%
101-150 feet	5%

APPENDIX C

Recommended Marysville Fire District "Standard For Computation of Needed Fire Flow"

If an exposure side is an undeveloped property, then the exposure charge shall take into consideration what the Marysville Zoning Code would allow for future construction. The total percentage shall be the sum of the percentages for all sides, but shall not exceed 75%.

Section 4 - Fire Area

4.1 General.

The fire area shall be the total floor area of all floor levels within the exterior walls, and under the horizontal projections of the roof of a building, except as modified in Section 4.

4.2 Area Separation.

Portions of buildings, which are separated by one or more four-hour area separation walls constructed in accordance with the Building Code, without openings and provided with a 30-inch parapet, are allowed to be considered as separate fire areas.

4.3 Type I and Type II-F. R. Construction.

The fire area of buildings constructed of Type I and Type II-F. R. construction shall be the area of the three largest successive floors.

Section 5 - Fire Flow Requirements For Buildings

5.1 One- and Two- Family Dwellings.

The minimum fire flow for one- and two- family dwellings having a fire area that does not exceed 3,600 square feet shall be 1,000 gallons per minute. Fire flow for dwellings having a fire area in excess of 3,600 square feet shall not be less than that specified in Table A.

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EXCEPTION: Reduction in required fire flow of 50% percent, as approved, is allowed when the building is provided with an approved automatic sprinkler system.

5.2 Buildings other than One- and Two- Family Dwellings.

The minimum fire flow for buildings other than one- and two- family dwellings shall be as specified in Table A.

EXCEPTION: A reduction in required fire flow of up to 75%, as approved, is allowed when the building is provided with an approved automatic sprinkler system. The resulting fire flow shall not be less than 1,500 gallons per minute.

Section 6 - Procedures

6-1 Type of Construction, Ground Floor Area, and Height in Stories.

Determine these variables and using Table A, determine the required fire flow to nearest 250 gpm.

6-2 Occupancy Consideration.

Determine the increase or decrease for occupancy and apply to the value obtained in Section 6.1. Do not round off the number.

6-3 Sprinkler System.

Determine the decrease, if appropriate, for an automatic sprinkler system protection. Do not round off the number.

6-4 Exposures.

Determine the total increase for exposures. Do not round off the number.

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6-5 Calculate the Final Fire Flow Required.

Round this number off to the nearest 250 gpm and compare it to the Fire Flow Available figure obtained from the city of Marysville Public Works Director.

TABLE A

Minimum required fire flow for buildings

(See Table A-III-A-I in Appendix A)

APPENDIX C

Recommended Marysville Fire District "Standard For Computation of Needed Fire Flow"

TABLE B

Examples of low and high hazard occupancies

Low Hazard Occupancies

Apartments	Asylums	Churches	Colleges
Dormitories	Dwellings	Hospitals	Hotels
Institutions	Libraries	Nursing Homes	Prisons
Public Buildings	Rooming houses	Schools	

High Hazard Occupancies

Aircraft hangers   Cereal, Feed, Flour and Grist Mills   Chemical Works

Explosives and Pyrotechnics Manufacturing   Oil Refineries

Paint Shops   Solvent Extracting   Varnish and Paint Works

Wood working with Flammable Finishing   Other occupancies involving processing, mixing, storage and dispensing flammable and/or combustible liquids