

Fire and Rescue Departments of Northern Virginia

Firefighting and Emergency Operations
Volume I - General Firefighting Procedures
Book 2
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Engine Company Operations

Developed through a cooperative effort
between the Fire and Rescue Departments of
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City of Fairfax
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1 INTRODUCTION

1.1 Background

1.1.1 Throughout the nineteenth and early parts of the twentieth century, firefighters controlled and extinguished fires by projecting streams onto a fire from the exterior of a structure. As a result, firefighters would not be able to meet their objective until either unreachable areas burned themselves out, or collapse occurred, thus exposing the fire to outside streams. This often resulted in exposure protection as the primary objective. Major improvements have been made in the last half of the twentieth century. The use of breathing apparatus, ventilation techniques, and protective clothing has allowed firefighters to operate on the interior of structure fires. **It should be remembered that the primary function of today's engine companies is to obtain and deliver a sufficient quantity of water in the safest and most effective configuration to the fire area to extinguish the fire.**

1.2 Purposes:

- To provide guidelines and general information regarding engine company operations
- To describe the duties and responsibilities of the engine company
- To identify tactical and strategic considerations for engine company operations
- To establish guidelines for fire stream positioning
- To define the engine company officer's roles and responsibilities
- To establish guidelines for apparatus positioning on the fireground
- To establish procedures for engine driver/operator qualifications

2 PLANNING AND PREPARATION

- 2.1 Planning and preparation starts the moment members assigned to the engine company arrive at work. Members should check for any pertinent information such as street closings, hydrants out-of-service, water main repairs, and standpipe and sprinkler systems that are out-of-service.
- 2.2 All tools and equipment not specifically assigned to a particular firefighter shall be checked to ensure that they are present and functioning properly. Additionally, firefighters shall ensure that the nozzles are inspected for proper settings and are functioning properly.

3 **RESPONDING**

3.1 Typical Response and Arrival Considerations

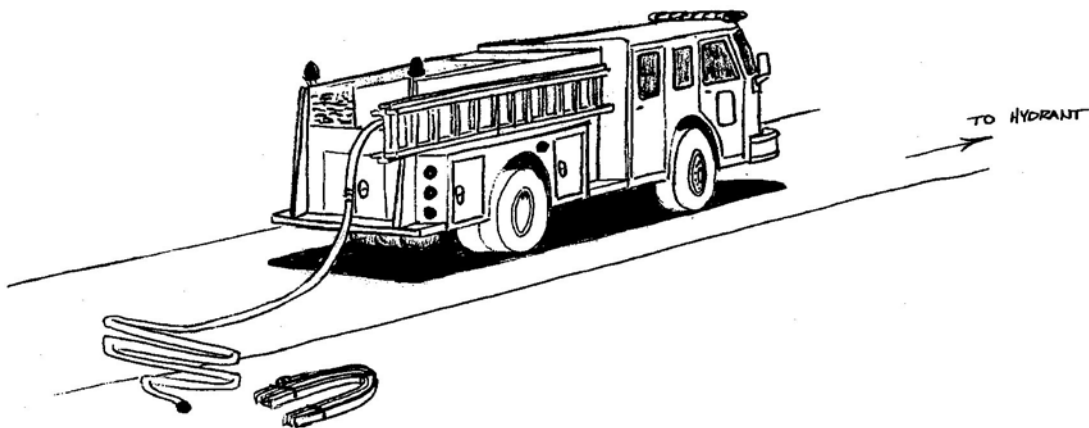
3.1.1 Whether an engine company is responding alone or as part of a larger assignment determines many of the actions, enroute preparations, and thought processes that take place during the response. Officers must be cognizant of assignments identified in specific operating books.

3.1.2 Engine companies must allow the Truck access to the front of the building to the truck companies. Room should be allowed for ladder companies to deploy their tools and ladders. Engine company officers shall communicate the water supply locations along with the type and method of hose layout. Additionally, any other pertinent information that may affect the operations on the fireground must be communicated to other units that are enroute or on the scene.

3.2 Single Engine Response

3.2.1 In addition to all of the preparations generic to any call, members must be prepared to confront, for a variety of reasons, an incident that requires more than a single engine. This type of situation might then require the engine company crew to perform tasks not normally associated with engine company work, i.e. ventilation to facilitate rescue, ground ladder placement, etc.

3.2.2 In situations where an engine is operating by itself for some time, alternative hose techniques should be considered. As an example, one option would be to drop off a sufficient amount of hose or standpipe pack at the fire, connect the supply line to that hose, and have the engine reverse lay to the water source.



3.3 Multi-Engine Response

3.3.1 The engine company's assignment is dependent upon where it is in the dispatch order for the alarm. In other words, the responsibility of the company is based upon it being first due, second due, etc. This assignment is paramount in determining the preparations to be made by the engine company crew while enroute to the incident. In most instances, the company assignments will fall in the dispatch order. If a unit is out of position or other circumstances indicate it will arrive on the scene significantly before or after it normally would, the unit shall communicate via radio with the controlling dispatch center and advise of the change in assignments.

3.3.2 First-Due Engine

- Engine companies shall assess primary water supply needs and identify the source
- Current conditions should be assessed and reported to other units on the alarm. Give a preliminary "on-scene" radio report consisting of type of structure and evident conditions and a command statement
- Determine an initial strategy, mode of operation, and any additional resources needed
- Determine the tactics necessary to carry out the strategy after viewing as many sides of the structure as possible
- As a crew, take the actions necessary to implement the tactics. Communicate these actions in your "situation report" so all responding units are aware of your location and intentions

Example: "Engine 209 is on the scene of a two-story colonial with fire out of two windows, second floor, side Adam. We will be in an offensive mode of operation stretching a 1 $\frac{3}{4}$ through the front door to floor 2 with a crew of three. Need the truck to ladder the second floor on sides Adam and Charlie and commence primary search."

3.3.3 Second-Due Engine

- Closely monitor **all** radio traffic, particularly that of the first arriving unit(s)
- Provide water supply to other units or fire suppression systems
- Be prepared to assume command where appropriate
- Prepare to stretch a back-up line or to assist the first engine with their hose deployment

3.3.4 Third-Due Engine

- Position at the rear (Side Charlie) of the structure where appropriate
- Lay supply lines from an alternate water source to the rear of the structure
- Monitor all radio traffic
- Continuously monitor and assess needs
- Keep the incident commander apprised of situation in the rear of the structure

3.3.5 Fourth-Due Engine

- Supply water to third engine if needed
- Report to command for any assignments
- Assume role of R.I.T., except on high-rise fires

3.3.6 First-Due Engine, Second Alarm

- In most cases, the first-due engine on the second alarm shall establish staging unless the unit has received different orders from command. The officer shall select and announce the location of staging unless the location was determined prior to their arrival. The driver of this unit should obtain the staging officer vest and assume that role. Note that in high-rise, mall, and some other special fire situations, this function will be known as “base” since “staging” is located within the building
- The officer and remaining crewmembers shall report to command for assignment, unless needed to manage staging
- It is recognized that many times greater alarm units are given tactical assignments before arriving at staging. In these cases, the responsibilities outlined above will fall to the first engine company that actually arrives in staging.

3.4 Monitoring Radio Traffic

- 3.4.1 Companies responding to alarms shall monitor radio traffic from the dispatch center as well as units that are operating on-scene. This will provide firefighters with vital information about conditions at the scene and make them aware of the problems encountered by first arriving units.

3.5 Safety

- 3.5.1 All responses must be made consistent with all current Commonwealth of Virginia driving laws as well as departmental regulations. The response must be as rapid as is reasonable while at the same time maintaining a high level of safety. The knowledge of all members regarding the area and routes of travel is of utmost importance.

3.6 Altered Response Routes

- 3.6.1 When apparatus is available away from quarters, altered response routes must be considered. The officer shall voice this information to alert incoming units of possible changes in company assignments.
- 3.6.2 When a response route is changed, be aware of the apparatus responding from normal routes of travel.
- 3.6.3 Be alert at intersections for other responding units. If units are responding from a location other than home quarters, the officer shall alert other responding companies via radio stating from the location from which they are responding, i.e. "Engine 249 from 51's quarters."

4 FIRE SCENE OPERATIONS

4.1 Objectives

4.1.1 The objectives of any firefighting operation are to protect life and property by performing rescues, protecting exposures, confining the fire, and extinguishing the fire. Water must be applied to the fire in conjunction with the simultaneous venting and primary search operations.

4.2 Strategy

4.2.1 Strategy is the general plan or course of action decided upon to reach the objectives. This is most often indicated by the mode of operation: offensive or defensive.

4.3 Tactics

4.3.1 Tactics are the operations or actions to implement the strategy of the officer in command.

4.4 Size-up

4.4.1 Size-up is an ongoing evaluation of the problems confronted within an emergency situation. Size-up starts with the receipt of the alarm and continues until the fire is under control. This process may be carried out many times and by many different individuals during the incident. The responsibility initially lies with the officer of the first company on the scene. However, all members on an incident must be constantly sizing-up the situation based upon their assignments and responsibilities.

4.4.2 Strategic factors that must be considered during size-up include:

- Time of day
- Life Hazard
- Area (square footage per floor as well as total square footage)
- Height (total building height and height of the fire within the building in relation to the street)
- Construction type
- Occupancy
- Location and extent of fire
- Water supply
 - Street conditions
 - Auxiliary appliances
 - Weather
 - Apparatus and equipment (responding and available to respond)
 - Exposures (interior and exterior)
 - Your resources
 - Hazardous materials

4.4.3 If in a multiple-story occupancy, either residential or commercial, check the floor below the fire floor for the layout and location of the reported fire.

4.4.4 The engine company officer must make the decision as to which actions will benefit fireground operations the most. These actions could include rescue, confinement, or extinguishment. Every effort must be made to coordinate the attack with other operations, especially water supply and ventilation. A good rule to follow is:

- R – Rescue
- E – Exposures
- C – Confinement
- E – Extinguishment
- O – Overhaul

4.5 Rescue

4.5.1 Engine companies are often confronted with life saving operations upon arrival. Undoubtedly, it is the most serious factor at any fire. Life-saving operations are placed ahead of firefighting when firefighters are not available to do both (no truck or rescue company on the scene). The best life saving measure may be a prompt attack on the fire which, if allowed to spread, would trap occupants. Life hazard, visible upon arrival, has to be addressed.

4.5.2 Factors entering into rescue decisions are:

- Are occupants in the immediate vicinity of the fire and in danger?
- How many people are trapped?
- Are occupants threatening to jump?
- Are they above the fire?
- Are exits cut off by fire?
- Can they be removed via portable ladders?
- RISK vs. GAIN: Is it a true rescue or is it body recovery?

4.5.3 Actions the engine officer can take to protect the victims are:

- Send firefighters to remove occupants using portable ladders or building exits.
- Protect interior stairways.
- Get hose lines between fire and occupants.
- Extinguish the fire.
- Initiate ventilation to draw fire, heat, and smoke away from occupants.
- Provide assurance to occupants by verbal contact and initiating fire tactics.

4.6 Locating the fire

4.6.1 An exterior survey of the structure and immediate area must be made upon arrival. If the size of the building permits, a lap should be taken to observe as much of the building as possible. Otherwise, the engine officer must solicit reports from units whose vantage point allows a view of the other sides of the structure. If a truck or rescue company is on the scene and the location of the fire is not obvious, the engines should consider using those units to locate the fire and identify the best routes for hose line deployment. The following information must be determined or considered:

- Location of fire or smoke
- The building area and height
- The building entrance(s) and exit(s) such as fire stairs, fire escapes, etc.
- Exposures
- Possibility of obtaining building information from evacuees

4.6.2 An interior survey of the structure must be made for the following:

- Visible fire, smoke, and odors
- Sensed heat or the sound of fire (crackling, etc.)
- Occupants who may provide information
- Stairways leading to that part of the building in which the fire is known or believed to be located
- Structural stability of the interior
- Secondary means of egress

4.6.3 When the initial size-up is completed and the fire located, all pertinent information, and as necessary initial task assignments should be communicated to the affected companies.

4.6.4 There may be cases where lines should not be stretched until the location of the fire has been assured. Premature stretching can take place in the wrong street, into the wrong building, or up the wrong stairs or stairway.

4.6.5 If the engine is on the scene alone, it may be beneficial for the officer and one firefighter to proceed inside to locate the fire, leaving the driver and other firefighter to stretch the line once the fire is found.

4.7 Confinement

4.7.1 Confining the fire means to restrain or prohibit the fire from extending beyond the area involved upon arrival. Confinement of a fire must take into consideration the intensity of the fire as well as the anticipated or known direction of fire travel. In some situations, the mere closing of a door or window may act to confine the fire and permit life saving operations while lines are being stretched. An engine company officer must keep in mind that effective ventilation can help to confine the fire and limit its spread.

4.7.1.1 All members must understand that great care shall be exercised when ventilating so as not to cause unwanted fire extension that might hamper the initial attack line. Good communications are important for a coordinated fire attack. This is particularly true for engines pressing the attack and trucks supporting the attack with ventilation.

4.7.1.2 Exterior fire spread. Officers must be cognizant of the potential fire extension via the exterior to other areas of the structure. This can be one of the fastest means of fire extension. This is the result of fire venting to the outside through a window, door, or other opening, and re-entering the structure through the vented eaves or windows above. In areas where structures are in close proximity to one another, the problem may be even greater in that we now have fire extension to an adjacent building as well. There are several factors contributing to this problem:

- Combustible siding materials
- Distance between dwellings; newer single-family dwellings may be less than 10 feet apart and in some cases as little as 3 feet
- Windows above the venting fire which allow for auto-extension (leapfrogging to floor above)
- Vents in eave lines which lead directly into the attic or cockloft area
- Combustible roofing materials

4.7.1.3 A tactical consideration for addressing exterior fire spread includes a quick sweep of the eaves or siding involved prior to entering the structure. The objective is to drench the siding in order to delay and prevent vertical fire spread. This will delay extension into the exposure. Hose streams should not be directed into windows that are venting fire. Doing so will cause the fire to be pushed into the occupancy.

4.7.1.4 Aggressive firefighting usually means the first engine on the scene will pull the initial attack line to extinguish the fire. However, the first line deployed may not, and in some cases should not, be the line that actually conducts the initial attack. It may be necessary to use the initial line to confine the fire, protect exposures, and protect means of egress. In special circumstances, a number of other tasks may initially take precedence over fire attack.

4.8 Extinguishment

4.8.1 In order to properly affect prompt and efficient extinguishment in as safe a manner as possible, all firefighters must have a thorough knowledge of fire behavior. This includes the “phases of burning” and how they relate to various engine company operations.

4.8.1.1 Particular care must be exercised in dealing with fires that are beyond the transition between free burning and the smoldering phase.

4.8.2 Members must be aware that, due to the tremendous amount of stored heat energy found in many man-made products today, the potential for rapid fire growth as well as “rollover” or “flashover” is great. Therefore, firefighters must be constantly aware of changes in the fire environment during all operations. Engine companies should make every attempt to cool the ceiling and walls with water application utilizing a straight stream pattern to prevent flashover or rollover. Firefighters shall have a thorough knowledge of the various types of attack (direct, indirect, and combination) and when to use each type.

4.8.2.1 Direct Attack – The attack crew advances into the fire area and utilizes a straight or solid stream. The stream is applied directly onto the burning materials until the fire darkens down. This is the attack method most often used for interior firefighting. If necessary, straight or solid streams should be directed at the ceiling to cool the overhead, before directing the stream toward the fire itself in a “Z” pattern. Before advancing, a sweep of the floor with the stream will cool embers and other hot material that could cause firefighter injury.

4.8.2.2 Indirect Attack – The crew attacks the fire from a doorway, window, or other protected area not entering the fire area. A narrow to wide-angle fog stream is directed into the fire room or area. The super-heated atmosphere will turn the water fog into steam. This method of extinguishment absorbs the heat and displaces the oxygen. This method of extinguishment **must not** be used in areas where victims may be located or firefighters are operating.

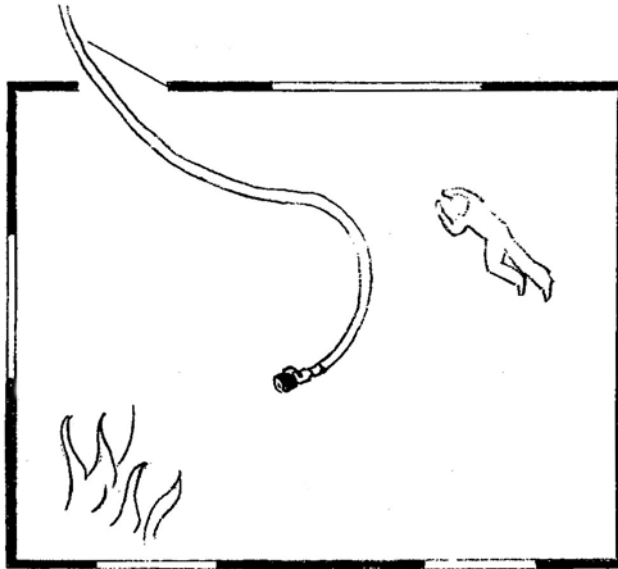
- 4.8.2.3 Combination Attack – This method utilizes both the direct and indirect methods at the same time. A narrow fog stream is used in a “T,” “Z,” or “O” pattern. The fog in the higher atmosphere turns to steam and the fog at floor level hits the burning material. As with an indirect attack, this method **must not** be used in areas where victims may be located or firefighters are operating.
- 4.8.3 Initial actions of hose lines should be to sweep the ceiling and walls to prevent flashover or rollover if needed. If the hose line cannot advance due to high heat conditions, the officer should call for *additional ventilation*. If the advance is being hindered by heavy fire, *additional lines or larger lines should be ordered*.
- 4.9 Determining Fire Flow
 - 4.9.1 There are several means for determining fire flow, all of which are based upon the amount of heat released from materials as they burn and the amount of heat that water absorbs while raising its temperature to that of vaporized steam. It must be recognized that these are general guidelines for determining the *amount* of water to be applied. Experience and logic must be employed in determining how the water should be applied.
 - 4.9.2 Care should be taken not to characterize fire loads based solely upon occupancy. It should be remembered that not all occupancies are used for their designed purpose. Outward appearances can be deceiving. For example, excessive storage of combustible liquids or other materials in a single-family structure would obviously change the fire loading within the structure.
 - 4.9.3 Light fire loads require a flow of 10 GPM per 100 square feet of involved area. This flow rate can most often be delivered using 1 ¾-inch hose lines.
 - 4.9.3.1 A typically furnished home or apartment may be classed as a “light” fire load.
 - 4.9.4 Medium fire loads require a flow of 20 GPM per 100 square feet of involved area. Use of 2 ½-inch hose lines should be expected.
 - 4.9.4.1 “Medium” fire loads would be characterized as commercial occupancies containing moderate amounts of combustible materials.
 - 4.9.5 High fire loads require a flow of 30 GPM per 100 square feet of involved area. Use of 2 ½-inch hose lines or heavy-caliber master streams will be needed.
 - 4.9.5.1 “High” fire loads would be characterized as storage facilities that house large quantities of combustible material or contents that are capable of unusually high rates of heat release.

4.10 Rules for Stream Positioning

4.10.1 It must be understood that more lives can be saved from fires by proper stream positioning than by any other fireground operation.

4.10.2 If the fire cannot be quickly confined and extinguished, then the following general rules for positioning streams shall apply:

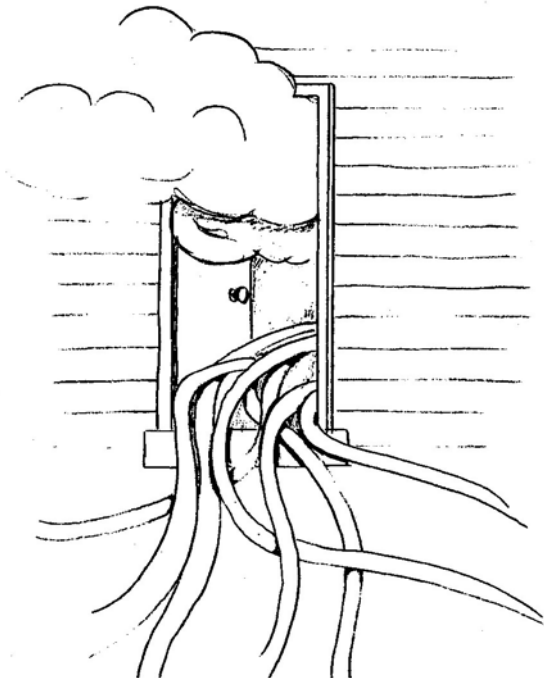
- When human life is endangered, the first stream is placed between the fire and persons endangered by it



- When human life is not endangered, then the first stream is placed between the fire and the most severe exposure

4.10.3 When a back-up line is deployed, it should be stretched to the same point as the first line or as otherwise directed. Normally, the back-up line is capable of equal or greater flow than the original line. However, a back-up line, at a minimum, should be capable of delivering the same amount of GPM as the original line.

- This hose line backs up the first in the event the first stream is inadequate or malfunctions. The second line is for support of the first line and to help ensure success
- This line must have enough hose to cover the floor above the fire floor
- Firefighters must not play two streams against each other
- If possible, attack should be made from the unburned side, however, this is often not practical.
- No more than two hose lines should be deployed through any one doorway.



- 4.10.4 When more than one line is deployed from a single engine, it is recommended to have a water supply established before the second line is charged. However, in almost every case, the attack engine is supplied by the 2nd due engine and the crew from the second engine deploys the second line. Water supply should be established concurrently with the deployment of the second line. The exception to this would include the “deluge blitz attack” where the 1st arriving engine opts to operate their master stream to knock down the bulk of the fire before a water supply is established.
- 4.10.5 Once water supply is established to any attack engine, the number of lines stretched from that engine is only limited by the amount of incoming water.
- 4.10.6 Additional lines may be stretched depending upon occupancy or fire situation. They may be deployed to:
- Cover secondary means of egress
 - Protect persons trapped above the fire
 - Proceed to adjoining buildings to protect exposures or operate through common horizontal openings
 - Prevent and extinguish the vertical spread of fire
 - Attack from the unburned portion of the structure and protect the stairway
 - Other priorities as determined by the incident commander
- 4.10.7 It must be understood that in order to coordinate ventilation operations with fire attack, the engine must convey to the outside vent team that they are ready to advance. Ventilation openings should be made prior to fire stream application. This communication can be made either by radio or face-to-face.
- 4.10.8 Members should consider the following points for proper stream application.
- 4.10.8.1 If it becomes necessary to conduct fire attack from the exterior of the structure, you must take into account members who might be operating inside the structure, i.e. search or ventilation crews. Additionally, any victims still in the structure must be considered. Again, effective communication via radio is of paramount importance in these situations.

- 4.10.8.2 When a direct attack cannot be made from the interior due to adverse wind conditions or excessive heat, consideration should be given to breaching the wall by making a hole in an adjoining room or compartment and conducting the initial attack in that way. In all cases, great care must be exercised in protecting the hallway or other means of egress. Maintaining the door to the fire room in the closed position until ready for interior attack will most likely be your best means of accomplishing this objective.
- 4.10.8.3 Fires that are free burning require a straight or solid stream to be effective. This technique is called the direct method of attack. A direct attack will be utilized on most interior fires. In order for the direct attack to be successful, coordination with the other units on the scene who are venting and searching must be considered. The direct method would not be utilized when fire is in areas that are unoccupied and areas which due to intense heat conditions cannot be entered. Examples are attics, knee-walls, and other confined areas.
- 4.10.9 To determine the type of attack that should be utilized, the following factors need to be taken into consideration:
- Fire attack crews have access to the seat of the fire
 - If other firefighters need to be in the fire area, such as performing primary searches
 - Victims and firefighters present or suspected to be in the fire area that could be affected by steam production
 - Inadequate ventilation that would not allow the smoke and hot gases to escape to the outside
 - If all of the above items exist, the direct method of attack should be used

4.11 Engine Officer

4.11.1 Once the decision to advance a hose line has been determined, a properly trained engine company should be able to do the following without close personal supervision of the officer:

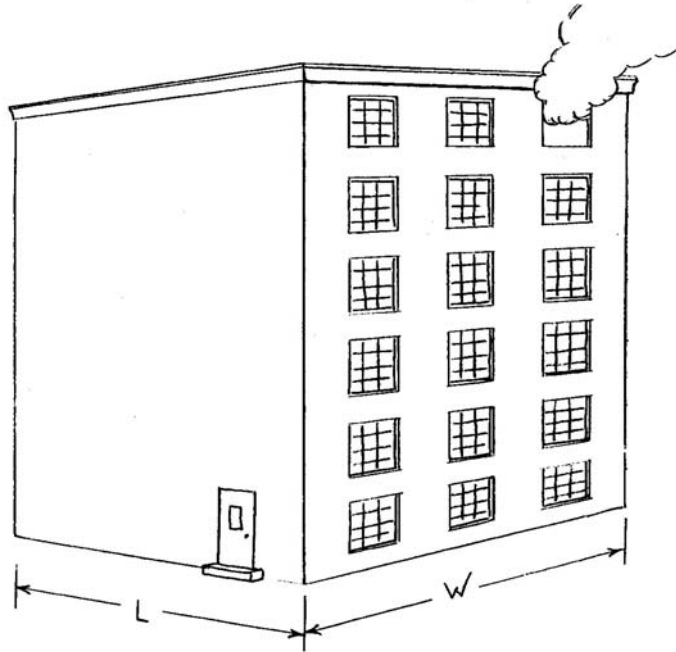
- Position the apparatus as necessary to effect an adequate water supply
- Estimate the amount of hose needed for the stretch
- Remove the hose from the apparatus
- Stretch the proper length of hose line to reach the objective
- Connect and utilize any appliances that may be needed

4.11.2 It is the first-due engine's responsibility to lay the supply line(s). When possible, the first-due engine company should forward lay the supply line. However, in some situations this may be impractical and a reverse or split lay may be utilized. The officer must make a proper decision to lay single or multiple lines. The old adage, "WHEN IN DOUBT, LAY IT OUT" seems to apply. It is much easier to lay dual lines initially than to try to hand lay a second one later.

- 4.11.3 If there is a known rescue situation, the officer should consider whether or not to stop at the water source and lay out, or proceed directly to the scene to avoid any delay to attempt rescue.
- 4.11.4 While the attack line is being stretched, the engine officer must be gathering information relative to the location and extent of the fire. The gathering of this information normally takes relatively little time. The advantages of proper line placement and rapid line advance are well worth the effort. The officer's size-up and tactical considerations for decision-making should include the following items:
 - 4.11.4.1 Monitoring *all* radio transmissions.
 - 4.11.4.2 The crew may need to locate the fire and search for victims without the aid of a hose line if no ladder or rescue company is present to accomplish this task.
 - 4.11.4.3 In a non-standpipe equipped multiple story occupancy, the engine officer must use good judgement in determining whether to stretch the attack line wet or dry.
 - 4.11.4.4 The engine officer should communicate to the nozzle team any information that might be critical, i.e. "straight down the hall, second door on the left." He should then ensure that the nozzle team is ready and initiate the advance. It is the engine officer's responsibility to ensure persons, either firefighters or civilians, are not adversely affected by the application of the fire stream. If there is any doubt as to whether there are victims or firefighters on the opposite side of the fire from where the attack is made, then a direct attack, utilizing a straight or solid stream, shall be used.
 - 4.11.4.5 While the attack line is being advanced, the engine officer should monitor all radio transmissions. This affords him knowledge of any hazardous condition that may be developing, i.e. ventilation problems, fire extension, collapse potential, and "Mayday" transmissions. It is understood that this may not be possible under the noise conditions of the typical fire attack. Therefore, the engine officer should, when possible, initiate communication and expect acknowledgment. The engine officer, in initiating communications, will be providing important information for the incident commander and other officers and units on the scene. These messages should be short and concise, i.e. fire knocked down. They shall include current conditions inside the structure as well as any resources that might be needed.
 - 4.11.4.6 The engine officer should constantly monitor progress and conditions. He directs the nozzle team's advance and instructs them as to their next objective.

- 4.11.4.7 Firefighters should avoid the fire floor and unprotected areas where active fire is present without an attack line.
- 4.11.4.8 The engine officer should constantly be monitoring the welfare of the nozzle team, being vigilant of anything or condition that might unnecessarily threaten their safety. He must be aware of the tendency of most firefighters to want to stay inside, well past the point when they should be relieved, and take action necessary to get other personnel to relieve them.
- 4.11.4.9 The engine officer should relay orders in concise and clear tones not higher than normal, dependant upon conditions, and in as few words as possible. He should keep his nozzle team informed of progress, giving estimates of what remains to be extinguished. It must be realized, due to the inevitable noise generated at a working incident, normal talking will be difficult to hear.
- 4.11.4.10 The engine officer should be with the nozzle or as close as possible. Due to the cramped quarters found at many incidents, the engine officer may find himself in the position of back-up person.
- 4.11.4.11 As the crew advances, the engine officer should be checking for fire extension in areas immediately adjacent to their position, such as adjoining rooms. Additionally, the officer must be looking for any victims that may be in the immediate area and always monitoring the structural conditions and fire behavior in their area of operation.
- 4.12 Booster lines are not normally considered for interior operations, other than to standby during overhaul operations to assist the investigator in cooling down an occasional hot spot.
- 4.13 Hose Line Advancement
- 4.13.1 The following should be considered when choosing the correct length of hose for deployment:
- Engine position and distance to the building, known as “setback”
 - Height of the fire floor
 - The area of the building and the location of the fire within that area
 - Amount of hose needed to reach the floor above the fire if the need arises
 - Attack line should be long enough to have at least one length available at the point the attack commences. (One length meaning 50 feet of hose).

- One method of calculating the proper length of hose in commercial buildings: take the setback + length of the building + width of the building + one length for each floor above the engine + one length at the point of attack = proper length of hose needed. Note that this formula would not apply to single-family dwellings.



4.13.2 Guidelines To Assist with Smooth Line Advancement

4.13.2.1 **Chock doors open!**

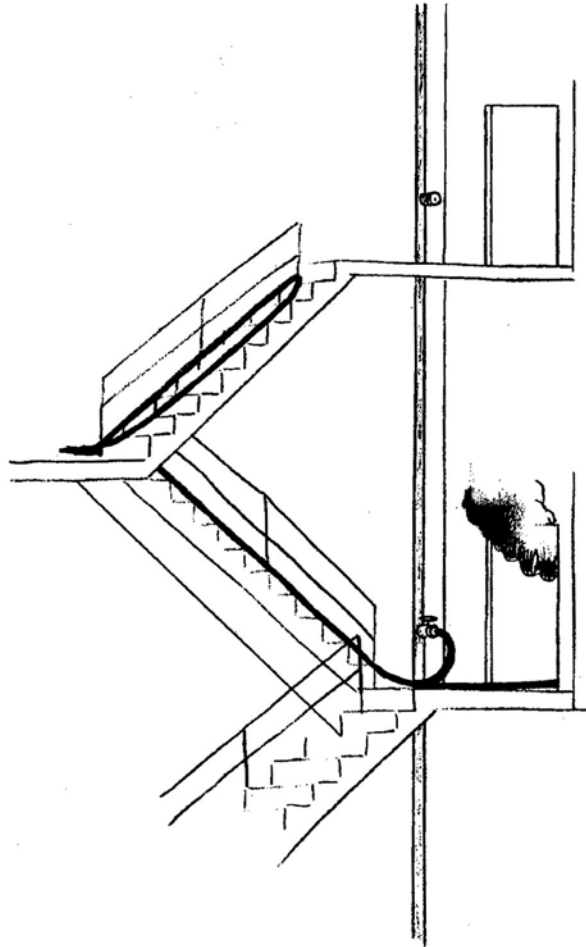
4.13.2.2 Ensure uncharged lines advanced into a structure do not become wedged under a partially closed door.

4.13.2.3 Stretching a line up a stairwell using the well-hole is very effective and uses only about one length per floor. However, if a crew is stretching up a narrow well-hole, ensure the line does not become wedged between the railing and the steps. Have additional members in the stairwell to advance the line into the hallway.

4.13.2.4 Limit the number of lines to no more than two through any one entrance. If additional lines are required, they should be advanced through alternate doors, windows, upper floors, over ladders or by hoisting with ropes.

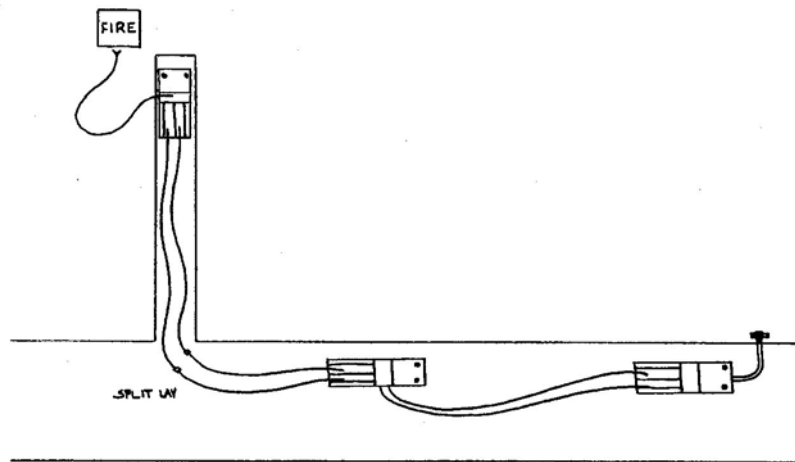
4.13.2.5 Use of the aerial as a permanent alternate standpipe is not generally advised. It should be free for other tasks, such as access to upper floors and the roof. More importantly, the aerial should be available to move into a position for emergency egress for firefighters or victims that show at a window or balcony. However, the aerial can be used to move hand lines into position.

- 4.13.2.6 When working out of a stairwell, stretch the line to the upper landing to ease advancement onto the fire floor from the stairwell. The uncharged hose should be laid out in accordion style to ease advancement.



- 4.13.2.7 At times, the best point of entry for the attack line might have to be accessed by advancing the line up and over a ladder or by entering the building and then hoisting the line.
- 4.13.2.8 Secure hose lines to the railings or windows on upper floor landings to prevent injuries to firefighters and occupants. This keeps stairwells free of clutter and prevents the hose from kinking.
- 4.13.2.9 When preparing to advance a hand line down a basement stairwell, ensure there is enough line poised at the top of the stairway to make a smooth unobstructed advance into the lower floor level.

- 4.13.2.10 When stretching lines inside a structure, ensure that firefighters are positioned at intervals over the length of the line in order to keep the line moving.
- 4.13.3 When multiple lines are required, consider utilizing more than one engine for attack positions. The entire operation would not be dependent upon a single attack engine if that engine were to malfunction. Reliance upon a single source of water supply should be avoided.
- 4.13.4 When the 2 ½-inch hose line is deployed it will take two crews to properly advance this hose line into a structure. Firefighter positions on the line should have the nozzle person and back-up at the nozzle and a member at approximately each coupling.
- 4.14 Rural Water Supply
- 4.14.1 In non-hydrant areas, engine companies have to rely on alternative water sources or utilize remote hydrants. Water supply is achieved by utilizing either a relay operation or a water shuttling operation.
- 4.14.2 The standard relay operation will place an engine approximately every 800 feet from the engine providing the fire attack.
- 4.14.3 A standard relay would:
- 4.14.3.1 Begin with an attack engine at the fire scene. (In restricted narrow access areas the attack engine will lay dual 3-inch supply lines or Large Diameter Hose (LDH) from the street and proceed to the fire).
- 4.14.3.2 A second engine would reverse or split-lay dual 3-inch supply lines (800 feet) or LDH toward the water source.
- 4.14.3.3 This sequence would continue until the water source is met and established ensuring an engine approximately every 800 feet.



4.14.4 Tanker shuttle

- 4.14.4.1 A guideline to use in deciding upon a relay or a shuttle is that if a relay requires more than 3 engines, in addition to the attack engine, a tanker shuttle should be considered.
- 4.14.4.2 Begin with an attack engine at the fire scene. (In restricted, narrow access areas, the attack engine will lay supply lines from the street and proceed to the fire).
- 4.14.4.3 The tanker will supply the attack engine as the portable folding tanks are set up at an accessible location, reasonably close to the attack engine, such as at the end of the driveway.
- 4.14.4.4 The supply engine will draft from the static source at the folding tanks and supply the attack engine. The supply engine shall position to allow complete access and egress for the tanker operations.
- 4.14.4.5 The tanker will begin to fill the portable tanks. In order to ensure that the supply engine has the capability to draft, one folding tank will only be half filled. When the supply engine obtains a draft, the tanker will completely fill the portable folding tanks.
- 4.14.4.6 The tanker would remain mobile and proceed to the closest reliable water source, refill, and shuttle water back to the folding tanks.
- 4.14.4.7 Additional engines and tankers could be added to the shuttle operation. If additional engines are used to shuttle water, a 100-foot supply line or lines should be placed near the folding tanks to be utilized by the shuttle engines to off-load. This will allow access for the tanker to operate without obstacles.
- 4.14.4.8 In order to fill the shuttle apparatus, an engine will be required to establish a water supply and fill site.
- 4.14.4.9 If the tanker is delayed or responds from a remote location, alternate supply methods need to be deployed.
- 4.14.4.10 When either a relay or shuttle operation is required, a water supply officer must be established.
- 4.14.4.11 To avoid obstructing the access of the shuttle operation where access to the structure is limited, it is advisable for the truck company to remain on the street and hand-carry equipment to the scene.

5 FIREGROUND HYDRAULICS

5.1 BACKGROUND

5.1.1 Hydraulics is a science that, in its broadest terms, deals with water and other fluids while at rest and in motion. In the fire service, the scope of this definition is usually limited to the study of water for firefighting purposes.

5.1.2 Often, the most practical method of fire extinguishment involves the application of water in a form that will quickly reduce the temperature of the burning material to a point where combustion no longer takes place.

5.1.3 Due to its availability and low cost, water has always been our most practical and commonly used extinguishing agent.

5.1.4 To produce an effective fire stream, a comprehensive knowledge of hydraulics is essential. Using water to its fullest potential requires the firefighter to be aware of the advantages, as well as the limitations associated with water.

5.2 PURPOSE AND SCOPE

5.2.1 The purpose of this section is to explain a practical method of determining the pump discharge pressure (PDP) necessary to produce an effective fire stream. The information presented in this document was prepared with the understanding that there are several methods used by firefighters to solve fireground hydraulics problems. It must be understood that, because of various factors encountered at each fire scene and the necessity of being able to quickly compute the correct pump discharge pressure for each situation, a practical approach to hydraulics is necessary. The information contained in this section is satisfactory for most fireground situations.

5.2.2 The scope of this section is limited to the essential hydraulic principles a firefighter must know to be an efficient pump operator. The International Fire Service Training Association (IFSTA) manuals have been adopted by our departments as the basic training guides. Several IFSTA Manuals were utilized in the development of this section. *Engine Company Fireground Operations* by Harold Richman, *E-One Training and Operations Manual*, *Fire Officers' Handbook of Tactics* by John Norman, and the *National Foam Manual* were also consulted in updating material. Members who wish to increase their knowledge and comprehension of hydraulics are encouraged to consult these and other references for additional information.

5.3 ABBREVIATIONS AND SYMBOLS

5.3.1 Fire service custom has developed certain symbols and abbreviations that are used in formulas necessary to calculate hydraulic problems. The following is a list of abbreviations and mathematical symbols that are used in this book and in the fire service:

- AL appliance loss
- D nozzle diameter
- EL elevation loss or gain
- FL friction loss
- GPM gallons per minute
- lb pound(s)
- NP nozzle pressure
- NR nozzle reaction
- PDP pump discharge pressure
- PSI pounds per square inch
- Q quantity of water flowing divided by 100
- RP residual pressure
- + Plus (addition)
- - Minus (subtraction)
- x Times (multiplication)
- / or ÷ Divided by (division)
- $\sqrt{\quad}$ Square root
- " Inch
- ' Foot or feet

8 MATHEMATICAL HINT: You will find as you proceed through this section of the book that your greatest chance of error will be in performing your mathematical calculations. In order to help reduce the possibility of error, there are some steps that can be utilized to assist you. You will notice that you will be squaring a lot of half numbers, such as $(2.5)^2$, $(4.5)^2$, $(7.5)^2$, etc. To help simplify this process, the following is suggested:

- Identify the two whole numbers that the half number is between. (2.5 is between 2 and 3)
- Multiply those two numbers together ($2 \times 3 = 6$)
- Add .25 to that total ($6 + .25 = 6.25$)
- That is your answer. This procedure will work when squaring any number that ends in .5.

5.4 DEFINITION OF TERMS

5.4.1 Firefighters must have a complete understanding of fire department hydraulics in addition to a solid working knowledge of the pump they are operating. Therefore, every operator must know and understand the following definitions of hydraulic terms:

- 5.4.1.1** Appliance – a device, other than a hand-held nozzle, where the direction of water flow is interrupted or changed.
- 5.4.1.2** Attack engine -- any pumper that is supplying water directly to attack lines.
- 5.4.1.3** Back pressure – the same as “head pressure.” Pressure generated by the weight of a column of water. This pressure is exerted at .434 psi per foot of elevation. On the fireground, this number is rounded to .5 psi.
- 5.4.1.4** Discharge – the quantity of water issuing from an opening and is expressed in gpm.
- 5.4.1.5** Supply engine – any pumper that is supplying water from a source, such as a hydrant or pond, to an attack engine.
- 5.4.1.6** Flow pressure – the forward velocity pressure of water issuing from a discharge opening. Flow pressure is usually measured by using a pitot gauge.
- 5.4.1.7** Friction loss – the loss in energy (pressure) due to friction. This results from the turbulence in the water and the water molecules rubbing on the interior surfaces of the hose and appliances.
- 5.4.1.8** Head pressure – see back pressure.

- 5.4.1.9 **Ladder pipe** – a master stream device that is attached to the rungs or rails of an aerial ladder. These may be pre-piped and permanently mounted or they may be appliances that must be attached to the aerial when needed.
- 5.4.1.10 **Master stream** – any fire stream that is too large to be controlled without mechanical aid. A master stream delivers more than 350 gpm. These devices may be fixed or portable. (Deck gun / Deluge gun)
- 5.4.1.11 **Normal operating pressure** – pressure on a water system during regular domestic consumption.
- 5.4.1.12 **Nozzle pressure** – the flow pressure of water as it leaves a nozzle.
- 5.4.1.13 **Nozzle reaction** – the backward force created by a stream of water as it is discharged from a nozzle.
- 5.4.1.14 **Pressure** – a measure of the energy contained in water, and measured and stated as psi.
- 5.4.1.15 **Residual pressure** – the pressure *remaining* in a water system when water is flowing.
- 5.4.1.16 **Siamese** – an appliance that combines two or more hose lines into one.
- 5.4.1.17 **Static pressure** – the pressure exerted by water when at rest.
- 5.4.1.18 **Velocity** – the speed at which water passes a given point, usually measured in feet per second. (FPS).
- 5.4.1.19 **Water hammer** – the concussion effect of a moving stream of water against the sides and ends of pipes, pumps, or hose lines when its movement is suddenly stopped.
- 5.4.1.20 **Wye** – an appliance that breaks one hose line into two or more hose lines.

10

5.5 STANDARDS AND MEASUREMENTS

- 5.5.1 **Because water is the most practical extinguishing agent, a comprehensive knowledge of its physical properties is essential. In addition, there are certain standards and measurements that are associated with fireground hydraulics that must be understood. These include:**
 - 5.5.1.1 **One cubic foot contains 1728 cubic inches.**
 - 5.5.1.2 **One cubic foot contains 7.5 gallons.**
 - 5.5.1.3 **One gallon contains 231 cubic inches.**
 - 5.5.1.4 **One cubic foot of fresh water weighs 62.5 pounds.**

- 5.5.1.5 One gallon of fresh water weighs 8.33 pounds (use 8.3 in formulas).
- 5.5.1.6 A column of water one foot high exerts a pressure of .434 psi at its base.
- 5.5.1.7 A column of water 2.31 feet high exerts a pressure of 1 psi at its base.
- 5.5.1.8 One inch of mercury equals 13.546 inches of water in the pressure it exerts downward. For drafting purposes, use 1 inch of mercury to indicate one foot of lift.
- 5.5.1.9 One length (50 feet) of 1 ¾-inch hose contains 6.24 gallons of water.
- 5.5.1.10 One length (50 feet) of 2 ½-inch hose contains 12.75 gallons.
- 5.5.1.11 One length (50 feet) of 3-inch hose contains 18.3 gallons.
- 5.5.1.12 One length (100 feet) of 4-inch hose contains about 125 gallons.

5.5.2 Sizes and types of fire streams

- 5.5.2.1 A small stream is 40 gpm or less.
- 5.5.2.2 A 1 ¾-inch hand line ranges from 100 to 210 gpm.
- 5.5.2.3 A 2 ½-inch hand line flows up to 325 gpm.
- 5.5.2.4 A master stream is considered to be 350 gpm and greater.

5.5.3 Nozzle pressure

- 5.5.3.1 Nozzle pressure for hand lines with smooth bore nozzles is 50 psi. The pressure can be increased to 65 psi to achieve a higher flow.
- 5.5.3.2 Nozzle pressure for master streams with smooth bore nozzles is 80 psi but can be increased to 100 to achieve higher flow rates.
- 5.5.3.3 Nozzle pressure for fog nozzles is 100 psi unless otherwise indicated.
- 5.5.3.4 Low-pressure fog nozzles are designed for 75-psi nozzle pressure. Knowledge of what nozzles you have on your apparatus is essential to ensure that the correct pressure is applied to achieve a good fire stream.

5.6 PRINCIPLES OF HYDRAULICS

- 5.6.1 There are six principles that cover the characteristics of pressure in fluids. They are:
 - 5.6.1.1 Fluid pressure is perpendicular to any surface on which it rests.
 - 5.6.1.2 Fluid pressure at a point in a fluid at rest is of the same intensity in all directions.

- 5.6.1.3 Pressure applies to a confined fluid from an outside source is transmitted equally in all directions.
- 5.6.1.4 The downward pressure of a liquid in an open vessel is proportional to its depth.
- 5.6.1.5 The downward pressure of a liquid in an open vessel is proportional to the density of the liquid.
- 5.6.1.6 The downward pressure of a liquid on the bottom of a vessel is independent of the shape of the vessel itself.

5.7 COMPUTING VOLUME

5.7.1 In order to determine the amount or weight of water contained in a vessel or container the volume of the container must first be determined.

5.7.1.1 The formula for determining volume for a rectangular or square shaped container is:

11

12
$$VOLUME = LENGTH \times WIDTH \times HEIGHT (L \times W \times H)$$

13

14 **Example 1:** What is the volume of a swimming pool that is 40 feet long, 20 feet wide, and 10 feet deep?

15

16
$$40 \times 20 \times 10 = 8000 \text{ cubic ft (ft}^3\text{)}$$

17

18 How many gallons of water can this pool hold?

19 Since 1 cubic foot of water contains 7.5 gallons, and the pool has a volume of 800 cubic feet, by multiplying 8000 by 7.5 it can be determined that the pool can hold 60,000 gallons of water.

20

21
$$8000 \times 7.5 = 60,000$$

22

23 **Example 2:** What is the weight of water on a flat roof of a townhouse that is 30 feet long, 25 feet wide and 1 ½ feet deep? (Hint: Keep all measurements in feet. As you will see later, you cannot combine feet and inches).

24

25
$$30 \times 25 \times 1\frac{1}{2} = 1125 \text{ cubic feet}$$

26 One cubic foot of water weights 62.5 pounds; therefore
by multiplying 1125 by 62.5, it can be determined that
there is 70,312 pounds of water on the roof.

27

28 $1125 \times 62.5 = 70,312.5$

29

30

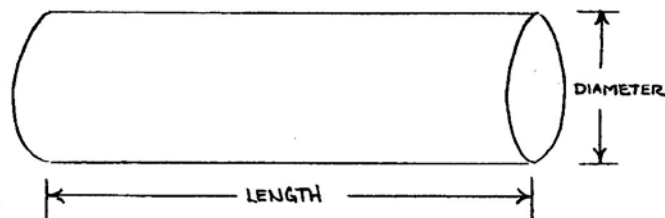
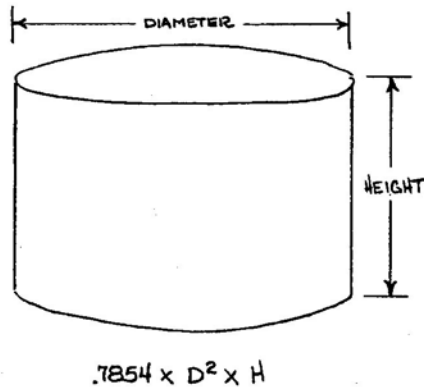
5.7.1.2 To determine the volume of a cylinder, the formula is:

31

32 $.7854 \times D^2$ (diameter squared) $\times H$ or

33 $.7854 \times D^2 \times L$

34 (In the above equation, H means height and L means length)



35

36

37 **Example 3:** What is the volume of a cylinder that is 6 feet in
diameter and 20 feet high?

38

39 $.7854 \times 6^2 \times 20 =$

40 $.7854 \times 36 \times 20 = 565.488$ cubic feet (round to 565)

41 By multiplying 565 by 7.5 (gallons in a cubic foot) it can be
determined that there can be 4237.5 gallons of water in
this cylinder.

42 $565 \times 7.5 = 4237.5$ (round to 4238)

43

44

45 **Example 4:** How much water is in a length or section (50 feet)
of 3" hose?

46

47 $.7854 \times D^2 \times 50$

48 The diameter of the hose is in inches. As mentioned
earlier, inches and feet cannot be combined. You must
convert to either all inches or all feet. In this case, it is
best to convert the inches to feet. 3 inches is $\frac{1}{4}$ or 25%
of a foot. The formula then works out as:

49

50 $.7854 \times (.25)^2 \times 50 =$

51 $.7854 \times .0625 \times 50 = 2.45$

52

53 The 2.45 here is in cubic feet. Multiply is now by 7.5 to
find out how many gallons are contained.

54 $2.45 \times 7.5 = 18.3$

55 If the problem was done by converting to inches, the
formula would then a work out as follows:

56

57 $.7854 \times (3)^2 \times 600$ (50 feet = 600 inches)

58 $.7854 \times 9 \times 600 =$

59 $.7854 \times 5400 = 4241$

60

61 Since one gallon contains 231 cubic inches, divide 4241
by 231.

62

63 $4241 \div 231 = 18.3$

64 One length of 3" hose contains 18.3 gallons of water.

5.8 COMPUTING DISCHARGE

5.8.1 In this section, we are concerned with obtaining adequate flow for an effective fire stream. A thorough knowledge of basic hydraulic formulas will enable us to understand and visualize all factors concerned with fire stream development. On the fireground, determining the proper pump pressure is mandatory. An important step in reaching this objective is the ability to compute the amount of water that is being discharged through hose lines and nozzles.

5.8.2 Smooth bore nozzle discharge

5.8.2.1 Determining the flow from a smooth bore nozzle can be computed by using a formula for gallons per minute when the nozzle pressure is known. The formula is stated: $GPM = (29.7D^2) \sqrt{NP}$

66 29.7 is a mathematical constant derived from the natural law of physics for a round opening. To simplify calculations, the factor 30 should be substituted in place of 29.7.

NOTE: When utilizing the 15/16" smooth bore tip on 200' of 1 3/4" hose, your pump pressure should be 160 psi, which would give you 185 GPM at 50 psi nozzle pressure. These figures are easily obtained by using the GPM, Friction Loss, and Engine Pressure formulas found in this manual. This shortcut is a known pressure to be utilized with 200' of 1 3/4" hose.

68

69

Example 5: A 1 ¼" smooth bore tip at 80 psi will discharge how much?

70

71 **GPM = 30 (1.25²) √80 =**

72 **30 x 1.5625 x 9 = 421**

73 **Note that 1.5625 is rounded to 1.56 and 9 is actually the square root of 81. Rounded numbers are used simply because precisely correct hydraulic calculations on the fireground are not practical or necessary. The difficulty is applying the above formula on the fireground is self-evident. On the fireground the exact number of gallons per minute is not important. We are approximating the flow with rounded numbers. For use on the fireground, the following list of standard flow rates may be used.**

74

75 $1\frac{5}{16}"$ = 185 gpm @ 50 psi and 210 gpm @ 65 psi

76 1" = 200 gpm

77 $1\frac{1}{8}"$ = 250 gpm Hand lines @ 50 psi

78 $1\frac{1}{4}"$ = 325 gpm

79

80 $1\frac{1}{4}"$ = 400 gpm

81 $1\frac{3}{8}"$ = 500 gpm

82 $1\frac{1}{2}"$ = 600 gpm Master Streams @ 80 psi

83 $1\frac{3}{4}"$ = 800 gpm

84 2" = 1000 gpm

85

5.8.3 Fog nozzle discharge

5.8.3.1 The Akron Turbojet nozzle is a constant flow, adjustable gallonage nozzle. That is, it is designed to deliver a particular amount of water at a given nozzle pressure. It is also equipped with a selector ring that allows the operator to select the flow desired. The standard setting for the Akron Turbojet nozzle is 150 gpm. The Turbojet is the nozzle used by Fairfax County on the $1\frac{3}{4}$ pre-connected attack lines. These nozzles should be operated at 100 psi at the nozzle.

5.8.3.2 Arlington County and the Cities of Fairfax and Alexandria use the Elkhart Chief nozzle which is a low pressure, constant flow nozzle. Arlington County Fire Department uses a 150 GPM nozzle, Alexandria uses a 175 GPM nozzle, and the City of Fairfax uses a 200 GPM nozzle. All these nozzles are designed to operate at a nozzle pressure of 75 psi.

5.8.3.3 The Airport Authority Fire Department uses Task Force Automatic Nozzles.

86

5.8.3.4 The Elkhart “Chief” nozzle is a constant flow nozzle that is used as part of Fairfax County standpipe packs. This nozzle is designed to deliver 150, 175, or 200 gpm at a nozzle pressure of 75 psi. The specific nozzles and hose loads used by each department are found in section 4.12.

5.8.3.5 The fog nozzle available for use on 2 ½-inch lines is also typically a Turbojet. This nozzle should be set to deliver 250 gpm at a nozzle pressure of 100 psi.

5.9 FRICTION LOSS

5.9.1 Factors affecting friction loss in hose lines.

5.9.2 All things being equal, friction loss will vary directly with the length of hose. For example, if there is 20 pounds of friction loss in 100 feet of hose, there will be 40 pounds of loss in 200 feet of hose, provided the flow remains the same.

5.9.3 For the same size hose, the friction loss will increase exponentially as the quantity of the water flowing increases. What that means to the pump operator is simply that if the officer asks for an increase in the amount of water, you cannot assume the friction loss will increase by the same amount.

5.9.3.1 If the quantity of water flowing in a hose is doubled, the friction loss will be four times greater.

5.9.3.2 If the quantity in a hose is tripled, the friction loss will be 9 times greater.

87 Example: Assume a hose line is delivering 100 gpm through 200 feet of hose and the friction loss is 20 pounds. If the flow rate is increased to 200 gpm, the friction loss would increase to 80 psi.

5.9.4 For the same discharge, friction loss varies inversely as the fifth power of the diameter of the hose. This principle proves the advantage of using larger hose to reduce friction loss.

88

89 Example 6: One hose line 1" in diameter, flowing the same quantity as another hose line 3" in diameter. Friction loss in the 3" hose is:

90

91 $(\frac{1}{3})^5 =$

92 $\frac{1}{3} \times \frac{1}{3} \times \frac{1}{3} \times \frac{1}{3} \times \frac{1}{3} =$

93 $\frac{1}{243}^{\text{rd}}$ that of 1" hose.

5.9.5 At a given quantity of flow, friction loss (FL) is nearly independent of pressure. The velocity of water through a hose line, not pressure, causes friction loss.

5.9.6 Other factors affecting friction loss in hose lines include:

- Rough linings in the hose
- Sharp bends or kinks
- Improperly seated gaskets
- Appliances
- Partially closed valves

5.10 CALCULATING FRICTION LOSS IN HOSE LINES

5.10.1 Fireground activities often prohibit the use of complex formulas to calculate the exact pump pressure. Because of existing conditions and lack of available time, it is necessary to utilize condensed formulas and rules of thumb for determining friction loss calculations at the fire scene.

5.10.2 Friction loss coefficients for the hose sizes used in Northern Virginia are as follows:

95	1 3/4-inch hose	= 15.5
96	2-inch	= 8
97	2 1/2-inch	= 2
98	3-inch	= 1 (rounded up from .8)
99	3 1/2-inch	= 0.34
100	4-inch	= 0.2

101 **NOTE:** Some manufacturers of hose used in Northern Virginia have made claims that friction loss coefficients are different in their hose. Tests of hose that has been in service have shown that these claims have not always held true.

5.10.3 The standard formula for calculating friction loss is:

102 $FL = C \times Q^2 \text{ per } 100'$ where "C" = coefficient

103

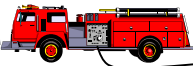
104

5.10.3.1 Friction loss in 1 3/4" hose

105 FL = $15.5 \times Q^2$ per 100 feet of hose (**Q = gpm ÷ 100**)

107

Example



106

200' 1 3/4"

100 GPM

108

109

110

FL = $15.5 \times Q^2$ per 100'

111 **= $15.5 \times (1 \times 1)$**

112

= 15.5×1

113

= 15.5×2 (200' feet of hose)

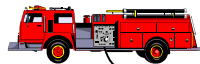
114

= 31 psi

115

116

Example 8:



200' 1 3/4"

150 GPM

117

118

119

FL = $15.5 \times Q^2$ per 100'

120 **= $15.5 \times (1.5 \times 1.5)$**

121

= 15.5×2.25

122

= 34.87

123

= 34.9×2 (200' of hose)

124

= 69.8 psi

125

This is rounded to 70 psi

126

5.10.3.2 Friction loss in 2 ½ " hose

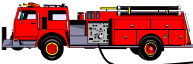
127

128 FL = $2Q^2$ per 100 feet of hose ($Q = \text{gpm} \div 100$)

129

130

Example:



200' 2 ½"

250

131

GPM

132

$$\text{F.L.} = 2Q^2 \text{ per } 100'$$

$$= 2 \times (2.5 \times 2.5)$$

$$= 2 \times 6.25$$

$$= 12.5 \times 2 \text{ (200' of hose)}$$

$$= 25 \text{ PSI}$$

5.10.3.3 Friction loss in 3" hose

133 FL = Q^2 per 100 feet of hose

134

135

Example 10:



400' 3"

300

136

GPM

137

138

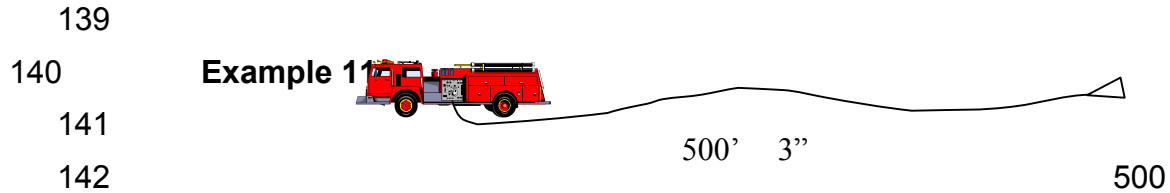
$$\text{F.L.} = Q^2 \text{ per } 100'$$

$$= 3^2 \text{ or } (3 \times 3)$$

$$= 9$$

$$= 9 \times 4 \text{ (400' of hose)}$$

$$= 36 \text{ PSI}$$



$$\begin{aligned} \text{F.L.} &= Q^2 \text{ per } 100' \\ &= 5^2 \text{ or } (5 \times 5) \\ &= 25 \times 5 \text{ (500' of hose)} \\ &= 125 \text{ PSI} \end{aligned}$$

145

146

147

5.11 Multiple supply lines

5.11.1 The friction loss in multiple supply lines is determined as follows:

5.11.2 When two lines are of equal size (diameter) and length, the procedure is to divide the total flow in half and figure the friction loss for one line. Pump both lines at that PDP.

5.11.3 When three lines of equal diameter and length, the procedure is to divide the total flow by three and figure the friction loss for one line. Pump all three lines at that PDP.

5.12 Friction loss in appliances

5.12.2 The appliance itself also causes additional resistance to the flow of water, which increases friction loss. Experience has shown that the following pressures will overcome friction loss in appliances:

- 5 psi loss – small appliances such as gated wyes and siameses. For flows greater than 350 gpm add 10 psi.
- 10 psi loss – ladder pipes
- 15 psi loss – deluge guns unless otherwise indicated

148

5.13 ELEVATION LOSS AND GAIN

5.13.2 When hose lines are laid to a location that is higher or lower than the pump, an additional factor must be considered. This factor is “back pressure” or “head pressure,” which is the amount of pressure that is exerted against the pump.

5.13.3 In the section on standards and measurements (5.5), we learned that a column of water one foot high and one inch square exerts a pressure of .434 psi at its base. Therefore, the same column of water at a height of 10 feet will exert a pressure of 4.34 psi. For our purposes in fireground operations, round off 4.34 to 5 psi for every 10 feet of elevation above or below the pumper. **When you are pumping downhill or to a location below the pump, subtract rather than add the 5 psi for every 10 feet of elevation.**

149

150 **Example 12: Pumping Downhill** supply
151 **engine**

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157 **Attack engine**

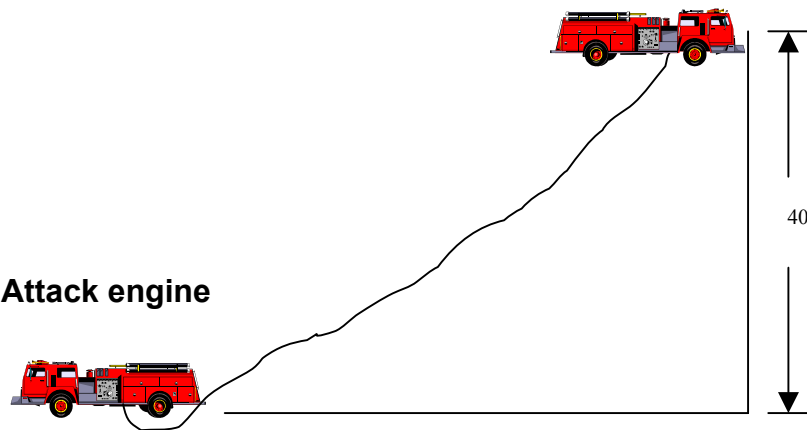
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40 ft. = 20 psi

160 **EL = SUBTRACT 20 psi.**



161

Example 13: PUMPING UP HILL

ATTACK PUMPER

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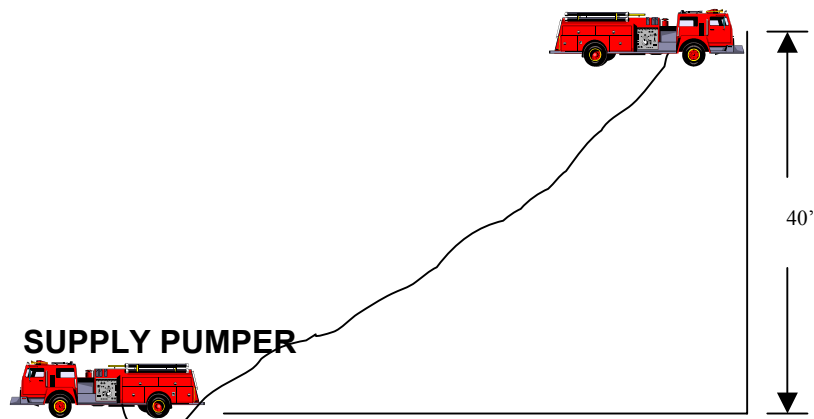
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40 ft. = 20 psi

171 EL = ADD 20 psi.

172

5.14 PUMP OPERATIONS

5.14.1 For our purposes, the function an engine performs on the fireground determines whether it is an attack engine or a supply engine.

5.14.2 Attack Engine

5.14.3 Pumping operations are concerned with 5 basic items in obtaining correct PDP.

- Nozzle pressure (NP)
- Friction loss in the hose (FL)
- Elevation loss or Gain (EL)
- Friction loss in appliances (AL)
- Maximum safe PDP 250 psi

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5.14.4 Basic Engine Operator's Formula

$$175 \quad \text{PDP} = \text{NP} + \text{FL} + \text{/- EL} + \text{AL}$$

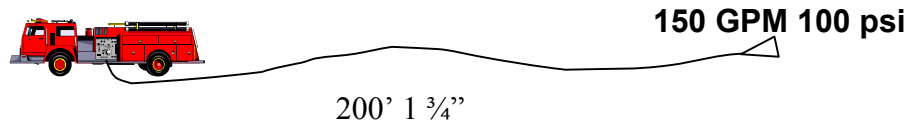
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Example 14:

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$$\text{PDP} = \text{NP} + \text{FL} + \text{/- EL} + \text{AL}$$

$$\text{FL} = 15.5 (Q)^2 \text{ per } 100'$$

$$= 15.5 \times (1.5 \times 1.5)$$

$$= 15.5 \times 2.25$$

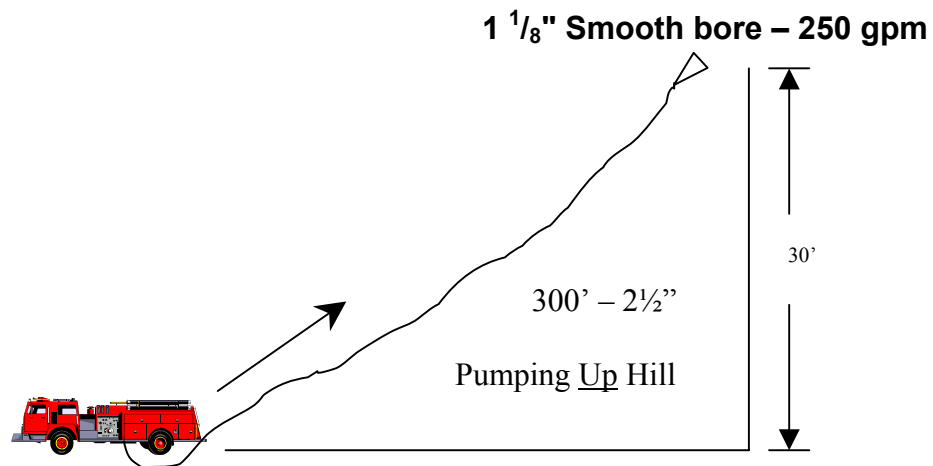
$$= 35 \times 2 (200')$$

$$\text{FL} = 70 \text{ psi}$$

$$180 \quad \text{PDP} = 100 + 70 + 0 + 0 = 170$$

181

Example 15:



$$\text{PDP} = \text{NP} + \text{FL} \pm \text{EL} + \text{AL}$$

$$\text{FL} = 2 (Q)^2 \text{ per } 100'$$

$$= 2 \times (2.5 \times 2.5)$$

$$= 2 \times 6.25$$

$$= 12.5 \times 3 \quad (300' \text{ of hose})$$

$$\text{FL} = 37.5$$

$$\text{PDP} = 50 + 37.5 + 15 + 0$$

$$= 102.5 \text{ psi} \quad (\text{Round to } 105 \text{ for pumping})$$

5.14.5 Supply Engine Operations

5.14.5.1 The 5 items that regulate the PDP that a supply engine should pump are:

- Residual pressure of no less than 20 psi is desired.
- Friction loss in hose lines between the attack and supply engines (FL)
- Elevation loss or gain (EL)
- Appliance loss (AL)
- Maximum safe PDP is 250 psi.

5.14.5.2 The basic pump operator's formula is slightly modified to reflect the fact that in this case there is no nozzle pressure to use, rather it is residual pressure. The formula, then, is:

205 $PDP = RP + FL \pm EL + AL$

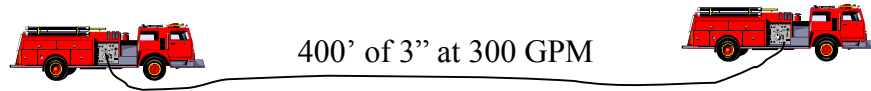
206 **Example 16:**

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$$PDP = RP + FL \pm EL + AL$$

$$= 20 + FL + 0 + 0$$

$$FL = Q^2 \text{ per } 100'$$

$$= (3)^2$$

$$= 9$$

$$= 9 \times 4 (400')$$

$$= 36 \text{ psi}$$

$$= 20 + 36$$

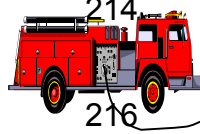
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$$= 56 \text{ psi PDP} \quad (\text{round to } 55 \text{ psi for pumping})$$

213

Example 17:

400' of 3" at 800 GPM
using two lines



Dual Lines, Equal Diameter

800 ÷ 2 = 400 GPM each line

$$\text{PDP} = \text{RP} + \text{FL} \pm \text{EL} + \text{AL}$$

FL = (Q)² per 100'

= 4 x 4

= 16 x 4 (400')

= 64 psi

$$= 20 + 64 + 0 + 0$$

217 = 84 psi (Round to 85 psi for pumping)

218

5.15 STANDARD OPERATING PRESSURES AND STARTING PRESSURES

5.15.1 Standpipe operations

5.15.1.1 **Standpipe operations involve an extra factor in addition to the ones previously studied, which is friction loss in the standpipe. In layouts involving hose lines and building systems, the PDP must be sufficient to:**

- **Overcome friction loss in the attack line**
- **Provide the proper nozzle pressure**
- **Overcome the elevation loss in the standpipe**
- **Overcome the friction loss in hose lines to the siamese**
- **Overcome the friction loss in the siamese, standpipe, and riser valve.**

5.15.1.2 In Fairfax County and the City of Fairfax:

- Start water into a standpipe system immediately upon arrival on the scene and without orders to 150 psi PDP. One line should be connected to the siamese and charged. Then every additional siamese shall be supplied.
- **Maximum PDP is 250 psi.**
- **Once water is flowing, refer to the High-Rise Standpipe Operations PDP chart in section. The pump operator can follow this chart and adequate volume and pressure will be delivered to the siamese outlets.**

5.15.1.3 The following chart is provided as a reference for engine operators for Fairfax County and Fairfax City pumping standpipe operations. Note that it is assumed that each hand line off of the standpipe connections is 200 feet long.

REQUIRED ENGINE PRESSURES FOR STANDPIPE OPERATIONS

100 feet of 2 ½ and 100 feet of 1 ¾ “ Hose			200 feet of 2 ½ “Hose	
FLOOR #	PSI		FLOOR #	PSI
1-5	160-170		1-5	100
6-10	200		6-10	125
11-15	225		11-15	150
16 & UP	250		16-20	175
			21-25	200
			26-30	225
			30 & UP	250

All pressures were calculated to the siamese.

NOTE: For fires above the 20th floor, pump at 250 psi and utilize the smooth bore nozzle.

5.15.1.4 In Alexandria:

- Start water into a standpipe system immediately upon arrival on the scene and without orders to 170 psi PDP. One line should be connected to the siamese and charged. Once the siamese is charged, calculate the elevation loss and add 5 psi for every floor above grade level. . Then every additional siamese shall be supplied.
- **The friction loss in the hoseline being used then needs to be added to this total.**

5.15.1.5 In Arlington:

- Start water into a standpipe system immediately upon arrival on the scene and without orders to 150 psi PDP. One line should be connected to the siamese and charged. Once the siamese is charged, calculate the elevation loss and add 5 psi for every floor above grade level. . Then every additional siamese shall be supplied.
- **The friction loss in the hoseline being used then needs to be added to this total.**

Example 18: Fire Reported on the 9th Floor

$$150 + 40 \text{ (8 floors above siamese x 5) = 190 PSI}$$

Pump Pressure

EXAMPLE 19: Fire Reported on the 15th Floor

$$150 + 70 \text{ (14 floors above the siamese x 5) = 220 Pump Pressure}$$

NOTE: For fires located above the 20th floor the ¹⁵/₁₆" smooth bore nozzle should be utilized to provide a sufficient fire stream at or near 185 GPM. This procedure will ensure proper NP for the various standpipe packs used.

5.15.1.6 If an inline gauge is available control of the outlet discharge pressure can be accurately controlled to match the configuration of the attack line.

5.15.2 Sprinkler systems

5.15.2.1 **Sprinkler systems present a complex array of considerations when attempting to determine the exact PDP. Due to the necessity of adequately supplying a sprinkler system early in a fire situation, a standard operating pressure has been assigned.**

5.15.2.2 **Standard starting PDP for sprinkler systems is 150 psi. This pressure is capable of providing adequate supply to the system without the danger of over pressurizing the system and causing damage to the piping.**

5.15.2.3 **Charge sprinkler systems when there is smoke or fire showing or upon confirmation of a working fire. As with a standpipe system, one line should be connected to the siamese and charged. All other siamese intakes must then be supplied.**

5.15.3 **Combination systems**

5.15.3.1 **Combination systems are those fire protection systems that use the same supply piping for both the standpipe and the sprinkler systems. These systems should be considered a standpipe and supplied and charged immediately upon arrival on the scene and without orders. Starting pressure for combination systems is also 150 psi. In Alexandria, the starting pressure is 170 psi.**

5.15.3.2 **In all cases, once the siamese is charged to the starting pressures, the procedures for supplying standpipes as described previously shall be followed.**

5.16 **Relay operations**

5.16.1 **Relays are defined as 2 or more engines that are in line between the water source and the nozzle. Attack engine and supply engine evolutions are the most commonly encountered relay operations. As previously stated, to calculate the proper PDP for the supply engine, there are 5 necessary factors to be considered:**

- **RP (minimum of 20 psi)**
- **FL**
- **EL**
- **AL**
- **Maximum PDP of 250 psi**

5.16.2 **This information is often unknown during the early stages of fireground operations. Due to the importance of getting water flowing early in such operations, a starting pressure has been established until proper operating pressures can be calculated. It is important, however, for the attack engine's operator to advise the supply engine of the amount of water being discharged. Equally important is for the supply engine's operator to know the length of the supply line(s) being pumped.**

5.16.3 **The starting PDP for a relay operation is 100 psi. The friction loss in 3" hose allows a wide margin of flow and hose length combinations and still is within the starting pressure limits. This does not eliminate the need for engine operator's to calculate PDP and adjust accordingly.**

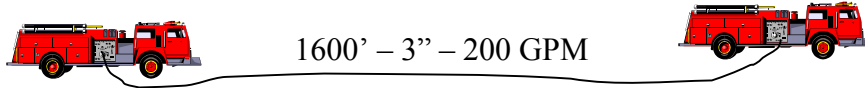
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Example 22:

221

222



$$EP = RP + FL \pm EL + AL$$

$$FL = (Q)^2 \text{ per } 100'$$

$$= (2)^2 \times 16 \quad (1600 \text{ feet of hose})$$

$$= 4 \times 16$$

$$= 64 \text{ psi}$$

$$PDP = 20 + 64 + 0 + 0$$

$$223 = 84 \text{ PSI} \quad (\text{Round to } 85 \text{ psi for pumping})$$

224

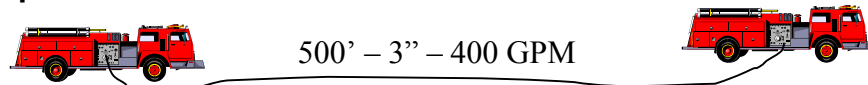
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Example 23:

226

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$$EP = RP + FL \pm EL + AL$$

$$FL = (Q)^2 \text{ per } 100'$$

$$= (4)^2 \times 5 \quad (500 \text{ feet of hose})$$

$$= 16 \times 5$$

$$= 80 \text{ psi}$$

$$PDP = 20 + 80 + 0 + 0$$

$$229 = 100 \text{ PSI}$$

230

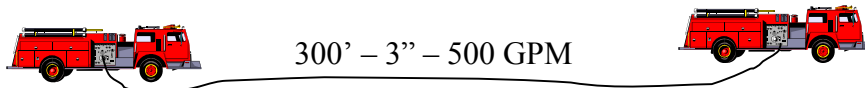
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Example 24:

233

234



$$EP = RP + FL \pm EL + AL$$

$$FL = (Q)^2 \text{ per } 100'$$

$$= (5)^2 \times 3$$

$$= 25 \times 3 \quad (300 \text{ feet of hose})$$

$$= 75 \text{ psi}$$

$$PDP = 20 + 75 + 0 + 0$$

$$= 95 \text{ psi}$$

5.17 ELEVATED MASTER STREAMS (Ladder pipes and tower ladders)

5.17.1 One of the most important uses of an aerial unit is to provide an elevated stream for fire attack and exposure protection. Elevated streams can be effectively directed into or onto the upper portions of tall buildings that are beyond the reach of ground mounted devices. These ground or apparatus mounted devices are usually only effective to about the third floor. Heavy streams from aerial devices (especially tower ladders) can also be very effective in controlling volume fires on the lower or ground floors.

5.17.2 When setting up aerial devices, consideration must be given to wind direction and exposure protection. Officers should anticipate the need for elevated master streams during escalating fires. Consideration should be given to initial truck placement for rescue, ventilation, access and the potential need to relocate for ladder pipe operations. If possible, spot the apparatus for current tactical assignments and future needs. Building collapse may be a possibility, so the truck and personnel should be placed outside the potential collapse zone.

- 5.17.3 Aerial units should be provided with their own supply engine with no more than 250 feet between the engine and the truck. If a hydrant is not available within that distance, another engine should be used to relay water to the unit supplying the aerial. When requesting a truck for master stream operations, consideration should be given to requesting an additional engine to be dedicated to the truck for water supply. At least two 3" supply lines should be used to supply the aerial device.
- 5.17.4 There are 5 factors that will determine the correct PDP when supplying a ladder pipe:
- NP
 - FL in hose between the siamese and the ladder pipe OR if you are supplying a pre-piped ladder pipe, do not calculate any friction loss.
 - FL in appliances (ladder pipe and the siamese)
 - EL (ladder height)
 - FL in hoses between the siamese the engine.
- 5.17.5 Clamp-on ladder pipes use 3 or 3 ½-inch hose. When supplying one of these appliances, use 150 psi PDP as a starting pressure and confer with the truck operator for more specific pumping information. If needed, the formula for calculating FL in 3 ½" hose is $\frac{1}{3}(Q^2)$ per 100 feet of hose. A constant that can be used is to figure 40 psi of FL in the 3 ½" hose when flowing 1000 gpm.
- 5.17.6 For fireground operations, use 150 psi as the starting pressure for supplying any ladder pipe or tower ladder. Once water has been started, the correct PDP should be calculated after conferring with the truck operator.
- 5.17.7 If the engine is supplying a tower ladder (TL), once the pressure calculations have been completed, the engine operator should confirm with the tower ladder operator that the bucket crew is receiving the necessary pressure. Tower ladders have a gauge at the nozzle in the platform. The driver of the TL should be positioned at the turntable. If at all possible, check with that member face to face. The TL crew can communicate over their intercom, keeping this communication off of the radio.

Example 25: You are supplying a ladder pipe that is using a 1 ½" tip and the ladder is raised 40 feet. There are two 3-inch lines between the engine and the siamese. The formula for this situation is:

$$\text{EP} = \text{NP} + \text{FL (3 ½ hose)} + \text{AL (siamese and ladder pipe)} + \text{EL} + \text{FL (dual 3" lines)}$$

$$\text{NP} = 80$$

$$\text{FL} = 12 \quad \left(\frac{1}{3} (Q^2) = \frac{1}{3} (6)^2 = 12\right)$$

$$\text{AL} = 15 \quad \begin{array}{l} 10 \text{ psi for the ladder pipe and } 5 \text{ psi for the} \\ \text{siamese} \end{array}$$

$$\text{EL} = 20$$

$$\text{FL} = 9 \text{ Split the flow and calculate for one line}$$

$$\text{EP} = 136 \quad (\text{Round to 135 psi for pumping})$$

5.17.8 **The tip sizes that are carried on ladder pipes and tower ladders include sizes 1 $\frac{3}{8}$ ", 1 $\frac{1}{2}$ ", 1 $\frac{3}{4}$ ", and 2". The fog nozzles have an operating range of 350 to 1500 gpm.**

5.17.9 **The following is a list of procedures that are common to all ladder pipe operations, regardless of the type of aerial device.**

- **The engine should be within 250 feet of the siamese for supply.**
- **Use a minimum of 2 supply lines for aerials, 3 for tower ladders.**
- **Charge lines slowly and gradually increase pressure.**
- **Charge lines on orders of the truck OIC.**
- **Shut down lines gradually, not abruptly.**

5.18 **PENETRATION AND EFFECTIVE STREAMS**

5.18.1 **Penetration refers to an effective hose stream reaching a predetermined and desired distance into a building. When using the term "effective fire stream" there are several "text book" definitions. However, an effective fire stream of water is defined as a stream of water that consists of the correct amount of water, in the proper configuration, with adequate reach that will safely extinguish the fire.**

5.18.2 **To find out the amount of penetration the stream is producing or to determine where you must place the nozzle for proper penetration, use the following quick method:**

- **Divide the horizontal distance between the nozzle and the building by the story into which the stream is to be directed. When the nozzle is elevated into an upper story by an aerial or tower ladder or other means, the story that is horizontally on a line with the nozzle shall be considered "ground level" and all calculations made from that point. Remember to count the ground floor as number one. This contradicts the procedures for standpipe pressure calculations and elevation loss calculations when pumping to handlines on floors above ground level. This is where most mistakes are made in this problem.**

5.18.3 **In order to achieve maximum penetration into a structure, the stream must enter a window or other opening at the lowest point in that opening at about a 30° angle.**

5.19 **CALCULATING ADDITIONAL WATER AVAILABLE FROM HYDRANTS**

- 5.19.1 The ability for the pump operator to calculate the available flow from a hydrant is an essential part of the overall role of the pump operator. Regardless of the size of the fire, pump operators should know the amount of water available from a particular hydrant when pumping during an incident. A minimum of 10 psi residual pressure should be maintained when pumping from a hydrant.
- 5.19.2 The following methods can be used to calculate additional water from a hydrant.
- 5.19.2.1 When a pumper is connected to a hydrant and not discharging water, the pressure on the intake gauge is the static pressure. This pressure reading alone tells nothing about the capacity of the hydrant! After the pumper begins discharging water, the intake gauge reading becomes the flow pressure. The difference between the static and flow pressure is known as residual pressure.
- 5.19.2.2 To determine how much water is available from a hydrant, the percent decrease in pressure must be calculated. This can be done by using the formula:

$$\% \text{ decrease in pressure} = \frac{(\text{static} - \text{flow}) \times 100}{\text{static}}$$

After determining the percent of decrease of pressure, apply the following table:

<u>% Decrease of pressure</u>	<u>Additional water available</u>
0 – 10%	3 times the original amount
11-15%	2 times
16-25%	1 time
> 25%	More water may be available but less than an equal amount of the original gpm.

Example 26: A pumper is supplying on line with 250 gpm. The static pressure was 80 psi and the flow pressure is 75 psi. How much more water can this hydrant deliver?

$$\begin{aligned}\% \text{ Decrease of pressure (psi)} &= \frac{(80 - 75) \times 100}{80} \\ &= \frac{5 \times 100}{80} \\ &= \frac{500}{80} \\ &= 6.25\%\end{aligned}$$

Since 6.25% falls between 0 and 10%, this hydrant can be expected to deliver at least 3 more time the original amount flowing. In this case, the original amount was 250 gpm. Therefore, the hydrant can be expected to flow an additional 750 gpm for a total of 1000 gpm.

5.20 NOZZLE REACTION

5.20.1 Nozzle reaction is based upon the principle: “For every action, there is an equal and opposite reaction.” As water leaves a nozzle under pressure, it causes a force in the opposite direction. The amount of this reaction depends upon the size of the nozzle tip and the pressure, and is due to acceleration of water in the nozzle. The maximum recommended nozzle reaction for a ladder pipe mounted on the fly section is 400 psi. In order to find out what this pressure is, the formula when utilizing a smooth bore tip is:

$$NR = 1.5 \times D^2 \times NP$$

NR means “nozzle reaction” measured in psi.

NOTE: It is recognized that pump operators are not likely to have the need to calculate nozzle reaction on the fireground. However, this information is provided in order for pump operators to have an understanding of nozzle reaction and to appreciate the forces developed by the flow of water. Pump operators must be cognizant of nozzle reaction, particularly when supplying heavy caliber streams and take extreme care to calculate PDP properly. Over pressurizing hand lines and master streams can lead to dangerous reaction pressures and injuries to firefighters.

Example 29: 1 ½" tip operating at 80 psi

$$NR = 1.5 \times (1.5^2) \times 80$$

$$= 1.5 \times 2.25 \times 80$$

$$= 270 \text{ psi.}$$

- 5.20.2 Nozzle reaction is less severe with fog nozzles because the water leaves the nozzle at an angle, which tends to cancel out some of the reactionary forces. The reaction will be greatest at the straight stream setting. The formula for nozzle reaction for fog nozzles is:

$$NR = .0505 \times Q \times \sqrt{NP}$$

Example 27: Fog nozzle flowing 750 gpm at 100 psi

$$NR = .0505 \times 750 \times \sqrt{100}$$

$$= .0505 \times 750 \times 10$$

$$= 378 \text{ psi}$$

- 5.20.3 An easy rule of thumb for estimating the nozzle reaction from a fog nozzle is to use $NR = \frac{1}{2} (\text{gpm})$. Using example 27, $\frac{1}{2}$ of 750 is 375.

APPENDIX A

JURISDICTIONAL HOSE LINE COMPLIMENTS

CITY OF ALEXANDRIA

- 235 Hose Line Options with Corresponding GPM Flows in **Alexandria**.
- 235.1 Elkhart “Chief” Low Pressure Fixed GPM Breakaway Nozzles are on all 1 ¾-inch hose lines.
- 235.2 1 ¾-inch pre-connected hose loads.
- 235.3 Front bumper has 100 foot of 1 ¾-inch.
- 235.4 All other pre-connected 1 ¾-inch lines are 200 foot.
- 235.5 The fog nozzle is 175 GPM @ 75 PSI nozzle pressure in the straight stream position. The engine officer has the option to have the nozzle pressure increased to 100 PSI to achieve 200 GPM. This nozzle allows the quick exchange to the 15/16-inch smooth bore tip providing a 185 GPM flow @ 50 PSI nozzle pressure. The engine officer has the option to have the nozzle pressure increased to 65 PSI to achieve 210 GPM. This size line would normally be appropriate for use in occupancies where the fire areas are separated by walls and hallways. The advancement of these hand lines will be room-to-room.
- 235.6 1 ¾-inch Standpipe Pack.
- 235.6.1 Standpipe packs consist of two bundles, each consisting of 100 feet of 1 ¾-inch hose.
- 235.6.1.1 The fog nozzle is 175 GPM @ 75 PSI nozzle pressure in the straight stream position. The engine officer has the option to have the nozzle pressure increased to 100 PSI to achieve 200 GPM.
- 235.6.1.2 This nozzle allows the quick exchange to the 15/16-inch smooth bore tip providing a 185 GPM flow @ 50 PSI nozzle pressure. The engine officer has the option to have the nozzle pressure increased to 65 PSI to achieve 210 GPM.
- 235.6.1.3 This size line would normally be appropriate for use in occupancies where the fire areas are separated by walls and hallways. The advancement of these hand lines will be room-to-room.
- 235.6.1.4 An accessory bag accompanies the standpipe pack that contains two spanner wrenches, standpipe wheel, 2 ½-inch to 1 ½-inch reducer, door chocks and vice grip pliers.
- 235.6.2 2 ½-inch Standpipe Pack.
- 235.6.2.1 Standpipe packs consist of two bundles each with 100 feet of 2 ½-inch hose.

235.6.2.2 The standard tip size is 1 1/8-inch, which delivers 265 GPM @ 50 PSI nozzle pressure.

235.6.2.3 The second tip size is 1 1/4-inch providing 325 GPM @ 50 PSI nozzle pressure.

235.6.2.4 Removing the 1 1/4-inch tip provides a standard 1 1/2-inch tip that allows the extension of a 1 3/4-inch line from the 2 1/2-inch breakaway nozzle. This adds flexibility and mobility after the larger volume of fire has been darkened.

235.6.2.5 This size line would normally be appropriate for use in occupancies with heavy fire conditions in large open spaces such as is found in warehouses, strip shopping centers, office high-rises, and other commercial establishments. If it is used as an interior line, adding a second engine company crew to assist with the deployment would be appropriate. Additionally, this line offers greater reach than the smaller hand lines.

235.6.3 Leader Line.

235.6.3.1 The leader line is 200 feet of 3-inch hose with a gated-wye. This allows for one or two 1 $\frac{3}{4}$ -inch line(s) to be added or one 2 $\frac{1}{2}$ -inch hose line for long hose lays.

235.6.4 Portable Master Stream Device.

235.6.4.1 These appliances shall be supplied with a minimum of two 3-inch lines.

235.6.4.2 Maximum flow of 1000 GPM should be no farther than 400 feet from the engine, 800 GPM not more than 600 feet away, and 600 GPM not more than 800 feet from the engine. The maximum effective reach will be approximately 100 feet from the appliance.

APPENDIX B

JURISDICTIONAL HOSE LINE COMPLIMENTS

ARLINGTON COUNTY

- 236 Hose Line Options with Corresponding GPM Flows in Arlington.
- 236.1 Elkhart "Chief" 4000 – 14 Low Pressure Fixed GPM Breakaway Nozzles are on all 1 ¾-inch hose lines including standpipe pack.
- 236.2 1 ¾-inch pre-connected hose loads.
 - 236.2.1 Front bumper has 150 feet of 1 ¾-inch.
 - 236.2.2 Cross lay pre-connect 1 ¾-inch lines are 200 and 300 feet.
 - 236.2.3 The fog nozzle is 150 GPM @ 75 PSI nozzle pressure in the straight stream position. This nozzle allows the quick exchange to the 15/16-inch smooth bore tip providing a 185 GPM flow @ 50 PSI nozzle pressure. The engine officer has the option to have the nozzle pressure increased to 65 PSI to achieve 210 GPM. This size line would normally be appropriate for use in occupancies where the fire areas are separated by walls and hallways. The advancement of these hand lines will be room-to-room.
- 236.3 1 ¾-inch Standpipe Pack.
 - 236.3.1 Packs consist of two bundles, each consisting of 100 feet of 1 ¾-inch hose.
 - 236.3.2 The standard nozzle tip is a 15/16-inch smooth bore tip providing a 185 GPM flow @ 50 PSI nozzle pressure. The engine officer has the option to have the nozzle pressure increased to 65 PSI to achieve 210 GPM. The alternate is to add a fog tip which will flow 150 GPM @ 75 PSI nozzle pressure in the straight stream position. The engine officer has the option to have the nozzle pressure increased to 100 PSI to achieve 175 GPM.
 - 236.3.3 This size line would normally be appropriate for use in occupancies where the fire areas are separated by walls and hallways. The advancement of these hand lines will be room-to-room.
 - 236.3.4 An accessory bag accompanies the standpipe pack that contains spanner wrenches, standpipe wheel, 2 ½-inch to 1 ½-inch reducer, pipe wrench and door chocks.
- 236.4 2 ½-inch Standpipe Pack.
 - 236.4.1 Pack consists of a bundle of 100 feet of 2 ½-inch hose. The 2 ½-inch pack has a Elkhart lightweight break apart nozzle with a 1 ¼-inch tip. Removing the 1 ¼-inch tip provides a standard 1 ½-inch tip that allows the extension of a 1 ¾-inch line from the 2 ½-inch breakaway nozzle.

- 236.4.2 This size line would normally be appropriate for use in occupancies with heavy fire conditions in large open spaces such as is found in warehouses, strip shopping centers, office high-rises, and other commercial establishments. If it is used as an interior line, adding a second engine company crew to assist with the deployment would be appropriate. Additionally, this line offers greater reach than the smaller hand lines. After a large volume of fire has been darkened down, a 1 $\frac{3}{4}$ " line can be extended from this line, adding flexibility and mobility for continued operations.
- 236.5 Leader Line.
- 236.5.1 The leader line is 300 feet of 3-inch hose with a gated-wye. This allows for one or two 1 $\frac{3}{4}$ -inch line(s) to be added or one 2 $\frac{1}{2}$ -inch hose line for long hose lays. This is not pre-connected.
- 236.6 Portable Master Stream Device.
- 236.6.1 These appliances shall be supplied with one 4-inch line or two 3-inch lines.
- 236.6.2 Maximum flow of 1250 GPM, The maximum effective stream reach will be approximately 100 feet from the appliance.

APPENDIX C

JURISDICTIONAL HOSE LINE COMPLIMENTS

CITY OF FAIRFAX

- 237 Hose Line Options with Corresponding GPM Flows in the **City of Fairfax**.
- 237.1 1 ¾-inch hose with Elkhart Chief 4000-24 Breakaway Nozzles.
- 237.1.1 Standard nozzle setting will be 175 GPM @ 75 PSI nozzle pressure in the straight stream position. The engine officer has the option of varying from these settings if the need arises. This size line would normally be appropriate for use in occupancies where the fire areas are separated by walls and hallways. The advancement of these hand lines will be room-to-room.
- 237.2 2 ½-inch Hose with the Stacked Tip Smooth Bore Nozzle.
- 237.2.1 The standard tip size is 1 inch, which delivers 210 GPM @ 50 PSI nozzle pressure.
- 237.2.2 The second tip size is 1 ⅛-inch providing 265 GPM @ 50 PSI nozzle pressure.
- 237.2.3 Removing the 1 ⅛-inch tip provides a standard 1 ¼-inch tip that allows the extension of a 1 ¾-inch line from the 2 ½-inch breakaway nozzles. This adds flexibility and mobility after the larger volume of fire has been darkened. This size line would normally be appropriate for use in occupancies with heavy fire conditions in large open spaces such as is found in warehouses, strip shopping centers, and other commercial establishments. If it is used as an interior line, adding a second engine company crew to assist with the deployment would be appropriate. Additionally, this line offers greater reach than the smaller hand lines.
- 237.3 Portable Master Stream Device.
- 237.3.1 These appliances shall be supplied with a minimum of two 3-inch lines.
- 237.3.2 Maximum flow of 1000 GPM should be no farther than 400 feet from the engine, 800 GPM not more than 600 feet away, and 600 GPM not more than 800 feet from the engine. The maximum effective reach will be approximately 100 feet from the appliance.
- 237.4 Standpipe Pack.
- 237.4.1 Standpipe packs consist of a bundle of 100 feet of 2 ½-inch hose and a separate bundle of 100 feet of 1 ¾-inch hose. The packs are equipped with a 1-inch smooth bore nozzle for 1 ¾-inch hose and a 1 ⅛-inch smooth bore for use on 2 ½-inch hose lines. The pack also has an

Elkhart “Chief 4000-24” low-pressure fog nozzle that is designed to deliver 200 GPM @ 75 PSI nozzle pressure.

- 237.4.2 The standpipe packs are designed for flexibility. One engine company can deploy a 200-foot line that consists of 100 feet of 2 ½ and 100 feet of 1 ¾-inch hose. Two engine crews can combine their packs in order to assemble and operate a 200 foot 2 ½-inch line or 200 foot 1 ¾-inch size line.
- 237.4.3 If 1 ¾-inch hose is being used with the 1-inch nozzle, the nozzle pressure can be increased to 65 PSI, which will deliver a flow of 210 GPM at the nozzle.
- 237.4.4 An accessory bag accompanies the standpipe pack that contains a pressure gage, spanner wrench, standpipe wheel, pipe wrench, and the 1-inch smooth bore nozzle.

APPENDIX D

JURISDICTIONAL HOSE LINE COMPLIMENTS

FAIRFAX COUNTY

- 238 Hose Line Options with Corresponding GPM Flows in **Fairfax County**.
- 238.1 1 ¾-inch hose with Akron Turbojet Adjustable-flow Breakaway Nozzles
- 238.1.1 Standard nozzle setting will be 150 GPM @ 100 PSI nozzle pressure in the straight stream position. The engine officer has the option of varying from these settings if the need arises. This nozzle allows the quick exchange to the 15/16-inch smooth bore tip providing a 185 GPM flow @ 50 PSI nozzle pressure. This size line would normally be appropriate for use in occupancies where the fire areas are separated by walls and hallways. The advancement of these hand lines will be room to room.
- 238.2 2 ½-inch Hose with the Stacked Tip Smooth Bore Nozzle.
- 238.2.1 The standard tip size is 1 1/8-inch, which delivers 265 GPM @ 50 PSI nozzle pressure.
- 238.2.2 The second tip size is 1 ¼-inch providing 325 GPM @ 50 PSI nozzle pressure.
- 238.2.3 Removing the 1 ¼-inch tip provides a standard 1 ½-inch tip that allows the extension of a 1 ¾-inch line from the 2 ½-inch breakaway nozzle. This adds flexibility and mobility after the larger volume of fire has been darkened. This size line would normally be appropriate for use in occupancies with heavy fire conditions in large open spaces such as is found in warehouses, strip shopping centers, and other commercial establishments. If it is used as an interior line, adding a second engine company crew to assist with the deployment would be appropriate. Additionally, this line offers greater reach and penetration than the smaller hand lines.
- 238.3 Portable Master Stream Device.
- 238.3.1 These appliances shall be supplied with a minimum of two 3-inch lines.
- 238.3.2 Maximum flow of 1000 GPM should be no farther than 400 feet from the engine, 800 GPM not more than 600 feet away, and 600 GPM not more than 800 feet from the engine. The maximum effective reach will be approximately 100 feet from the appliance.
- 238.4 Leader Line – 400 feet.
- 238.4.1 These lines shall contain 200 feet of 2 ½-inch hose gated down to 200 feet of 1 ¾-inch hose with the Turbojet nozzle. The standard flow will be 150 GPM. This allows an additional 200 feet of 1 ¾-inch line

flowing 150 GPM to be deployed from the gated wye. The total flow in this situation is 300 GPM. Two or three lengths of 1 ¾-inch hose should be carried to the wye and connected to act as the back-up line. This can be accomplished by a second engine company.

238.5 Standpipe Pack.

238.5.1 Standpipe packs consist of a bundle of 100 feet of 2 ½-inch hose and a separate bundle of 100 feet of 1 ¾-inch hose. The packs are equipped with a 15/16-inch smooth bore nozzle for 1 ¾-inch hose and an 1 1/8-inch smooth bore for use on 2 ½-inch hose lines. The pack also has an Elkhart “Chief” low-pressure fog nozzle that is designed to deliver 200 GPM @ 75 PSI nozzle pressure.

238.5.2 The standpipe packs are designed for flexibility. One engine company can deploy a 200-foot line that consists of 100 feet of 2 ½ and 100 feet of 1 ¾ hose. Two engine crews can combine their packs in order to assemble and operate a 200 foot 2 ½ line.

238.5.3 If 1 ¾-inch hose is being used with the 15/16-inch nozzle, the nozzle pressure can be increased to 65 PSI, which will deliver a flow of 210 GPM at the nozzle.

238.5.4 An accessory bag accompanies the standpipe pack that contains a pressure gage, spanner wrench, standpipe wheel, pipe wrench, and spare nozzle.

APPENDIX E

JURISDICTIONAL HOSE LINE COMPLIMENTS

METROPOLITAN WASHINGTON AIRPORTS AUTHORITY (MWAA)

- 239 Hose Line Options with Corresponding GPM Flows in MWAA.
- 239.1 334/373 Attack units.
 - 239.1.1 2 – TSFM Elkhart nozzles 95-200 GPM 150' 1 ½-inch on one 150' 1 ¾-inch on the other.
 - 239.1.2 Booster reel line SM 3FG 10-75 GPM.
- 239.2 338 Truck.
 - 239.2.1 2 200' pre-connected 1 ¾-inch cross lay hand lines with Task Force Tip 50-350 GPM combination or Foam Jet Nozzles 200 GPM nozzle.
 - 239.2.2 1 100' 1 ¾-inch attack line on running board with 200 GPM Elkhart nozzle.
 - 239.2.3 Pre-piped waterway on 75' ladder with Akromatic 1000 GPM style, 5058 combination nozzle. Also available are stacked smooth bore tips from 1 3/8-inch to 2 inches.
- 239.3 327 Reserve Engine.
 - 239.3.1 2 200' 1 ¾-inch pre-connected cross lays hose lines with Task Force Tip 50-350 GPM combination or Foam Jet Nozzles.
 - 239.3.2 200' 2 ½-inch pre-connected hose line with Akron solid bore 1-1 ¼" tips.
 - 239.3.3 400-foot leader line, 200' 2-inch, and 200' 1 3/4-inch hose with Task Force Tip 50-350 GPM combination or Foam Jet Nozzles.
 - 239.3.4 100' pre-connected front bumper line with Akron 1722 Turbo Jet 200 GPM nozzle.
- 239.4 Master stream devices.
 - 239.4.1 Akron Master Turbo Jet 750-1000 GPM with replacement stacked smooth bore tips from 1 3/8-inch to 2 inches.
- 239.5 Spare nozzles.
 - 239.5.1 Task Force Tip 50-350 GPM combination or Foam Jet Nozzles.
 - 239.5.2 TFTH
- 239.6 324 Rescue Engine.
 - 239.6.1 1 3/4-inch pre-connected front bumper line with Elkhart SM 20F 60-200 GPM nozzle.

- 239.6.2 2 200 foot 1 ¾-inch pre-connected cross lays with Task Force Tip 50-350 GPM combination nozzles.
- 239.6.3 400' 2-inch pre-connected hand line with Task Force Tip 50-350 GPM combination nozzle.
- 239.6.4 200' 2 ½-inch pre-connected attack line with Elkhart solid bore 1-1 ½-inch tips.
- 239.6.5 200' 2 ½-inch pre-connected attack line with Elkhart 125-250 GPM nozzle.
- 239.6.6 Booster reel line with Elkhart SM 3 FG 10-75 GPM nozzle.
- 239.7 Master stream devices.
- 239.7.1 Elkhart 8297 Stinger portable monitor with SM-100 300-1000 GPM combination nozzle and Elkhart model 8297 stacked smooth bore tips from 1=3/8 to 2 inches.
- 239.8 335 Rescue Engine.
- 239.8.1 1 ½-inch rubber pre-connected front bumper line with Akron 1722 Turbo Jet 200 GPM nozzle.
- 239.8.2 2 200 foot 1-¾-inch pre-connected cross lays with Task Force Tip 50-350 GPM combination or Foam Jet Nozzles.
- 239.9 Standpipe cart.
- 239.9.1 100', 1 ¾-inch hose 6' 3-inch hose with Elkhart TSFM 200 GPM breakaway nozzle.
- 239.9.2 Secondary deployment bag.
- 239.9.3 100', 1 ¾-inch hose
- 239.9.4 Spare Task Force Tip 350 GPM nozzle.
- 239.9.5 400', 1 ¾-inch pre-connected hand line with Task Force Tip 50-350 GPM combination nozzle.
- 239.10 200', 2 ½-inch pre-connected attack line.
- 239.10.1 Booster reel line with Elkhart SM 3 FG 10-75 GPM nozzle.
- 239.11 Master stream devices.
- 239.11.1 Elkhart 8297 Stinger portable monitor with SM-100 300-1000 GPM combination nozzle and Elkhart model 8297 stacked smooth bore tips from 1 3/8 to 2 inches.
- 239.12 ARFF Units.
- 239.12.1 DCA 331/337/345 all units standardized.
- 239.12.2 250', 1 ¾-inch pre-connected hand line with Task Force Tip 50-350 GPM combination or Foam Jet Nozzles.

- 239.12.3 150' Dry chemical attack line with Bar way 1-inch smooth bore nozzle.
- 239.12.4 150', 1 ¾-inch attack line with Task Force Tip 50-350 GPM combination or Foam Jet Nozzles.
- 239.12.5 6', 1 ½-inch piercing nozzle.
- 240 DULLES
- 240.1.1 326/358
- 240.1.2 100', 3", and 200', 1 ¾-inch Hand line Pre-connected with Task Force Tip 50-350 GPM combination or Foam Jet Nozzles.
- 240.1.3 150', 1 ¾-inch pre-connected hand line with Akron style 4720 95 GPM @ 100 PSI.
- 240.1.4 150', Dry chemical attack line with Bar way 1-inch smooth bore nozzle.
- 240.1.5 6', 1 ½-inch piercing nozzle.
- 240.2 328/336
- 240.2.1 100', 3-inch 200 foot 1 ¾-inch Hand line Pre-connected with Task Force Tip 50-350 GPM combination or Foam Jet Nozzles.
- 240.2.2 150', 1 ¾-inch pre-connected hand line with 150 foot Dry chemical attack line with Task Force Tip 50-350 GPM combination or Foam Jet Nozzles.
- 240.2.3 Bar way 1-inch smooth bore nozzle (Foam 336 only).
- 240.2.4 6', 1 ½-inch piercing nozzle.
- 240.3 High Rise packs.
- 240.3.1 200', of 1 ¾-inch hose plus a 10 foot section of 3-inch hose.
- 240.3.2 250', 1 ¾-inch hose with Task Force Tip 50-350 GPM combination or Foam Jet Nozzles.
- 240.4 Leader Line.
- 240.4.1 All rescue and reserve engines, the truck, the ARFF units and attack units have 3-inch supply lines capable of creating a leader line with the above attack lines, if not pre-connected.