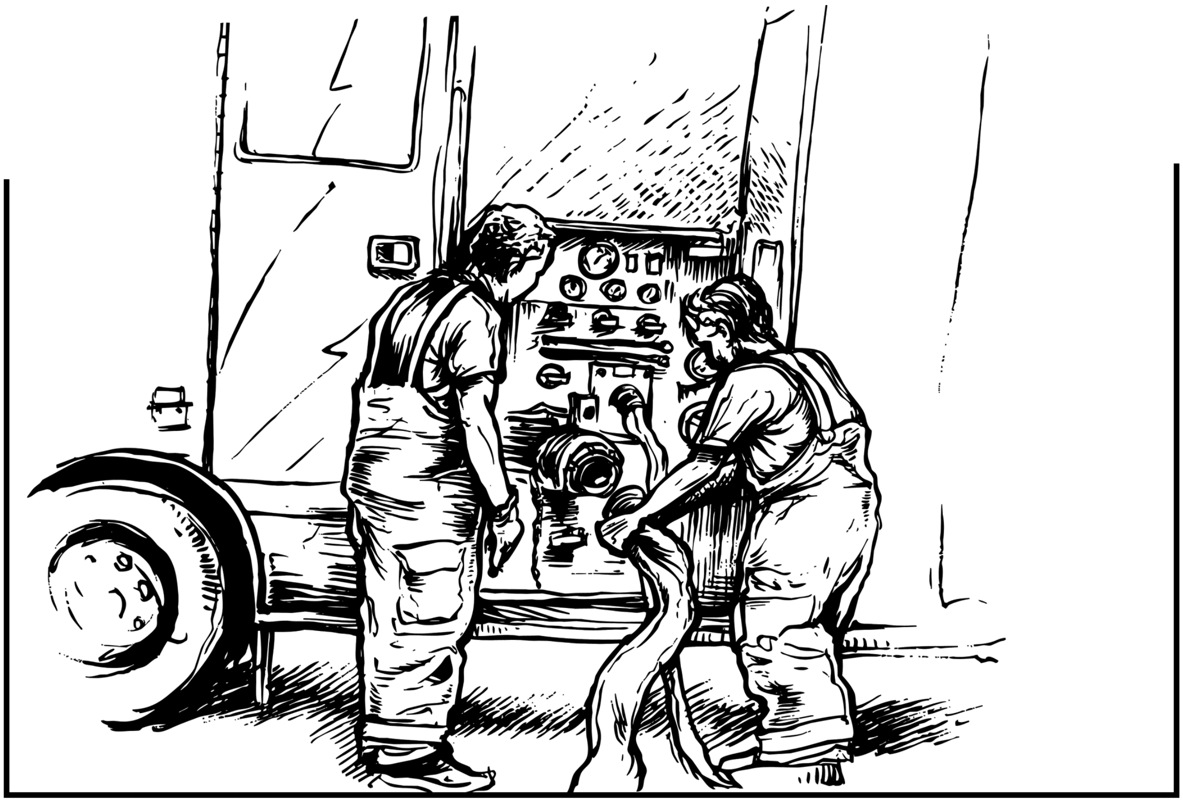
Apparatus Operator - Pump

Student Manual

Fire Suppression
01-05-0005 (Rev. 2019 1.1)



STATE OF NEW YORK
DIVISION OF HOMELAND SECURITY AND EMERGENCY SERVICES

Office of Fire Prevention and Control

Welcome to the New York State Fire Training Program

Apparatus Operator - Pump

The Department of State recognizes that providing training for paid and volunteer firefighters and related officials is an important part of the services it makes available. Our Office of Fire Prevention and Control (OFPC) places a very high priority on training because we believe it is essential for the men and women of the fire and emergency services in New York State.

The Office of Fire Prevention and Control's programs include the most complete progression of training available today -- beginning with probationary firefighters and extending the full length of a firefighter's career with the fire service. While our training programs address specific fire and arson prevention and control issues, we also encourage expansion and improvement of local training facilities and programs in cooperation with fire companies, municipal corporations and districts.

Apparatus Operator - Pump course provides information and skills essential to pump operation. Based on objectives from the National Fire Protection Association (NFPA), Fire Apparatus Driver/Operator standard, this course includes the topics of pump operator responsibilities, hydraulics and friction loss, pump controls and accessories, fire streams, pumper practices, pumping from draft and pressurized source evolutions, including using the fire pump at the hydrant. Demonstrations and practice sessions are included.

Your comments and suggestions about this student manual, our training classes or any OFPC program are always welcome. Your input will help us build on our successes and make needed changes, when appropriate.

On behalf of the citizens you serve, we want you to know that your participation and commitment are greatly appreciated.

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Training Policy-Firefighter Safety Training
Required by the Public Employees Safety and Health Act

Date of Issue: 07/01/03

An evaluation of the Office of Fire Prevention and Control's Outreach Training Programs was conducted by the New York State Department of Labor to determine what course components meet the initial fifteen hour and annual eight-hour safety training required for firefighters under the Public Employees Safety and Health Act. This listing provides the approved time for each subject area of the designated courses. Students completing the listed courses should receive credit as listed below:

Based on OSHA Safety Training Requirements
CFR 1910.156 & CFR 1910.134

COURSE #	COURSE TITLE	SUBJECT AREA	TIME
1F	Truck Company Operations	General Hazard Recognition	60 min.
		Fire Scene Safety	60 min.
		Tool and Equipment Safety	60 min.
		Total	180 min.
03	Fire Behavior and Arson Awareness	General Hazard Recognition	60 min.
06	Ladder Company Operations	General Hazard Recognition	30 min.
		Fire Scene Safety	30 min.
		Tool and Equipment Safety	30 min.
		Total	90 min.
23	Commanding the Initial Response	Fire Scene Safety	30 min.
1Y	Apparatus Operator – Emergency Vehicle Operation	Response Safety	60 min.
		Fire Scene Safety	30 min.
		Tool and Equipment Safety	60 min.
		Total	150 min.
27	Mask Confidence	SCBA	120 min.
		Recent Developments in Fire Safety	60 min.
		Total	180 min.
29	Incident Command System	General Hazard Recognition	30 min.
		Response Safety	15 min.
		Fire Scene Safety	45 min.
		Total	90 min.
35	Confined Space Awareness and Safety	General Hazard Recognition	15 min.
		Response Safety	15 min.
		Fire Scene Safety	45 min.
		Protective Clothing	30 min.
		SCBA	15 min.
		Total	120 min.

38	Water Supply Operations	General Hazard Recognition Response Safety Fire Scene Safety Protective Clothing Tool and Equipment Safety Total	15 min. 30 min. 45 min. 15 min. 30 min. 135 min.
45	Introduction to Fire Officer	General Hazard Recognition Fire Station Response Safety Fire Scene Safety Protective Clothing Total	30 min. 30 min. 30 min. 60 min. 30 min. 180 min.
47	Rescue Technician – Basic	General Hazard Recognition Fire Scene Safety Protective Clothing Tool and Equipment Safety Total	30 min. 30 min. 15 min. 60 min. 135 min.
78	Apparatus Operator – Pump	Response Safety Fire Scene Safety Tool and Equipment Safety Total	30 min. 30 min. 30 min. 90 min.
91	Basic Firefighter	Subject matter in Basic Firefighter exceeds both the fifteen-hour initial and the eight-hour refresher safety training requirements.	
92	Intermediate Firefighter	Subject matter in Intermediate Firefighter exceeds both the fifteen-hour initial and the eight-hour refresher safety training requirements.	
93	Advanced Firefighter	Subject matter in Advanced Firefighter exceeds the eight-hour refresher safety training requirements.	
80 81 82 83	Refresher Courses	To be determined at the local level after the content of the presentation has been evaluated.	

Table of Contents

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Apparatus Operator – Pump

Course Administration

Acknowledgements

The Office of Fire Prevention and Control wishes to thank all the contributors for their knowledge and dedication in the creation of Apparatus Operator - Pump. A very diverse group of highly qualified individuals from our Fire Service worked diligently on this project. Many of the current pump manufacturers and component designers and suppliers contributed to this new pump operator's course as well.

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Contributors

The following companies generously provided technical materials for use in this manual:

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Hale Products Inc., Conshohocken, PA
Waterous Company, South St. Paul, MN
Trident Emergency Products – Air Prime – Hatboro, PA
ISO Mitigation

The following individuals or companies provided photos and/or video clips used in this manual:

Jack L. Cottet, Dominic De Bellis, Mahlon Irish, Norman Jacobsen, John F. Kenealy, Michael Miles; FOAM PRO – HYPPRO LLC, New Brighton, MN; Hale Products Inc., Conshohocken, PA; Trident Emergency Products – Air Prime – Hatboro, PA; Waterous Company, South St. Paul, MN; Fort Drum Fire & Emergencies Services Department, Fort Drum, NY; Stratton Air National Guard Base Fire Department, Schenectady; NY; and Clayton Fire Department, Clayton, NY

Course Overview

Eight 3-hour sessions with knowledge and skills evaluations

Course Title	Apparatus Operator – Pump
Course Number	78
Course Hours	24
Course Units	8
Minimum # of Students	8
Maximum # of Students	16*

* No exceptions – To ensure student and instructor safety.

<u>Mandatory</u> Second Instructor authorized for Units 5, 6, 7, and 8

Six hours of administration time is authorized as follows:
Four hours to lead instructor
Two hours to second instructor

It is strongly recommend that both instructors meet and review the available equipment before the class begins

Course Prerequisites

All students must have completed SSO, Basic FF, or Essentials of Firefighting.

All students must have completed an authorized Emergency Vehicle Operators Course

- Course 1Y AO-EVO
- Course 26 NYS EVOC
- ESIP
- VFIS
- Utica National

Unit Topics

Unit 1	EVOC Review and Pumper Classification Introduction Lesson 1 – EVOC Review Lesson 2 – Fire Apparatus Classification and Typing
Unit 2	Components, Maintenance, and Inspections Lesson 1 – Pump Components Lesson 2 – Maintenance, Inspections, & Testing Lesson 3 – The Operational Inspection
Unit 3	Hydraulic Principles and Practices Lesson 1 – Hydraulics Lesson 2 – Pressure and Fire Pumps Lesson 3 – Math Skills Review Lesson 4 – Determining Fire Flow
Unit 4	Hydraulic Calculations and Exercises
Unit 5	Operating a Fire Pump
Unit 6	Operating Fire Pumps
Unit 7	Operating Fire Pumps
Unit 8	Evaluations and Testing

Effective training requires extensive hands on work with Engines. Spend all possible time on the practical applications.

Equipment Requirements

- Three Pumpers
  - Recommend that all pumpers be Service tested and pass NYS Heavy Truck Inspections
  - Drafting sources
- Static Sources
  - Portable pond, rivers, lakes, etc.
  - Hydrants*
- Assortment of LDH and appliances
- Master streams devices
- Hand lines and nozzles
- Calculator
- Turnout Gear

*In the event it is absolutely impossible to get to a hydrant, use a large distribution manifold or phantom pumper.

Course Schedule and Time Allotments

Unit	Time Allotted
Unit 1	
Introduction	½ hour
Lesson 1 – EVOC Review	1¼ hours
Lesson 2 – Fire Apparatus Classification and Typing	1¼ hours
Unit 2	
Lesson 1– Pump Components	1 hour
Lesson 2 – Maintenance, Inspections, and Testing	1 hour
Lesson 3 – The Operational Inspection	1 hour
Unit 3 – Hydraulic Principles and Practices	
Lesson 1 – Hydraulics	¾ hour
Lesson 2 – Pressure and Fire Pumps	¾ hour
Lesson 3 – Math Skills Review	¾ hour
Lesson 4 – Determining Fire Flow	¾ hour
Unit 4	
Hydraulic Calculations and Exercises	3 hours
Unit 5	
Operating a Fire Pump	3 hours
Unit 6	
Operating Fire Pumps	3 hours
Unit 7	
Operating Fire Pumps	3 hours
Unit 8	
Evaluation and Testing	3 hours

Foreword

This course is not a pump operator certification. It is designed to give the student the requisite knowledge and skills to meet the intent of the NFPA 1002 apparatus driver/operator professional qualifications standard. This course is only one part of the ongoing training that is needed for driver/operators to perform their responsibilities safely and effectively. Students who wish to become Pump Operators must meet the requirements of their specific apparatus manufacturer and their Fire Department's SOPs/SOGs. They must continue their training at the company level and improve their skills at the pump. Also, not to be forgotten is the act of driving the apparatus to the scene. Driver training should occur as a normal training exercise on a regular schedule.

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New York State
Office of Fire Prevention and Control

Apparatus Operator – Pump

UNIT 1 EVOC Review and Pumper/Engine Classification

Objectives

At the conclusion of this unit the student will:

- Understand the importance of safe and efficient response of fire apparatus
- Understand the state and federal laws and national standards pertaining to driving apparatus
- Recognize the high number of accidents involving fire apparatus and the associated deaths and injuries to firefighters and members of the public
- Know the types, conditions, and causes of fire apparatus accidents
- Describe the various types and classes of apparatus equipped with a fire pump
- Understand the ICS typing system for pumping apparatus

NOTE: For the purposes of this book the terms "engine" and "pumper" are interchangeable.

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Unit I

Introduction and Welcome

Prerequisites

- Emergency Vehicle Operators Course (EVOC)
  - Approved EVOC courses include the NYS Outreach Course (1Y), the VFIS Insurance course, and the ESIP Insurance course, or the Utica National Insurance course
- Scene Support Operations, Essentials of Firefighting, Basic Firefighter, or Firefighter 1

Registration

- Fill out registration cards
- Overview of the Office of Fire Prevention and Control

Course Overview

Eight 3-hour sessions with written and practical tests, covering the following topics:

- EVOC review, pumper classifications and typing
- Pump components and inspection
- Hydraulics and pump theory
- Hydraulic calculations and problems
- Operating fire pumps
- Practical exercises
- Review and evaluations

Equipment Requirements

One fully equipped engine for every five students. This includes a full assortment of hose, hose accessories, and appliances based on NFPA 1901—*Standard for Automotive Fire Apparatus*, Chapters 3 and 4. See Appendices A and B of this course for more information on this topic.

NOTE: Students will need a calculator for this course.

Expectations

What can I expect to get out of this course?

When you complete this course you will be capable of basic pumper operations.

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Introduction

Before any fire apparatus can be placed into service and operated at an emergency, it must respond to the incident, delivering its crew and equipment safely and efficiently. The driver/operator's major responsibilities are delivering the unit to the fire ground in a safe, timely manner, and operating the fire pump effectively. One of the primary goals of the driver/operator is to get the equipment to the fire. You cannot perform any fire ground activity if you do not get there.

Failure of a piece of apparatus to respond safely to an emergency can mean the difference between life and death, or whether property is saved or destroyed.

Consider what happens when the first-due pumper is involved in a motor vehicle accident. The fire department has to deal with the initial call, as well as a new call involving one of its own units. Suppose the initial alarm was for a house fire with people trapped. If the responding pumper runs a red light, strikes a car and rolls over, the engine crew would likely be trapped, as would be the occupants of the car. We now have a major motor vehicle incident to deal with in addition to the house fire. How many lives are impacted? How many lives may be lost due to our failure to respond safely?

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Not only do we have to deal with the human suffering caused by fire apparatus accidents, we also have to deal with the financial implications that may result from a failure to respond, or from damage to property and apparatus.

Municipalities, fire departments, fire officers, and apparatus drivers have been sued and/or charged criminally because of their failure to adhere to vehicle and traffic laws, federal guidelines, and standards. The following lessons are not a substitute for an approved emergency vehicle operator's course. One of the prerequisites for this class is the Apparatus Operator (AO) - Emergency Vehicle Operation course (EVOC) training.

Every driver/operator needs to know the various classes of apparatus equipped with a fire pump, and how these classes integrate into overall fire ground operations and strategies. When departments operate within the incident command system, the typing of apparatus is intended to assist the incident commander in calling the exact type of unit needed to handle the incident. All driver/operators need to be familiar with the current apparatus classification systems that are part of the Incident Command System (ICS). Apparatus typing and classification will be discussed in more detail later in this Unit.

NOTES

In 2003, the NFPA reported 105 firefighter fatalities in the U.S. Of the 105 deaths, 37 firefighters (35.2%) died while responding to or returning from alarms. This category of death accounted for the highest percentage of deaths by this duty type since the mid-1970s.[1]

Of these 37 firefighters, collisions or rollovers accounted for 24 of these fatalities. Eight individuals were not wearing seatbelts and at least 6 were speeding.[2] In the worst fatality report of that year (2003), eight Oregon firefighters returning from a wildland fire in Idaho were killed when their van was struck head-on by a tractor-trailer when their van crossed the center line of a highway to pass other vehicles. Alcohol may have been a factor in the crash; however, at the time of the report the driver's blood alcohol level had not been reliably assessed.[3]

The year 2004 yielded the second smallest number of deaths from crashes in the past decade, and almost half as many as in 2003—17 firefighters died. Unfortunately, the number of firefighters struck and killed by vehicles in 2004 was the highest since 1989, with eight being struck and killed. In addition, one firefighter fell from a pumper's jump seat and two fell from pickup trucks. Of the 17 firefighters killed in these crashes in 2003, 12 (about 70%) were responding to or returning from incidents when they died.[4]

In 2005, 26 of the 87 U.S. firefighters reported to have died in the line of duty died while responding to or returning from alarms.[1] Of these 26, 18 firefighters died in vehicle crashes; 10 of whom were killed during the crashes.[5] Vehicle crashes in 2005, either as part of an alarm response or other on-duty function involved tankers, pumpers, passenger vehicles, all-terrain vehicles (ATVs), aircraft, and a boat.[5,6]

Firefighters are being injured and killed in vehicle accidents each day. Why are these injuries and deaths happening? How can such tragedies be stopped? Each firefighter must be aware of this ongoing problem and make an effort to develop safe driving and safe riding habits – always wearing seatbelts and taking extra care to drive responsibly and sensibly. Our members are far too important to let even the slightest injury take place; we owe it to ourselves and to each other.

NOTES

References

[1]http://www.nfpa.org/itemDetail.asp?categoryID=955&itemID=23471&URL=Researcj%20&%20Reports/Fire%20statistics/&cookie%5Ftest=1. Firefighter Deaths By Duty Type. NFPA, Fire Incident Data Organization. Accessed online 1/30/2007.

[2]Vehicle crashes cause more firefighter deaths than fires, NFPA study finds. NFPA Press Release, June 9,004, http://www.nfpa.org/newsReleaseDetails.asp?categoryid=488&itemId=18797, accessed on line 1/30/07.

[3]USFA, Firefighter Fatalities in the United States - 2003, pp. 13.

[4]LeBlanc, P, and Fahy, R, NFPA, Firefighter Fatalities in the United States-2004, Fire Analysis and Research Division, NFPA, June 2005, pp. 6.

[5] LeBlanc, P, and Fahy, R, NFPA, Firefighter Fatalities in the United States-2005, Fire Analysis and Research Division, NFPA, June 2006, pp. 2, 6-8.

[6]USFA Releases 2005 Firefighter Fatality Statistics: News Release Date: January 10, 2006; http://www.usfa.fema.gov/about/media/2006releases/010906.shtm; accessed 02/24/06.

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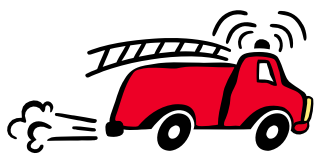
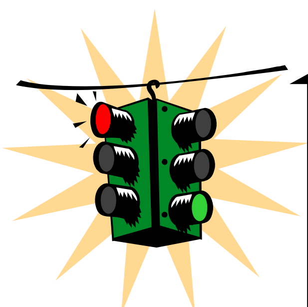
Unit 1

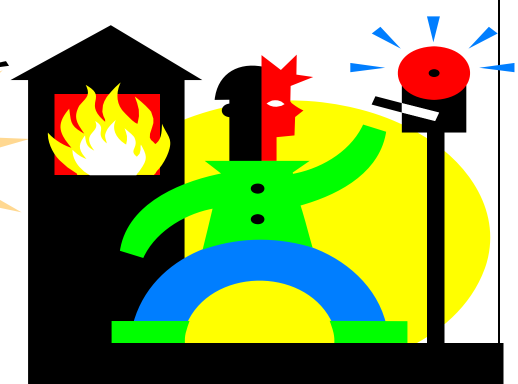
Lesson 1 – Apparatus Operator – Emergency Vehicle Operation (EVOC) Review



Common Causes of Fire Apparatus Accidents

Analysis of accidents involving fire apparatus identifies these as the most common causes:





- Excessive speed over the posted limit during good driving conditions or excessive speed for poor driving conditions
- Failure to stop at controlled or uncontrolled intersections
- Lack of driving skill and experience of the apparatus driver/operator
- Improper backing of fire apparatus
- Reckless driving by the public
- Poor apparatus design or maintenance

In most cases, the apparatus operator has control over each of these areas. This means that with proper training, practice, and supervision, most accidents can be eliminated.

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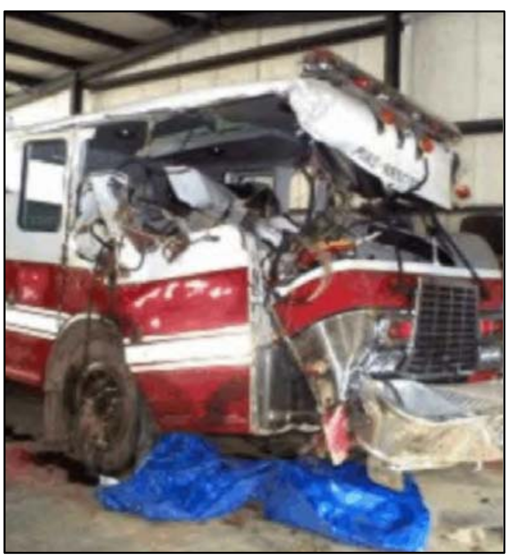
Question: What visible factors could contribute to an apparatus accident?

The driver lost control of the apparatus when the right-side wheels left the road, causing the apparatus to impact the tree shown.



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NIOSH Case Report No. F2004-43

September 23, 2005
A summary of a NIOSH fire fighter fatality investigation

One Part-time Fire Fighter Dies and Another Is Seriously Injured When Two Fire Engines Collide at an Intersection While Responding to a Fire - Illinois

On April 27, 2004 a 34-year-old male part-time fire fighter died after the engine in which he was riding (Unit 1) crashed into an engine from another department (Unit 2) as they passed through an intersection. Both engines/departments were responding to the same call for a structure fire. The force of the impact caused the front of Unit 1 to collapse inward and cause crushing injuries to the unrestrained driver whose legs were pinned between the seat and the dashboard. He was extricated and transported to the hospital for treatment. The rear passenger of Unit 1 received minor injuries and was transported to a local hospital where he was treated and released. The victim, who was riding unrestrained in the officer's seat, was ejected from the vehicle. He was transported to a local hospital where he was pronounced dead on arrival.

NIOSH investigators concluded that to minimize the risk of similar occurrences, fire departments should

- **provide training to driver/operators as often as necessary to meet the requirements of NFPA 1451, 1500, and 1002. This training should incorporate specifics on intersection practices.**
- **develop and enforce standard operating procedures (SOPs) for seat belt usage, intersection practices, and response to mutual/automatic aid incidents.**

INTRODUCTION

On April 27, 2004, a 34-year-old male, part-time fire fighter (the victim) died after being ejected from the engine in which he was riding (Unit 1) after crashing into an engine from another department (Unit 2). On May 3, 2004, the U.S. Fire Administration (USFA) notified the National Institute for Occupational Safety and Health (NIOSH) of this fatality. On September 26, 2004, NIOSH received a written request from a representative of the local International Association of Fire Fighters (IAFF) to investigate this incident. On November 30 and December 1, 2004, two safety and occupational health specialists from the NIOSH Fire Fighter Fatality Investigation and Prevention Program investigated the incident. The NIOSH team met with an attorney for the village where the incident occurred, the

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driver and the fire fighter riding in Unit 1 and their attorney, the Safety Officer for the victim's department who was standing in for the Chief, and the Chief and several fire fighter/union representatives of the career department involved in the incident (Unit 2). The three career fire fighters (Unit 2) declined interviews. The State Occupational Safety & Health Administration (OSHA) compliance officer who investigated this incident was contacted by phone and a copy of her report was reviewed. The detective of the police department that investigated the crash was contacted by phone, as was the Chief of the victim's department. NIOSH investigators reviewed the state police traffic collision report, training records for the victim and the driver, standard operating procedures (SOPs), photos, and the medical examiner and autopsy reports.

Department/Training: The victim's department has 30 uniformed personnel operating out of one station. It serves a population of approximately 5,000 covering about one square mile. Fire fighters are part-time, paid-on-premises, including responding to calls. The victim had been a part-time fire fighter with this department for almost 3 years. He was a full-time, career paramedic at another department. The victim had completed State fire fighter Level I and II, EMT, Paramedic, and HazMat training. The driver of Unit 1 had completed State fire fighter Level II, HazMat awareness, and HazMat first responder. In May 2003 the driver of Unit 1 received his certification for driving Class B, non-CDL vehicles. This certification required two weeks of classroom and practical training. Records obtained by NIOSH indicated that the department offered driver training in April and September 2003 and in March 2004. The records indicated that the driver of Unit 1 had not participated in these classes. The victim's department did not have a written training program at the time of the incident.

Standard Operating Procedures (SOP): At the time of the incident, the victim's department had an *Employee Handbook* containing departmental policies and procedures as well as requirements of employment and responsibilities of fire fighters. Included was a seat belt policy stating that all members must wear seat belts per state statute. The SOP concerning driver/engineer responsibilities stated that drivers are not allowed to move an apparatus until all persons on vehicle are seated and secured with seat belts. At the time of the incident, the victim's department did not have a procedure concerning mutual or automatic aid response, or for intersection practices.

Weather/road: The incident occurred at the intersection of two concrete roadways bordered on both sides by raised concrete curbs. The east-west roadway (R1) has two lanes; the north-south roadway (R2) has three northbound and three southbound lanes. (Diagram). R2 has dedicated left-turn-only lanes on both the north- and southbound sides. Traffic at the time of the crash was reported as being of medium density. The crash occurred during daylight hours; the weather was clear and the roads were dry.

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Traffic control: Traffic was controlled by multiple overhead and pole-mounted traffic control lights. The traffic control devices at the intersection are connected to an emergency traffic light control system. According to the police and the State Department of Labor (DOL) reports, shortly after the incident, the emergency traffic light system was checked on the scene by a technician and found to be functioning properly in all modes. The data log for the control device indicated that it had been activated at 1741 hours on the day of the crash. The log further indicated that the device had been activated in an east/west direction and that the traffic lights in that direction were green at the time of the crash.

Apparatus: Unit 1 was a 2001 engine/pumper with a 1000-gallon water tank and a gross vehicle weight rating of 45,000 lbs. Unit 2 was a 1999 engine equipped with an emitter that generates a signal to a sensor on the traffic light as the apparatus approaches. Unit 1 did not have such an emitter. Maintenance records indicated that Unit 1 had been serviced twice since the date of purchase: in July 2003, at 3606 miles, and in March 2004, at 7633 miles.

INVESTIGATION

On April 27, 2004, at approximately 1735 hours, a call came in for a garage fire in a local township. Three fire departments, including the two involved in the crash, responded via automatic-aid response. The victim and two fire fighters responded in Unit 1. Three career fire fighters from another department responded in Unit 2. According to the state police report, at approximately 1742 hours, Unit 2 was heading east on R1 when it entered the intersection where the crash occurred. Unit 2 had a sending unit for the emergency traffic light control system and the traffic light was green as it entered the intersection. As Unit 2 crossed the northbound lane of the intersection, it was struck by an engine from the victim's department (Unit 1) just behind the enclosed cab (Photo 1). *Note: No speed estimates were available.* Upon impact, the victim (who was unrestrained) was thrown forward striking his head on the interior of the cab. Unit 1 then rotated clockwise approximately 180 degrees and rolled onto its left side. According to the police report, during this rotation, the victim was ejected through the windshield and landed on the northeast side of the intersection. As the front of the cab of Unit 1 collapsed inward (Photo 2), the legs of the driver (who was also unrestrained) were pinned between the seat and the dashboard causing crushing injuries. The driver of Unit 1 had to be extricated and hospitalized. The rear passenger of Unit 1, who was restrained, received minor injuries. He was taken to a local hospital where he was treated and released. After being struck, Unit 2 rotated clockwise about 320 degrees before coming to rest on the east side of the intersection facing northeast. The three fire fighters in Unit 2, who were wearing restraints at the time of the incident, had minor injuries. They immediately exited their apparatus to help the fire fighters in Unit 1. Later they were

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taken to a hospital where they were treated and released. The victim was transported to a local hospital where he was pronounced dead on arrival.

CAUSE OF DEATH

The county medical examiner listed the cause of death as craniocerebral injuries with aspiration of blood within the lungs.

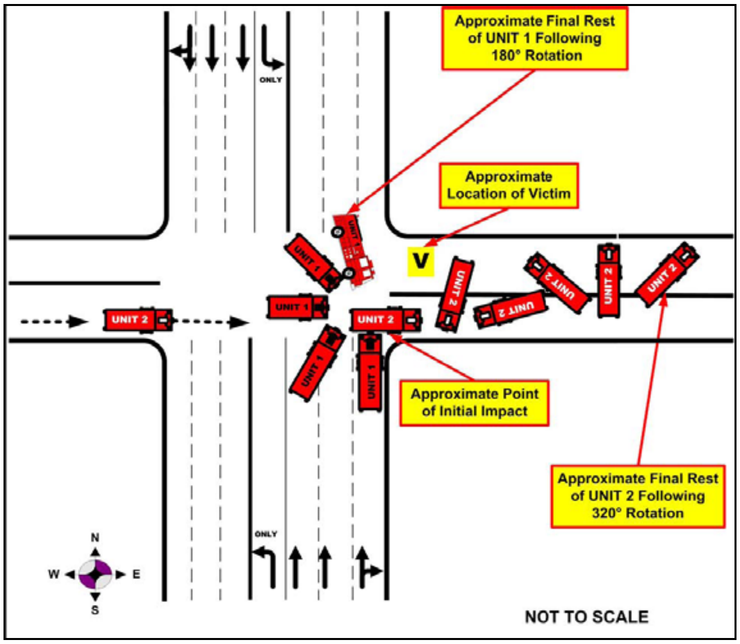

Diagram. Aerial view of intersection where crash occurred

Photo 1. View of Unit 2 which was struck on the passenger side

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Photo 2. Crushed front end of Unit 1

Use this case history as a serious discussion point for stopping at intersections; viewing **each lane** as a separate intersection.

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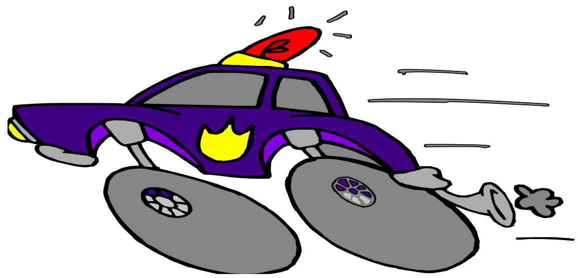
SPEED



How fast is too fast? How much time will really be saved by driving 45 mph, rather than 30 mph? Generally, apparatus should never exceed the posted speed limit. If a time difference was calculated for an emergency response of 5 miles, the difference between 55 and 65 miles per hour amounts to less than 1 minute. How far are your average response distances? Does weaving through heavy traffic with a 20-ton apparatus with lights flashing and siren blowing, on the way to a car fire, make sense? What would a judge and jury think if this engine ran a stop sign or red light and struck a car broadside?

Speed coupled with rain-slick or snow and ice-covered roads adds a new dimension to speed management for a safe response. An inexperienced driver, a column of smoke rising in the distance, and the radio blaring "Hurry up, we need that truck now," are ingredients of a recipe for disaster. Driver/operators must drive within their abilities, their vehicle's capabilities, and their department's Standard Operating Guidelines (SOGs). Outside influences **must not** affect or interfere with the safe operation of the apparatus. Every department should establish SOGs for apparatus response for all driver/operators.

INTERSECTIONS

According to the VFIS, fire apparatus accidents at intersections account for about one quarter of the accidents; of these, about 45% are severe.[1] The vast majority of accidents could be avoided if apparatus driver/operators and officers followed the NFPA 1500 guidelines when approaching intersections. We will discuss these standards and other guidelines and regulations that govern response in detail later.

A typical intersection is shown above.
VFIS, Emergency Vehicle Driver Training Program, 2000 Edition

NOTES

LACK OF SKILL/EXPERIENCE

The lack of skill and experience has become one of the most crucial aspects of firefighter safety. This cause of apparatus accidents can be lessened in a number of ways. First and most important is the driver/operator selection process. Every department should have criteria for the selection of drivers. These criteria should include physical fitness, vision and hearing requirements, mathematical and writing skills, as well as a basic mechanical aptitude. According to NFPA 1002, every department shall have a thorough training program for prospective driver/operators, along with continuous in-service driver training and evaluation.

BACKING ACCIDENTS

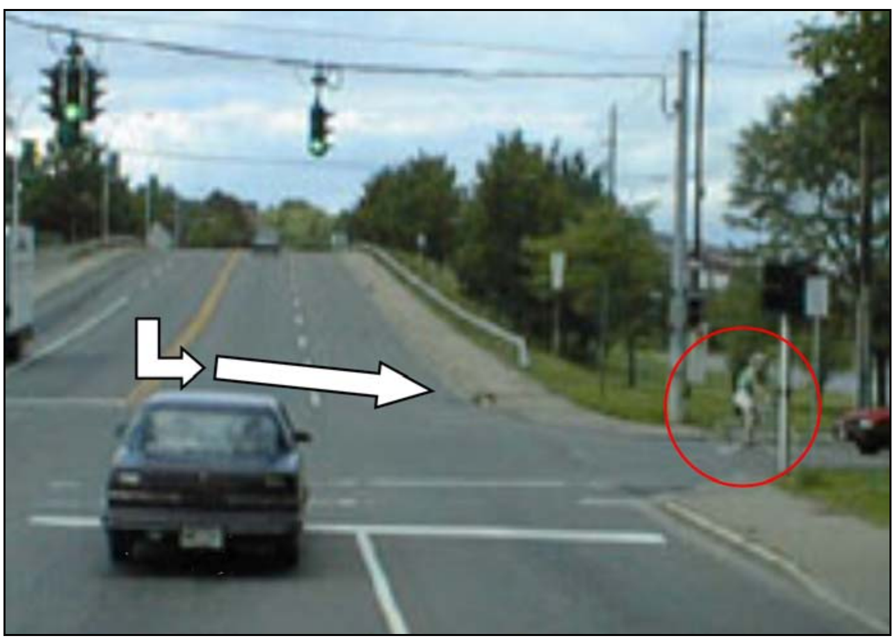
Backing accidents should never occur. All departments having a written policy stating that a spotter will be present at the left rear of the vehicle any time a vehicle is backed up, can eliminate almost all of these occurrences. The spotter can look for any fixed hazards, other vehicles, people, and can immediately alert the operator to their presence.

NOTES

OTHER DRIVERS

As any experienced fire apparatus driver/operator will tell you, "You never know what the other driver is going to do." Defensive driving habits must be coupled with good situational awareness to reduce accidents.

Despite good visibility, unexpected actions of others can occur, as shown below:



NOTES

POOR DESIGN

All new fire apparatus today have to meet standards for design criteria. Problems can develop when departments design and build their own units from a used cab and chassis, old fuel or milk tank, and other spare parts. While we can all appreciate the need to save money, thought must be given to what we are putting on the streets and to the lives that could be affected by using poorly designed apparatus.

SUMMARY

Firefighter injuries or deaths from vehicle related incidents that occurred while responding to or returning from fires are too high: 35% of duty-related deaths in 2003, 34% in 2004, and 30% in 2005[1]. It is obvious that more emphasis must be placed on driving our apparatus safely and maintaining it properly.

[1]http://www.nfpa.org/itemDetail.asp?categoryID=955&itemID=23471&URL=Researcj%20&%20Reports/Fire%20statistics/&cookie%5Ftest=1. Firefighter Deaths By Duty Type. NFPA, Fire Incident Data Organization. Accessed online 1/30/2007.

NOTES

LEGAL RAMIFICATIONS

As society continues to demand accountability, firefighters, fire officers, and governments are being charged civilly as well as criminally because of their actions, or lack of proper action. No longer are the driver/operators of an emergency vehicle or officers of a department exempt from either criminal or civil suits. If the fire apparatus driver/operator is found guilty of improper operation, or inadequate training, he/she, the officers, and city or town officials can be held accountable. There are a variety of local, state, and national regulations and laws that affect fire apparatus driver/operator training and operations. These are generally classified into five categories:

- State motor vehicle and traffic laws
- Nationally accepted standards
- State and federal occupational safety and health regulations
- Local ordinances
- Organizational SOGs

There are three principles of law that apply to fire apparatus driver/operators:

- Drivers are subject to all traffic laws unless a specific exemption is provided
- Exemptions only apply when the vehicle is responding to a true emergency
- Drivers can be found criminally and/or civilly liable if involved in an accident, even if they are operating under the provisions of an exemption

NOTES

LEGAL DEFINITIONS

Federal Department of Transportation (DOT) definitions -

True Emergency - is defined as a situation in which there is a high probability of death or serious injury to an individual(s) or significant property loss, and actions by the emergency vehicle driver may reduce the seriousness of the situation.

Due Regard - for the safety of others means that a reasonably careful person performing similar duties and under similar circumstances would act in the same manner.

Negligence - is a legal deficiency or wrong, which results whenever a person fails to exercise that degree of care, which a prudent person would exercise under similar circumstances. The negligence may be slight, ordinary, or gross.

Gross Negligence - is reckless disregard for the consequences of an act to another person. It occurs when a person's actions (or lack thereof) result in the failure to exercise even a slight degree of care.

NOTES

APPLICABLE STANDARDS

There are a number of standards that apply to driver/operators:

NFPA 1002—Fire Department Vehicle Driver/Operator Professional Qualifications

NFPA 1500—Firefighter Occupational and Safety Standard

One of the most important standards that has been used in legal trials of apparatus driver/operators is the NFPA standard that states:

During emergency response, drivers of fire department vehicles shall bring the vehicle to a complete STOP for any of the following:

- When directed by a law enforcement officer
- Red traffic lights
- Stop signs
- Negative right of way intersections
- Blind intersections
- When a driver cannot account for all lanes of traffic in an intersection
- When other intersection hazards are present
- When encountering a stopped school bus with flashing warning lights

This 2002 NFPA 1500 standard can be found at section 6.2.8.

NOTES

All fire service organizations should review and incorporate all pertinent portions of each standard into any driver training programs and SOGs.

Additional sections of the NFPA 1500 standard clearly state how emergency vehicle operators should proceed through intersections. These are sections 6.2.8, 6.2.9 and 6.2.10. It is important to understand that the NFPA standard *differs* from the New York State Vehicle and Traffic Law in that the NFPA standard requires operators to **stop** at specific types of intersections (as noted on the previous page) they intend to cross while operating in emergency mode. This is a critical difference that must not be overlooked during vehicle operations.

NOTES

APPLICABLE NEW YORK STATE LAWS

New York State Vehicle and Traffic Law - applies to any municipal fire department apparatus, and contains a section regarding private vehicles.

All fire service organizations should review and incorporate all pertinent portions of these laws into any driver training programs and SOGs.

§1104. Authorized Emergency Vehicles.

(a) The driver of an authorized emergency vehicle, when involved in an emergency operation may exercise the privileges set forth in this section, but subject to the conditions herein stated.

(b) The driver of an authorized emergency vehicle may

1) Stop, stand or park irrespective of the provisions of this title;
2) Proceed past a steady red signal, a flashing red signal or a stop sign, but only after slowing down as may be necessary for safe operation;
3) Exceed the maximum speed limits so long as he does not endanger life or property;
4) Disregard regulations governing directions of movement or turning in specified directions.

(c) Except for an authorized emergency vehicle operated as a police vehicle, the exemptions herein granted to an authorized emergency vehicle shall apply only when audible signals are sounded from any said vehicle while in motion by bell, horn, siren, electronic device or exhaust whistle as may be reasonably necessary, and when the vehicle is equipped with at least one lighted lamp so that from any direction, under normal atmospheric conditions from a distance of five hundred feet from such vehicle, at least one red light will be displayed and visible.

NOTES

(d) The foregoing provisions shall not relieve the driver of an authorized emergency vehicle from the duty to drive with due regard for the safety of all persons, nor shall such provision protect the driver from the consequences of his reckless disregard for the safety of others.

It is critical to keep in mind that there are many standards that apply to apparatus response that should be included in a departments SOGs. If a firefighter is involved in a criminal or civil action, usually the court will judge the actions of the driver/operatotr on three main points:

Was the unit responding to a True Emergency?

Did the driver/operator exercise due regard for the safety of others?

Did the driver/operator violate any local or state laws or recognized standards?

NOTES

EMERGENCY RESPONSE SUMMARY

If an emergency vehicle driver/operator is to understand the intricacies of driving under emergency conditions, and have a successful and safe career, he/she must know what qualifications and certifications he/she must have to properly operate his/her unit. Proper department guidelines, training, record keeping, and maintenance programs must be in place to support the driver/operator.

All fire service organizations should have a comprehensive selection and training program for all driver/operators. The department should have SOGs that cover all types of responses and include all applicable local, state, and federal laws, and nationally accepted standards. It is recommended that all driver/operators successfully complete a certified emergency vehicle operator training course before they are assigned as driver/operators.

Historically, far fewer injuries occur if seatbelts are worn during a vehicle crash.

All firefighters must buckle-up.

NOTES

UNIT 1

Lesson 2 – Fire Apparatus Classification and Typing

Generally, fire apparatus are classified by function. We will discuss fire apparatus that are equipped with a fire pump. There are many different types of apparatus equipped with a fire pump such as aerial ladders, specialized rescue units, and other similar units; however, our focus will be on apparatus whose primary function is to provide water for fire suppression purposes. These units will be referred to as an engine or pumper, the common terms used in New York State.

FIRE DEPARTMENT PUMPERS

The NFPA Standard 1901, *Standard For Automotive Fire Apparatus*, contains the requirements for pumper design. Pumpers, sometimes called engines, wagons, or triples depending on jurisdiction, have one primary mission—to produce an adequate gallons per minute flow through fire streams for fire suppression. Water supplied by an engine may come from a number of different sources, including the unit's tank, fire hydrants, or static water supplies such as lakes, ponds, or streams. Water may also come from another engine through a relay evolution.

The NFPA standard states that the minimum pump capacity for pumper fire apparatus shall be 750 gallons per minute (gpm). Pumps delivering a minimum of 750 gpm are rated at 1,000, 1,250, 1,500, 1,750, 2,000, 2,250, 2,500, or 3,000 gpm. Larger pump capacities can be found in industrial settings, but generally, fire department pumps rarely exceed 2,250 gpm.

Fire pumps are rated at draft, thru 20 feet of appropriate size hard suction hose and strainer, at a 10-foot lift height. This applies to fire pumps up to and including 1,500 gpm pumps.

For 1,750 gpm pumps, the required lift height drops to 8 feet, and requires the use of double suction hose, each with appropriate strainers. This means that two lengths of suction hose (of any size up to 6-inch or greater) are to be attached to separate pump intakes. This same information applies to 2,000 gpm pumps or larger, except that the lift height drops to 6 feet.

NOTES

A fire department engine must be equipped with pump controls, gauges, intakes, discharges, and other instruments and devices to allow the driver/operator to properly operate and monitor the system. The unit must also be equipped with various sizes of hose for intake, supply, and attack. Fire department engines also carry a wide variety of portable equipment in addition to the equipment needed to produce fire streams or to handle water supply operations. The standard equipment that must be carried is listed in NFPA 1901, and an equipment list is provided in Appendix A. Most fire departments will also carry additional equipment to meet their operational needs. Generally, the following equipment can be found on most fire department engines:

- Ground ladders
- SCBA
- General hand tools
- Appliances, adapters
- Portable extinguishers

NOTES

RESCUE PUMPERS

As the role of the fire service continues to change and departments adapt to new response needs, many agencies have adapted their apparatus to function in areas other than fire suppression. Many departments are combining engine and rescue company functions into single units with multiple missions. It is common to see units listed as rescue pumpers, paramedic pumpers, and foam or special pumpers, depending on the specialized equipment carried. The most common type of unit being built today is the rescue pumper. In most cases, these units carry all the standard pumper equipment, as well as extrication equipment, cribbing, ropes, and other tools to deal with motor vehicle accidents and specialized rescues. These units almost always have more storage space than standard pumpers. Depending on the nature of the call, the crew can function as a fire suppression unit, rescue unit, or both.

NOTES

FOAM-EQUIPPED PUMPERS

Many departments commonly have pumpers capable of discharging foam on class A or class B fires. Many jurisdictions have large quantities of flammable and combustible liquids produced, stored, or transported in their response area. These departments will always have engines with some type of foam system, whether built-in or portable.

Pumpers may be equipped with around-the-pump, direct injection, or balanced pressure foam proportioning systems. Some apparatus are set up with fixed class A and or class B systems. Class A foam would generally be used for structure, brush, or vehicle fires. Foam systems can be high energy Compressed Air Foam Systems (CAFS), or low energy, low and medium expansion foam tubes or fog/combination nozzle delivery systems. Regardless of the type used, only a limited number of discharges on the pumper are capable of flowing foam. Units with high-energy systems require a sizable air compressor. Most units with foam systems will have foam concentrate tanks to supply the system. The most common tank sizes range from 20 to 100 gallons.

Digital control panel for an onboard foam proportioning system is shown below.

NOTES

PUMPERS WITH ELEVATED STREAMS

Pumpers with elevated master stream capabilities fill a role between pumper and aerial device. These units use telescoping or articulating booms with large capacity nozzles to deliver up 1,000 gpm. They range from 50 to 75 feet in length, and some may be equipped with an escape ladder. These units will be covered in detail in the Apparatus Operator – Aerial Device course. Many departments that do not need full aerial ladder capability opt for pumpers with these devices. This allows them to flow large quantities of water to upper floors of structures, without the cost of large-scale aerial units.

NOTES

MINI-MIDI PUMPERS

Many fire departments use mini or midi pumpers for initial attack in their daily operations. Generally, trucks of this type are scaled down versions of full-size pumpers.

Mini pumpers are small, quick attack units designed to handle small fires that do not require the high volumes of water that a standard-sized pumper can deliver. Many are four-wheel-drive–equipped and maneuverable. Most of the mini pumpers produced today are manufactured on 1- to 1 ½-ton chassis with custom bodies. Pump capacities range from 250 gpm to 1,000 gpm. The equipment carried on these units usually is the same as a regular size pumper, although in smaller amounts. Some mini pumpers carry extrication, medical, and other special equipment. Mini pumpers are also used by many rural departments for off-road use and for water supply from static sources that a large unit could not reach due to terrain, ground conditions, or snow.

Midi pumpers are used in the same manner as mini pumpers and can have the ability to start an initial attack on larger fires. Due to their larger size, they can carry almost as much general equipment as a regular pumper. The general differences between a midi and mini pumper are larger chassis, tank and pump size, and amount of equipment carried. Some departments use a midi pumper in conjunction with a Type 1 pumper. This is usually called the midi-maxi concept. Other departments use a mini and maxi in their response operations. Both the mini and midi pumper concepts have their place in the fire service.

NOTES

TANKERS/TENDERS

Known as mobile water supply apparatus, tanker/tenders are used to carry water to areas without a municipal water system, or to areas that lack natural water sources, such as ponds, streams, rivers, and lakes. Tankers carry a much larger amount of water than the normal engine. The size of the water tank on the unit varies. Factors affecting tanker size include terrain, bridge weight limits, size, and cost. Variations in tanker design and configuration result in these units carrying 1,000 to 6,500 gallons or more of water.

Tankers may be equipped with a small PTO-driven pump, a portable pump, or a larger pump. Units equipped with an NFPA-rated fire pump are called pumper tankers. Mobile water supply apparatus are used to support units that are attacking the fire. There are two methods of employing tanker/tenders.

One method is for the tanker/tender to act as a nurse unit. The unit is parked near the scene, and its water is taken directly from its tank by the attack pumpers.

Another method is for the tanker to be involved in a water supply shuttle operation. In this type of operation, the unit dumps its load into a portable water tank, or other tanker (nurse tanker) at the scene, and then goes to a water source for another load of water. The use of portable tanks is a highly effective method for providing a continuous supply of water when using tankers/tenders.

These methods are discussed further in NYS Water Supply Operations course.

NOTES

BRUSH FIRE/WILDLAND UNITS

This classification of apparatus can vary from small slide-on units to large all-wheel drive machines with large pumps and tanks. Sometimes these units are called urban/wildland interface pumpers, but whatever terminology is used, these machines are specifically designed to fight ground cover fires. These pumpers are usually small, light weight, highly maneuverable trucks that are most always four-wheel or all-wheel drive.

Most brushfire/wildland units have the ability to pump and roll. Vehicles with pump and roll features have either a separate engine to power the fire pump, or a power take-off mounted to the transmission for pump power. Many different arrangements are used for discharging water from the fire pump. Some apparatus have short sections of attack line from the pump, which allow the firefighters to walk along side the unit as it drives through the fire area. Other units have fixed or remotely controlled nozzles on the front or side of the apparatus, which allows the driver/operator to attack the fire. In recent years, some departments are equipping these units with small class A foam systems. Class A foam has proven to be highly effective in attacking wildfires and protecting exposures. More information on units of this type can be found in NFPA Standard 1906.

NOTES

AIRCRAFT RESCUE & FIREFIGHTING APPARATUS (ARFF)

The main focus of these apparatus is to apply quick knock-down and suppression of flammable liquid fires, and suppression of spill vapors. Many times these units are called off airport property to assist at large flammable liquid incidents. There are three classifications for ARFF apparatus; major firefighting vehicles, rapid intervention vehicles, and combined agent vehicles. These units usually carry a large quantity of water and specialized extinguishing agents, have large turret pipes, and have all-wheel drive capabilities. The major firefighting units usually have a separate engine for the fire pump, and most have pump and roll capabilities.

NOTES

FIRE BOATS

Fire boats can range from a small, lightweight boat with a portable pump, to vessels that can deliver over 26,000 gpm. Most fire boats use master stream devices to fight fires on ships, piers, or structures on or near the waterfront. In some cases, these units have served as a water supply unit for land-based apparatus.

NOTES

TYPING OF PUMPING APPARATUS

Many departments operate within the NIMS Incident Command System, (ICS), which is a method used to classify fire department pumpers by their pump capacity. By using apparatus typing, incident commanders will be able to call the exact type of units they will need to handle incidents. Many cities, towns, or counties have their own method of typing and identifying pumpers and other apparatus. Driver/operators must be familiar with the type of system used in their jurisdiction or surrounding areas. Following is the Federal Emergency Management Agency (FEMA) typing system for Tanker/Tenders and Pumpers.

Student Exercise: Using the worksheet provided in Appendix C, each student shall identify the type of each apparatus currently in use in their respective fire departments.

Appendix D contains the National Wildland Coordinating Group (NWCG) apparatus typing information for reference.

U.S. Department of Homeland Security
Federal Emergency Management Agency

Resource: Water Tender, Firefighting (Tanker)

Category: Firefighting (ESF #4)
Kind: Equipment

Minimum Capabilities (Component)	Minimum Capabilities (Metric)	Type I	Type II	Type III	Type IV	Other
Tank		2,000 gallon	1,000 gallon	1,000 gallon		
Pump		300 GPM	120 GPM	50 GPM		

Resource: Engine, Fire (Pumper)								
Category: Firefighting (ESF #4) **Kind: Equipment**								
Minimum Capabilities (Component)	**Minimum Capabilities (Metric)**	**Type I**	**Type II**	**Type III**	**Type IV**	**Type V**	**Type VI**	**Type VII**
Pump Capacity		1,000 GPM	500 GPM	120 GPM	70 GPM	50 GPM	50 GPM	50 GPM
Tank Capacity		400 Gallon	400 Gallon	500 Gallon	750 Gallon	500 Gallon	200 Gallon	125 Gallon
Hose, 2.5 inch		1,200 Feet	1,000 Feet					
Hose, 1.5 inch		400 Feet	500 Feet	1,000 Feet	300 Feet	300 Feet	300 Feet	200 Feet
Hose, 1 inch		200 Feet	300 Feet	800 Feet	300 Feet	300 Feet	300 Feet	200 Feet
Personnel		4	3	3	2	2	2	2

Comment:

The engine typing needs to be taken out to Type VII. Compromise between FIRESCOPE and NWCG is to use NWCG Standards for Engines and Crews. NWCG has seven engine types.

FIRESCOPE is the California version of the NWCG.

NOTES

Specialty Vehicles – New York State (only)

The following specialized vehicles are unique to New York State and as of this writing are classified according to the following criteria. These criteria may not necessarily match the Federal guidelines shown above, but should approximate the apparatus type.

Storm Emergency Fire Unit (SEFU)

This type of unit is used for most storm related activities. The Regional Fire Administrator should have this unit already designated within the county for faster deployment.

2 to 3 Firefighters
4-wheel drive vehicle (Fire Department owned)
Portable pump, suction with strainer
200-ft discharge hose with fittings
Portable generator with adapters and lights
Chain saw and shovels
Fuel for above
Carbon monoxide detector (recommended)

Emergency De-Watering Unit (EDU)

2 to 3 Firefighters
4-wheel drive vehicle (Fire Department owned)
Portable pump with adaptors
Hard suction with strainers
200-ft discharge hose
Portable lighting for night operations
Fuel for above

4-WD Brush Truck

4-wheel drive brush truck
Minimum of two (2) personnel
250 gpm pump with 200-gallon water supply

NOTES

Summary

We have discussed the classification of fire apparatus according to function. In addition, we have presented the various apparatus with fire pumps, including rescue pumpers, foam-equipped pumpers, pumpers with elevated streams, mini/midi pumpers, tanker/tenders, brush fire/wildland units, ARFF, and fire boats. The use of the evolving apparatus typing systems aids in efficient deployment and more defined operations. Given the growing awareness for apparatus typing, blank worksheets are provided in the Appendix for students to use in typing their department's different response vehicles.

Instructor Note:

New York State uses the NIMS when classifying the types of emergency vehicles. However, Type 1 pumpers are broken down into other more specialized units as follows:

Type 1 Pumpers –

a) Rescue pumpers, with 4 interior-qualified firefights.

b) Two-man cabs with pumping equipment.

c) Four-man or six-man cabs with a fire pump.

NOTES

UNIT 2

Lesson 1 – Pump Components

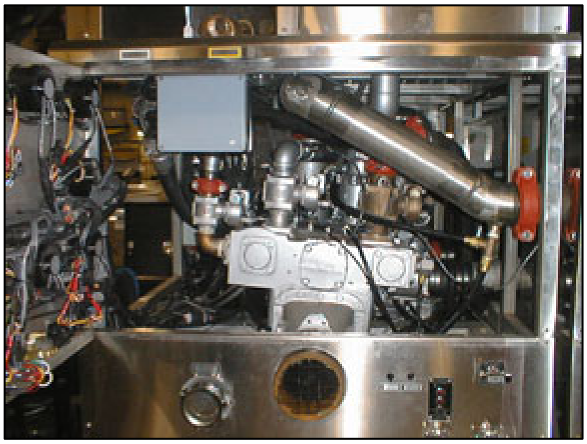
Objectives

At the conclusion of this unit, the student will:

- Identify pump type, mounting, and components
- Identify and operate priming devices
- Identify and operate pressure relief devices
- Identify and operate intake/discharge valves
- Identify and use engine and pump gauges
- Operate auxiliary engine and pump cooling systems
- Define apparatus maintenance and repair programs and understand the differences between them
- Perform and document vehicle inspections
- Perform a vacuum (dry prime) test

Unit 2

Lesson 1: Pump Components



The basic concept of pump operation is to get water into the pump, get water out of the pump, and deliver it at the correct pressures and flows. To do this we need to understand how the pump operates.

Over the past several years many innovations have been developed to aid in pump operation. However, the basic principles of pump operations are still the same. For specific information regarding components on your apparatus consult your operations manual or contact your local representative or manufacturer.

PUMP TYPES

Centrifugal and positive displacement pumps are the two pump types we will talk about.

Positive Displacement Pumps

There are two types of positive displacement pumps in use today. They are the piston pumps, not commonly used in the fire service, and rotary gear pumps. Positive displacement pumps deliver a definite volume of water or air. They are self-priming and will exhaust the air from the pump system and deliver water. The unique feature of these pumps is that they do not need a separate priming device.

We will discuss three types of positive displacement pumps. They are the piston pump, rotary gear, and the rotary vane.

Piston pumps were found in operations utilizing high pressures, like booster lines. They are self-priming.

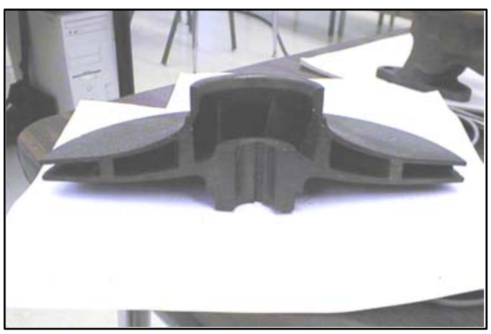
Rotary gear pumps operate by trapping water or air in cavities between the two turning gears and then moving the material to the discharge side of the pump. This style pump is self-priming and was widely used as a priming pump for the larger centrifugal pumps.

Rotary vane pumps work on the same principle of trapping a material and forcing it out the discharge side. A vane pump uses a round housing and an offset camshaft with moveable vanes in it. As the shaft turns, the vanes ride along the housing removing the air each time the vane passes the input side of the pump. As the vanes rotate, the volume of the cavity decreases and the air is expelled. This style pump is self-priming and is used as a priming pump for fire service centrifugal pumps.

Centrifugal Pumps

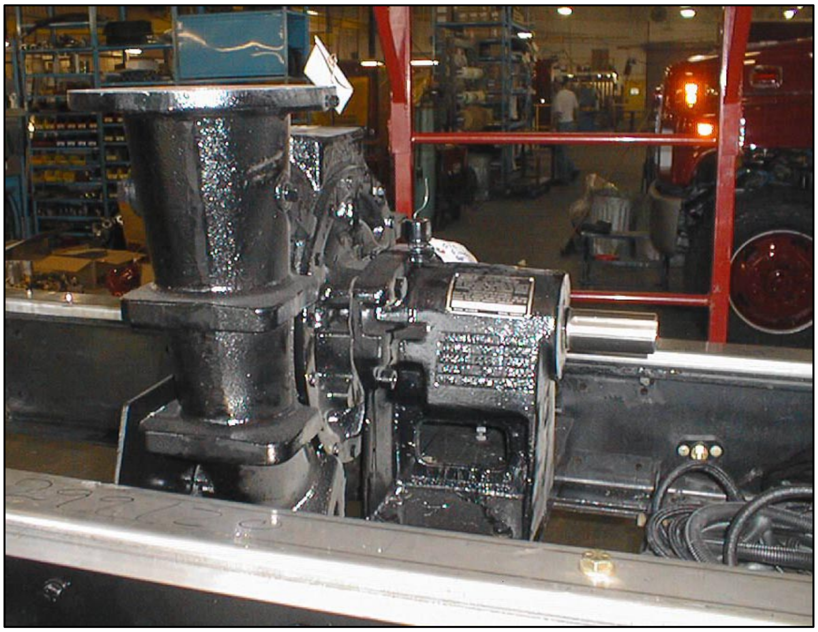
Centrifugal fire pumps are not self-priming nor will they deliver a set amount of water with every revolution of the pump. A priming pump is used to remove the air from the centrifugal pump to allow the atmospheric pressure to push water into the pump housing.

The Centrifugal Pump is the most commonly used fire pump today. Pump size is commonly 750gpm to 3,000gpm. It is not unusual to see some applications that will use pumps that are much larger.



NOTES

The centrifugal pump works by drawing water in through the eye of the impeller and throwing it out through the impeller into the volute or the ballooned section the pump housing that goes around the outside rim of the pump housing. As the turning speed or velocity of the impeller increases the volume and pressure increase as more water is forced from the impeller.



Shown above is a 3,500 gpm rear-mount pump.

We will discuss two types of centrifugal pumps. They are the single-stage pump and the two or multi-stage pump. The most popular pump used today is the single stage pump. In some older fire trucks, it was common to see three- and four-stage pumps.

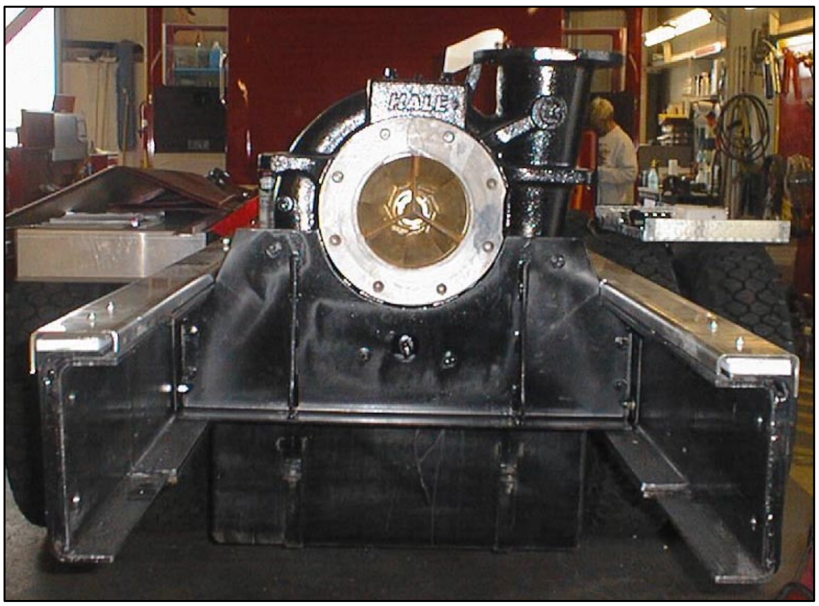
The single-stage pump develops pressure and volume using one impeller. It is a simple well-designed system.

NOTES

Two-stage pumps have two impellers on one shaft and a double-sided housing. When high pressure or low volume of water is needed, the series setting of the pump is used. This means the transfer valve is set so that the water is routed from one side to the other, in series, for higher pressures. If a higher volume is needed, the transfer valve is set so that water is routed through both impellers at the same time so that more water is pumped at a lower pressure. Multi-stage pumps work using the same principles.

What type pumps do you have at your own department?

What size are they?



See figure below to follow the actions of a two-stage pump

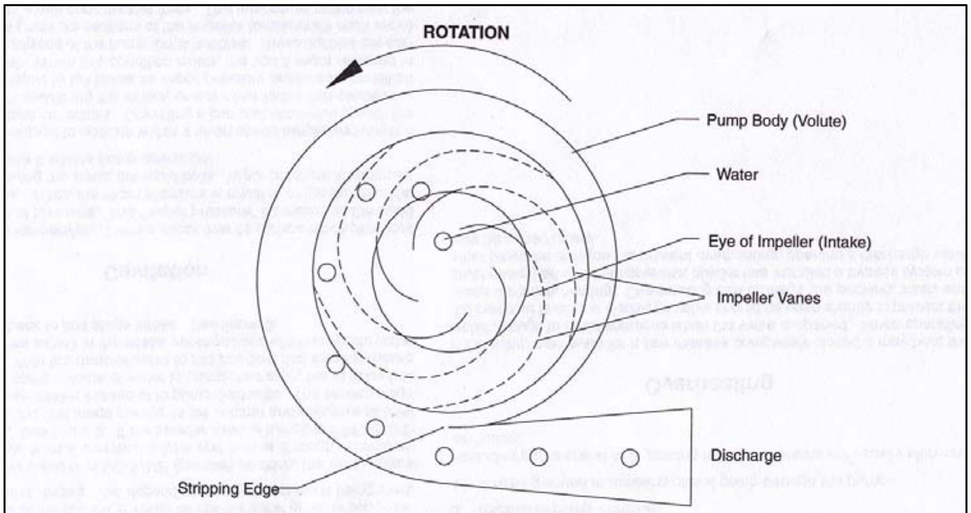
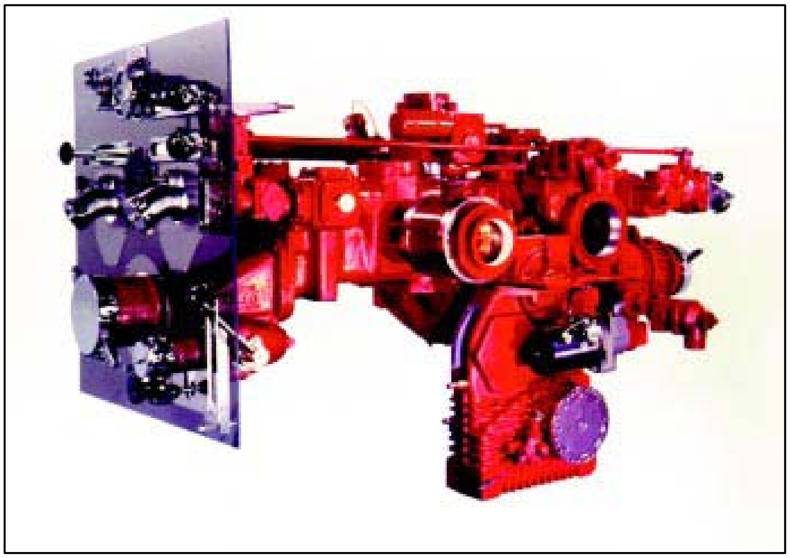


Figure 1
Path water takes through pump body and out discharge passageway.

Waterous Corporation, used with permission.

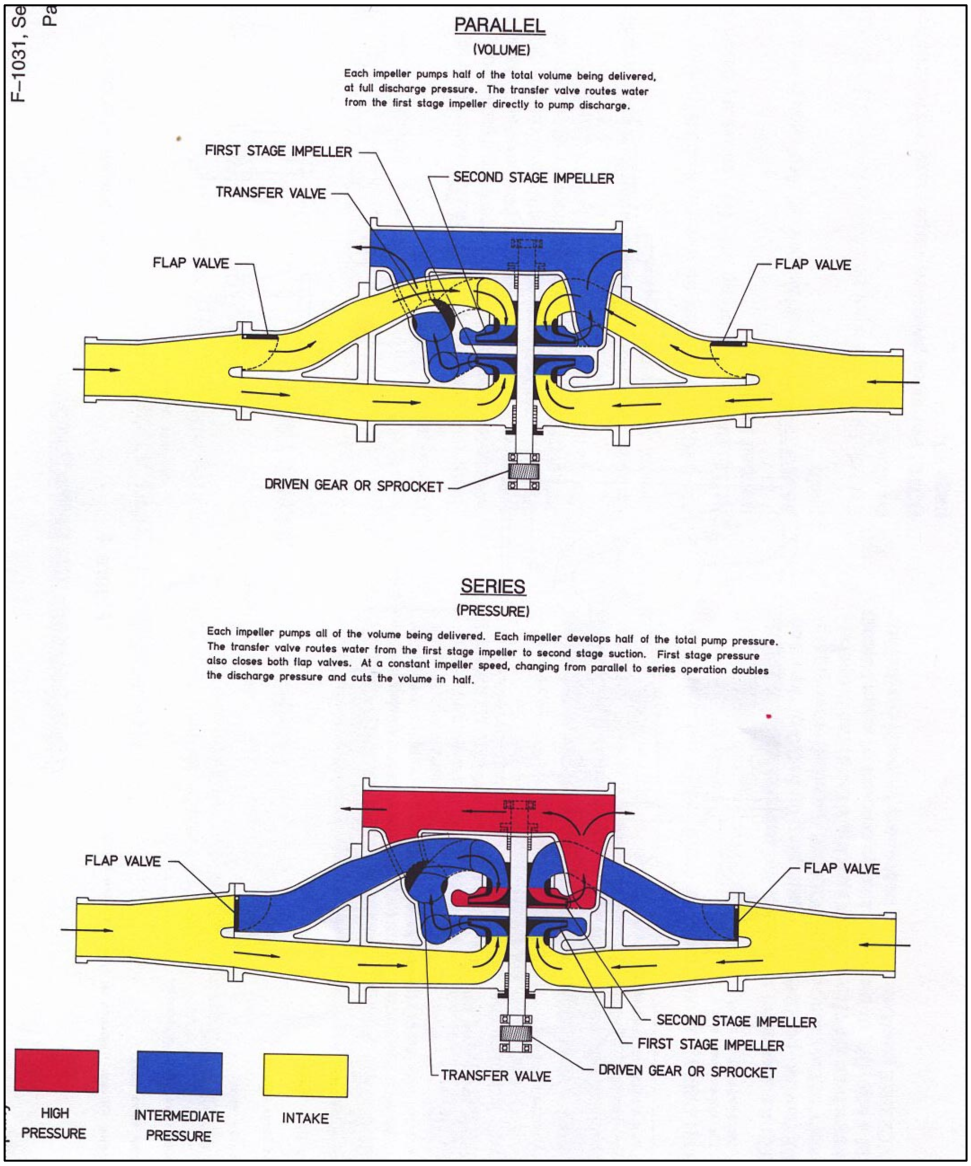
A two-stage fire pump showing midship mounting with pump panel.



QTWO SERIES Two Stage Midship Fire Pump (1000 to 2000 GPM)

Hale Corporation, used with permission.

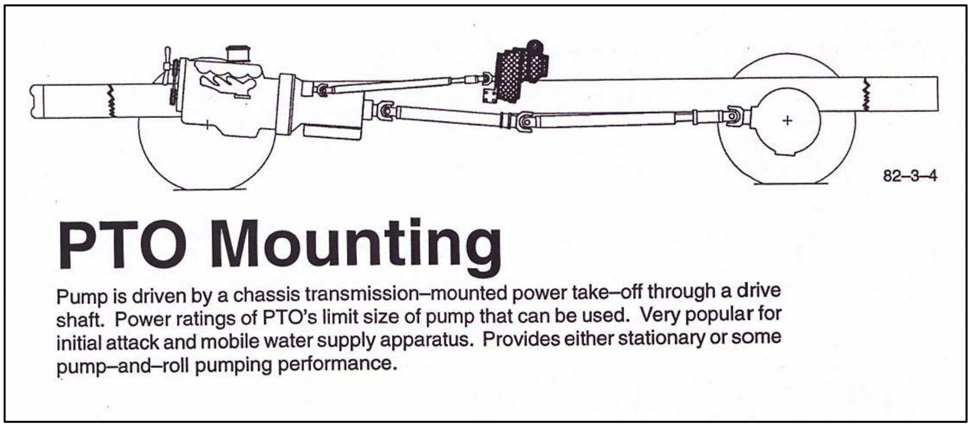
Direction of water flow in a typical two-stage centrifugal pump.



Waterous Corporation, used with permission.

NOTES

Pump Mounting and Configuration



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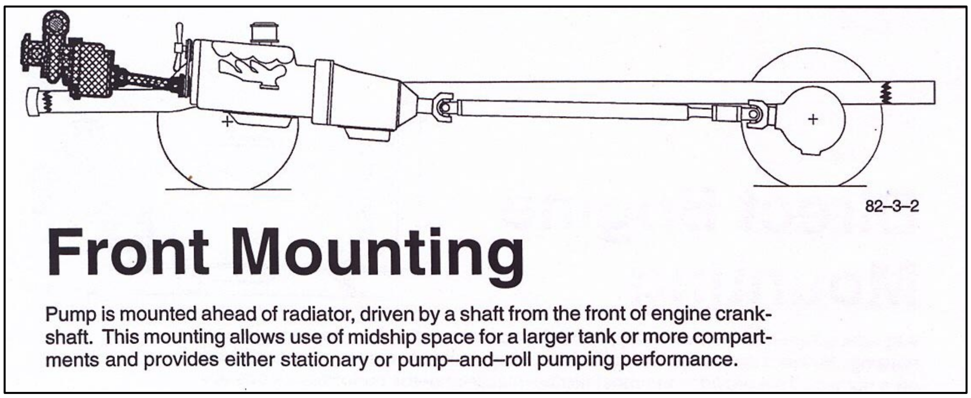

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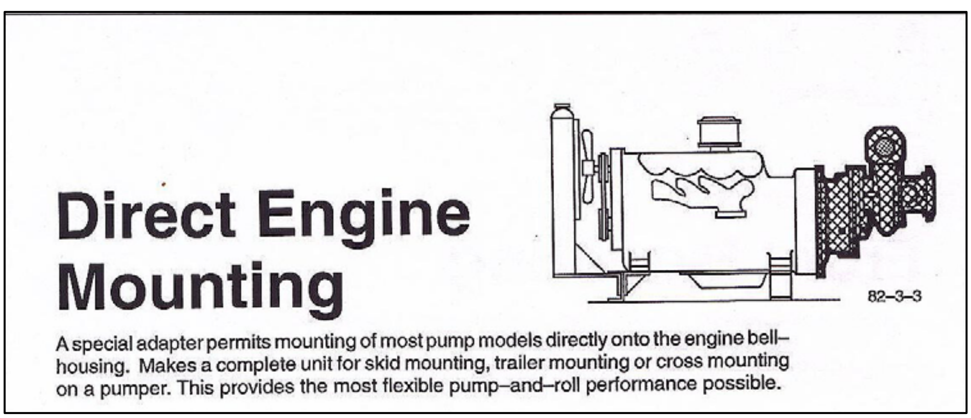
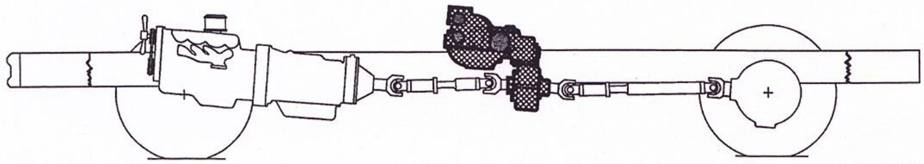


Waterous Corporation, used with permission.

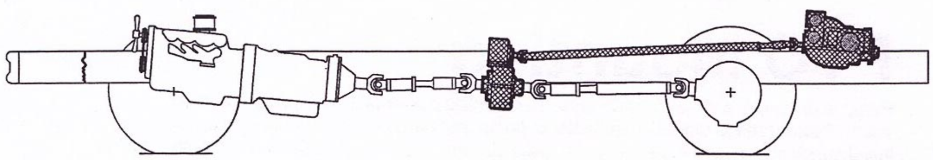
NOTES



Midship Mounting

The pump has a close coupled, split–shaft chain drive transmission located in the drive line between truck transmission and rear axle. This arrangement provides for the largest capacity stationary pump performance when using a single engine to power both the chassis and fire pump.

Waterous Corporation, used with permission.



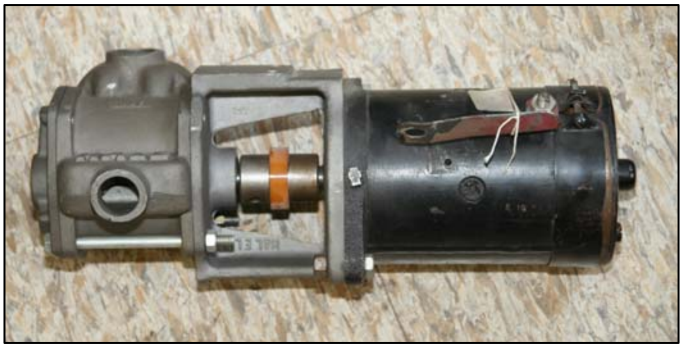
Rear Mounting

A Waterous full torque, split–shaft or PTO driven pump transmission is mounted in the midship driveline location. The pump can be mounted to the rear of the chassis and appropriate drive shafts connect the two. This provides tremendous flexibility in vehicle design and operation.

Waterous Corporation, used with permission.

Types of Priming Devices

The most common type of priming devices is the Rotary Vane pump; however, the Rotary Gear pump, an older design, is still in use. These are small positive displacement pumps.



Rotary Vane Priming Pumps

- A slotted rotor mounted off center from the pump casing
- The vanes are fitted in a slot in the rotor and held against the casing wall by centrifugal force as the rotor revolves.
- As the rotor turns, the vanes move outward.
- The space between the rotor and casing increases as the vanes pass the intake point.
- Air, and later water, is picked up and carried toward the discharge port.
- The vanes move back into the rotor slot as the space between the rotor and casing wall decreases when the vanes approach the discharge port.
- Air and water are forced out through the discharge port.
- This action continues until air is exhausted and water fills the fire pump.
- This rotary vane pump is self-priming

Rotary vane priming pumps have bakelite or plastic vane that slide in the slots shown.

The photo at the right illustrates a worn vane that has been removed from the housing.

NOTES

Rotary Gear Priming Pumps

- The rotary action consists of two meshing gears on cams that revolve in opposite directions within a close-fitting casing.
- Water is trapped in cavities between the teeth and casing walls and carried to the discharge side of the priming pump.
- Pressure is built up in the pump by the meshing action of the gear teeth as they return to the suction side of the pump.
- This action forces water out of the discharge side of the priming pump.
- This type of pump is self-priming.

Power to the priming device can be furnished by a separate electric motor or mechanically driven from the transfer case of the vehicle.

Examples of Rotary Gear Pumps –

Note: This type of primer is found on pre-1960 apparatus.

Practical tip (!)

Any positive pressure source such as head pressure from the tank, or a supply line attached to an open intake may force the air from the pump. A hydrant or a pumper in relay may accomplish this task.

Air Primers

Recently, a new type of primer has been developed. The Trident Air Prime device is an air-actuated priming device that is being used on newer fire apparatus. This new primer can activate multiple locations, and works off of the vehicle's air system.

Additional information about this new type of primer is found in Appendix K.

NOTES

Pressure Control Devices

In modern fire pumps there are different ways to control intake and discharge pressure to prevent injury to firefighters as well as damage to apparatus, hoses, and equipment. As centrifugal pumps generate pressure as well as flow, we must be able to control the pressure in order to safeguard the operator and firefighters. Without controlling the pressure, the pump and hose system can be susceptible to a condition called water hammer. Water hammer is created when a valve is closed suddenly causing a backpressure that will travel back towards the pump. This backpressure may cause a high-pressure spike in the pump system. This may cause the hose to burst, the pump to seize, or damage to the engine. In order to control the internal pressure as per NFPA 1901, manufactures must incorporate relief devices on the intake and discharge sides of the pump. Such devices can be a pressure relief valve, an intake relief valve, or a pressure-regulating governor.

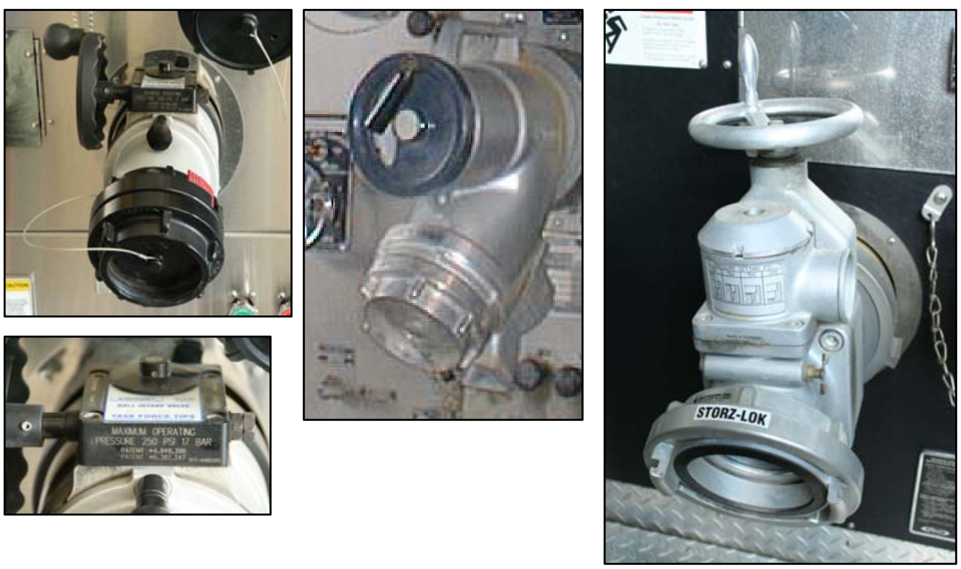
Intake Pressure Relief Valve

This device consists of an arrangement of valves and springs. When the pressure on the discharge side exceeds the pressure at which the controlling spring is set, the excess pressure opens the relief valve. The pressure relief valve permits water to flow into the suction side of the pump. The pressure rise should not exceed relief valve settings in excess of 30 psi. When the pressure within the system drops below the setting of the spring, the pressure relief valve will close. The flow of water from the discharge to the suction side of the pump stops. This system maintains operating pressures.

The relief valve operates when the nozzle is shut off and excess pressure is diverted through the valve mechanism to atmosphere.

External Devices

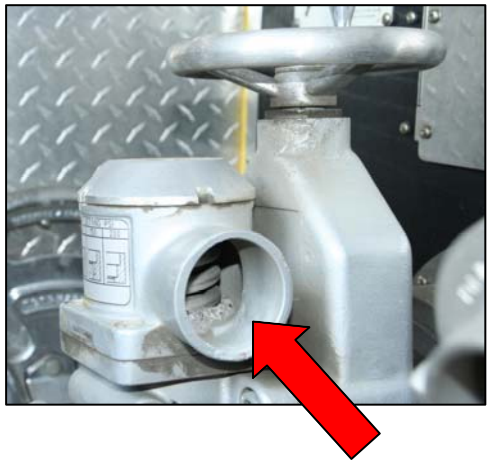
External intake relief valves, such as Large Diameter Hose (LDH) piston intake valves, are attached to the primary intake of the fire pump. The pressure relief setting is adjustable. The position of the adjustment screw may not make the pressure setting adjustable without removing the entire valve from the pump.



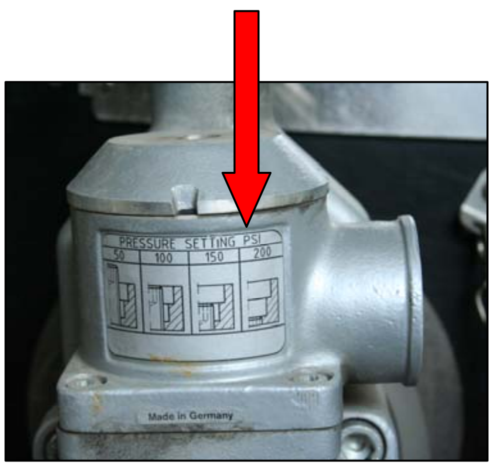
Examples of different types of external intake relief valves.

NOTES

External Intake Relief Valve – Note adjustable spring for 4 different pressure settings (arrows).



Pressure Setting (psi)



Intake Pressure Relief System

The NFPA standard on Automotive Fire Apparatus 1901 requires an adjustable 3-1/2" or larger intake pressure relief system. NFPA 1901 also specifies the pressure range for the relief system from 90 psi to 185 psi or greater. If the relief system is field adjustable, the purchaser must state what pressure is to set. NFPA 1901 requires, unless otherwise directed by the purchaser, the manufacturer will set the value at 125 psi.

NOTES

Newer intake pressure relief systems are a part of the fire pump plumbing, but remain external to the pump housing itself. Separately, external intake relief valves are also located outside the pump enclosure. These external devices are discussed below.

Setting the relief valve

The pressure relief valve is located in the bypass piping between the discharge side of the pump and the intake (suction). To set the relief valve you must do the following:

- Turn the relief valve control to the closed (“higher”) position.
- Advance the engine throttle to obtain the desired discharge pressure and flow. You must have the pump discharge pressure above 60 psi in order to activate the pressure relief valve spring.
- Turn the relief valve control to the open (“lower”) position until pressure within the pump starts to drop. An indicator light will show relief valve is operating (water is now flowing directly from the discharge of the pump to the suction, thus reducing the pressure within the system)
- Turn the relief valve control clockwise (toward “higher”) to restore the pump pressure to the desired operating pressure until the indicator lights are either “off” (Hale) or “green” (Waterous or Darley), indicating that the valve is closed.
- The relief valve setting can be re-adjusted to meet the operating pressure of each pumping operation. The relief valve setting has to be changed as pressure requirements change.

The relief valve activates due to the excess backpressure (the indicator light comes on). When the nozzle is re-opened the relief valve would cease to operate (the indicator light will go off) and pressure will return to normal.

Internal devices

One type of pressure control device is the internal pressure relief valve. This valve is adjustable by the pump operator to increase or decrease the pressure. When activated water is rerouted from the discharge side of the pump back into the suction side.

Another type of pressure control device is a pressure relief valve that “dumps” the excess water outside the pump (to atmosphere). This valve may or may not be adjustable by the pump operator at the pump panel. Some relief valve pressure settings are not accessible to the pump operator and may be adjusted during regular maintenance.

An intake/discharge pressure regulator uses one control to set pressure regulating relief valves on the intake, as well as, the discharge side of the pump. By setting the relief valve based on the discharge pressure needed for fire ground operations, an intake relief valve and a discharge dump valve work in tandem to protect the discharge pressure from excessive changes due to intake pressure or discharge pressure fluctuations.

Pressure Governors

Pressure control can also be accomplished by adjusting the engine RPM to regulate the pump discharge pressure. These devices are called pressure governors. They may be mechanical or electronic, depending on the age of the apparatus.

Automatic pressure regulating governors

There are two types of engine governors that may be installed on fire apparatus today.

Each of these is designed to maintain the pump discharge pressure by regulating the engine RPM. The early governor designs were mechanical and required many moving parts. Today’s governors are electronic and work with the electronically controlled engines and transmissions. With these units there are no moving parts.

The basic operation of each of these governors is to maintain the set pump discharge pressure (PDP) by controlling the engine RPM. If the PDP is set at 150 psi, and a firefighter closes a nozzle, the governor will slow the engine rpm to maintain the 150 psi. When the nozzle is returned to operation the governor will then increase the engine rpm to maintain the PDP at 150 psi and compensate for the now increased flow.

The governor will maintain the engine rpm to meet 150 PSI in the event that an additional line is added to the operation. The engine rpm will be increased to bring the PDP up to the 150 PSI, compensating for the increased flow.

In the event that the pumper runs out of water for any reason, the mechanical governor will try to increase the RPM to make up for the decrease in PDP created by the lack of incoming water. With these governors, the pump operator needs to be aware of this and react accordingly. The electronic governors may default to engine idle when they run out of water.

If your apparatus is equipped with an electronic governor you must read the operations manual to ensure that you are completely familiar with its operation. Governors are made by pump manufacturers, engine manufacturers, or third party companies. Driver/operators need to be familiar with the operation of the governors found on their apparatus.

Apparatus with pressure governors do not normally have mechanical pressure relief valves. The purpose of the pressure-regulating governor is to maintain a pre-set pump pressure by controlling the engine throttle setting. The governor protects the discharge pressure from pressure increase by reducing the throttle opening and the reduced throttle opening will reduce the engine speed.

Hale

It operates to prevent excessive discharge pressure rise when one or more lines are shut off or when increased pressure is introduced from an outside source. Conversely the governor will increase rpm to maintain pressure to compensate for additional flow. Because mechanical engine governor regulators only react to changes in discharge pressure, an operator must ensure a continuous water supply. This type of regulator will continue to try to maintain pressure by increasing engine rpms even if the water supply is interrupted. Electronic governors will make several attempts to maintain discharge pressure if the water supply is interrupted but will eventually return the engine to idle rpms.

Principles of Operation

The process of the mechanical governor in controlling speed:

- The nozzle is shut off.
- The pressure increases in the discharge side of the pump.
- The governor piston moves against the pre-set spring.
- The control linkage between the governor piston and the engine throttle operates to reduce fuel to the engine.
- The engine slows down and the pump pressure decreases.

The process of the mechanical governor in resuming speed:

- The nozzle is reopened allowing water to flow
- The pressure decreases in the discharge side of the pump.
- The governor piston returns to the original position it was set for.
- The control linkage opens on the engine throttle
- Fuel to the engine is restored and the engine resumes speed.

Note: Electronic governors accomplish the same task, but an electronic control unit (ECU) controls the engine speed to regulate the pump pressure.

Setting the Mechanical governor

NOTE: You must follow the manufacture's instructions for your specific type of governor.

American LaFrance

- Turn control knob of governor to Set.
- Set throttle to required pump pressure.
- Wait required time (between 5 and 30 seconds depending on manufacturer).
- Quickly turn governor control knob to run.
- The governor is now set at the desired operating pressure.

Setting the Electronic Governor

Class 1

Detroit Diesel

<u>NOTE:</u> *You must follow the manufacture's instructions for your specific type of governor. Each governor is different, so be sure to read the operations manual.*

- Push "On" button
- Select psi or rpm mode (Note: rpm mode will not control pressure but will maintain engine speed).
- Use 'increase' or 'decrease' button to adjust the governor to desired discharge pressure.
- The governor will regulate engine speed to maintain desired discharge pressure.

See Appendix E for more information about the Class 1 Electronic Governors.

Using Presets

- You may have a choice of programmed presets based on rpm or psi (refer to your department's SOGs).
- Push "On" button.
- Push "preset" button.
- Governor will now set the programmed discharge pressure or rpm.

Example

One hundred-fifty feet of 1 3/4" hand line at 100 lbs of nozzle pressure requires a Pump Discharge Pressure of 150 lbs. If you pull a second line that requires the same PDP the engine speed will **increase** to compensate for the increased flow of water. If you were to pull 200 feet of 2 ½" line at 50 lbs nozzle pressure, which requires a PDP of 70 lbs, the governor will again **increase** rpm to compensate for the increased water flow. However, the pump operator will have to ensure that the 2 ½" line only receives 70 lbs pressure at the pump by controlling the valve for that line.

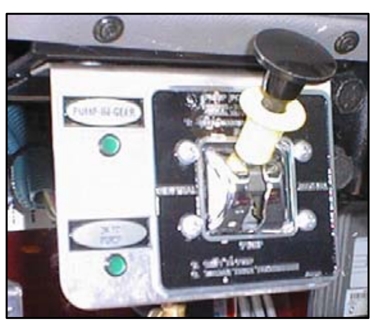
NOTES

Pump Controls

Pump Shifts

In order to make the pump work, we need to be able to transfer the power from the wheels that drive the apparatus to the pump. This can be done by a variety of methods. It can be done by the pull of a handle, shifting a lever, or flipping a switch. It may be electrical, pneumatic, or manual. You must consult the manufacturer's operation manual for the proper way to transfer the apparatus from road gear to pump gear. There may be indicator lights associated with the pump shift operation. These are found on or next to the pump shift mechanism, and the pump panel. These lights may be found singly or in pairs, where the pairs will indicate both a pump transmission shift, and a proper engagement of the automatic road transmission for pumping.

Different types of pump shifts are shown here.



NOTES

Transfer Valves

Some apparatus are equipped with pumps that have more than one impeller. These are called multi-staged pumps. Multi-stage pumps can deliver water at low volume with high pressure or high volume at lower pressures. In order to do this these pumps must have a device know as a transfer valve.

The transfer valve changes the pump from pressure to volume or vice versa depending on what flow and pressure is required. The transfer valve may be powered manually, electrically, hydraulically, or by vacuum or air.

Refer to the diagram on page 2-7 of this Unit to view how the transfer valve redirects water flow within the fire pump.

Transfer valve operation

The transfer valve should be operated at less than 50 psi above the intake pressure. Some hydraulic operated valves must have 70-psi pressure in order to operate. Again, you must consult the owner's manual for specific operation details.

- The "pressure" stage is selected for capacity flows less than 50 percent of the pump rating. Each impeller passes water to the succeeding impeller to increase pressure. An example would be a 1000 gpm pumper being operated at less than 500 gallons per minute.
- The "volume" setting is for capacity flows greater than 50 percent of the pump rating. In this mode, all the impellers pass water simultaneously from the suction to the discharge. Again, this would be the 1000 gpm pumper being operated above 500 gallons per minute.

NOTES

Throttle Control

The throttle control provides an engine speed (rpm) control. The throttle control is normally found on the pump panel. You may find a manual control in the cab as an option. The throttle control screw-like system is known as a vernier control. Turning the knob counter clockwise tightens a cable to the engine and increases the engine rpm's. Turning the knob clockwise will decrease the rpms. Within the center of the control knob is a button that can be used for "EMERGENCY SHUTDOWNS ONLY." It must be remembered that this button will cause an instant decrease in pump rpms. This in turn will cause a sudden decrease in pressure, which may cause injury to firefighters working on hose lines, ground ladders, and aerial devices. The throttle control may be a part of the pressure governor.

Electronic throttle controls are found on newer apparatus, as shown here.

NOTES

Discharge / Intake Valves

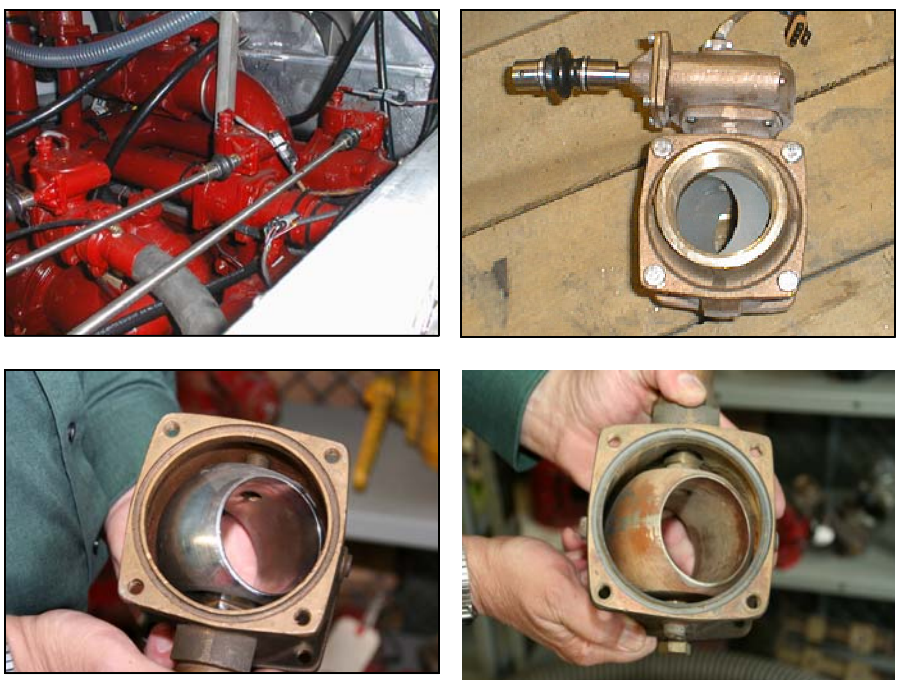
The purpose of these valves is to control water flow. You may find them in the form of gate valves, check or clapper valves, butterfly valves, needle valves or sliding valves.

Butterfly valves are typically use on suction inlets. Needle valves are used to dampen gauge lines making it easier to read the pressure. (Be sure not to over dampen the gauge). The sliding valves are used for drains.

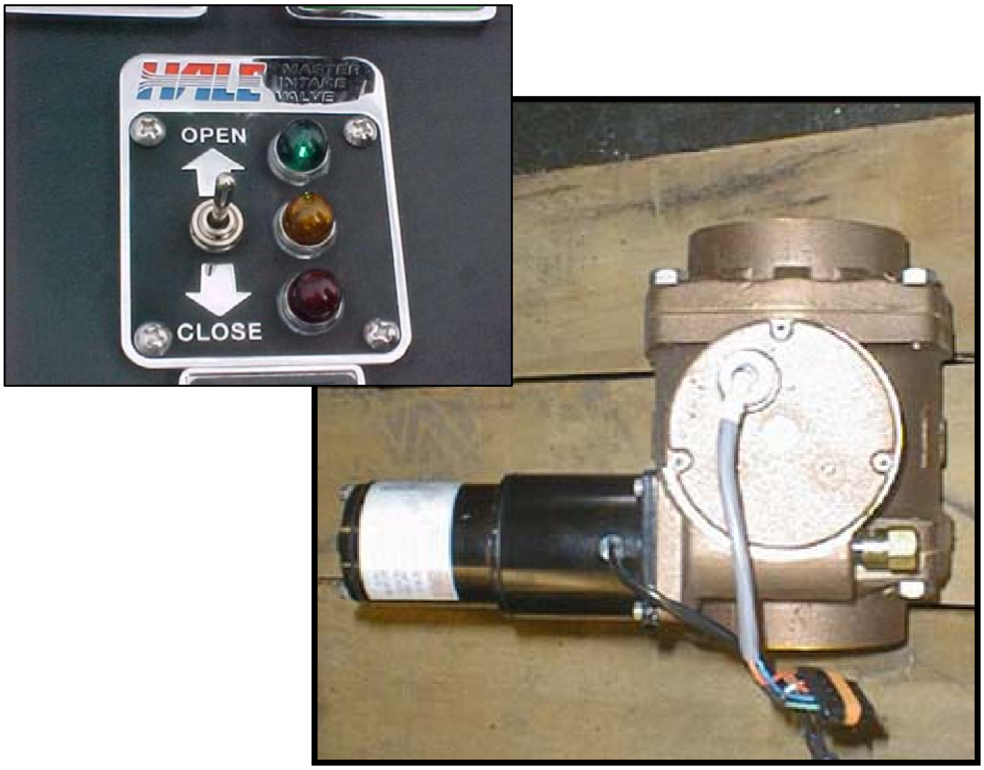
The ball valve is the most popular type of valve. Ball valves are used in discharge lines, suction inlets and tank fill and tank to pump lines. Check and/or clapper valves are used to control water flow direction.

The ball in a ball valve is rotated 90 degrees, to open or close. There are several ways to operate a ball valve. These include cranks, levers, pull rods, handles, as well as electrical or air actuators.

All intakes and discharges 3 inches and over must be equipped with a slow operating valves, which cannot open or close in under 3 seconds.



Various ball valves are shown in these photos. Note the actuator rods for these valves, shown in the upper left panel.



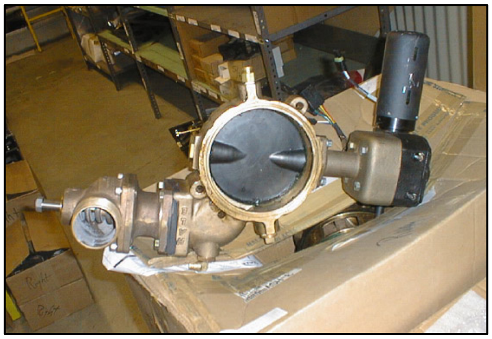
Electrically Actuated Ball Valve

Check and Clapper Valves

- To control water flow only in one direction
- Inside the pump casing on multi-stage pumps
- For tank to pump piping
- Siamese connections

NOTES

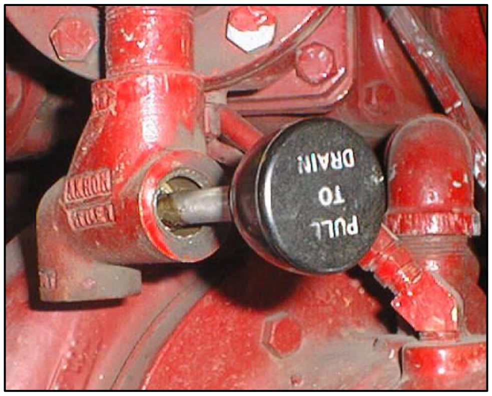
Butterfly Valves



- For the suction inlet
- Require only a ¼ turn to operate

The valve illustrated is a Hale MIV (Master Intake Valve) with electric actuator and relief valve combined into a one-piece bolt-on unit.

Sliding Valves

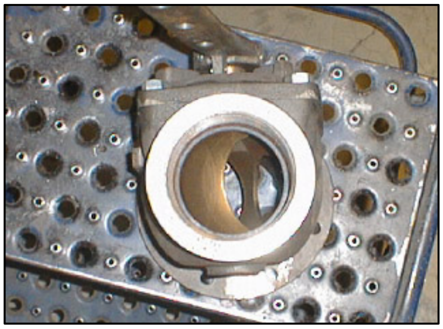


- Pump and low point drains
- Require a push-pull operation

The valve illustrated is a drain valve on an outlet on a Hale front mounted pump.

Discharge valves are ¼-turn ball valves. They can be controlled by push/pull, forward/back, in/out, and up/down movements. The discharge valves can be locked into the desired position. Care should be taken not to over tighten the valve. Damage may occur to the valve handle making it impossible to maintain the flow setting**.**

NOTE: All valves have a tendency to close under pressure. A valve that has been damaged may close itself without the operator being aware or may close suddenly causing a dramatic increase in pressure. This is one reason why it is important to have the pressure relief valve or pressure governor set.



Gauges

The purpose of gauges is to provide information to the operator on how the vehicle and pump are performing. There are two main groups of gauges, motor gauges and pump gauges. The motor gauges provide information on the condition and ability of the engine to perform. The pump gauges provide information on the condition and performance of the pump and its accessories.

Typical Motor/Cab Gauges

Speedometer

- Indicates the speed of the apparatus in mph / kph
- If the pump operates with the transmission in gear, the speedometer may read while the pump is running.

Tachometer

- Indicates the speed of the engine crankshaft in rpm while driving or pumping

Engine Hour Meter

- Records the total time that the engine has been operated
- It provides accurate information for scheduling of preventative maintenance for the vehicle and accessory components.

Fuel Gauge

- Records the amount of gas or diesel fuel remaining in the tank

Oil Pressure Gauge

- Measures the amount of pressure in the lubricating system
- This gauge DOES NOT indicate the amount of oil in the lubricating system.

Water Temperature

- This gauge indicates the temperature, in degrees Fahrenheit, of water in the engine cooling system.

- It consists of a metallic thermometer element inserted permanently in the cooling space surrounding the engine cylinders.
- The correct temperature is generally 160 degrees F to 190 degrees F for maximum efficiency.

Air Pressure

- The air pressure gauge indicates the pressure available in the air system for apparatus equipped with air brakes.

- The compressor automatically activates to replenish the air supply when the reading falls below 90 psi.
- Apparatus accessories that utilize air pressure include air brakes, emergency brakes, air horns, and air operated valves and controls.

Ammeter

- It indicates how much current is flowing into (charge) the battery.
- Most all electrical equipment on the apparatus, except the starter, is connected through this gauge.

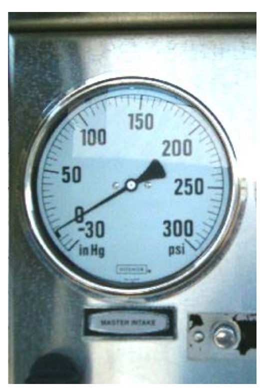
Voltmeter

- The voltmeter indicates the potential energy (voltage) of the electrical systems
- It also indicates low voltage (below 12v), normal voltage (12v to 15v), or high voltage (greater than 15v).

Pump Gauges

Pump gauges read pressure in pounds per square inch (psi). We use this pressure reading to set our flow requirements. There are several types of gauges.

Compound Gauge



- Used on the intake (suction) side of the pump.
- It will measure **both** positive and negative pressure (vacuum) in the pump casing.
- The gauge indicates the amount of vacuum in inches of mercury.
- It reads static pressure with no water flowing.
- It will also read residual pressure with water flowing.

NOTES

Pressure gauge

- Is used on the discharge side of the pump
- It measures positive pressure on the discharge side of the pump

Gauge Operation

- A closed-end, hollow curved tube known as a Bourdon tube activates the gauges.
- Pressure on the tube tends to straighten out the curvature of the tube.
- A mechanical connection (rack & pinion) operates a gear connected to a needle pointer that gives us the pressure reading.

Dry Gauges

Dry gauges operate under the same principle as liquid filled gauges; however, water from the fire pump fills the Bourdon tube, which activates the gauge. Dry gauges typically have snubber needle valves to control needle flutter inside the gauge face.

Liquid Filled Gauges

- Oil fills the Bourdon tube.
- A freeze resistant diaphragm located at the gauge connection keeps water out of the Bourdon tube.
- Silicon or glycerin oil completely fills the entire gauge case, except for a small air bubble behind the lens that acts as an internal breathing diaphragm to relieve case pressure.

Note: The Bourdon tube gauge is susceptible to its own problems.

- If a nozzle is shut off fast water hammer may cause damage to the gauge
- If temperatures are below freezing (32 degrees F) (0 degrees Centigrade) water inside the gauge may cause permanent deformation of the tube.
- Typically 2% to 3% error is common in this type of gauge.
- 2% error on a gauge reading 0 to 600-psi range will equal 12 psi.
- Actual gauge readings of 150 psi may range from 138 psi to 162 psi actual pressure.
- Actual gauge readings of 20 psi on compound gauges range from 8 psi to 32 psi (2% ±12 psi).
- It is recommended to carefully select gauge range to suit the application. Most gauges are more accurate in the middle third of its range (0-300 psi range and 0-600 psi range).

Flow meters

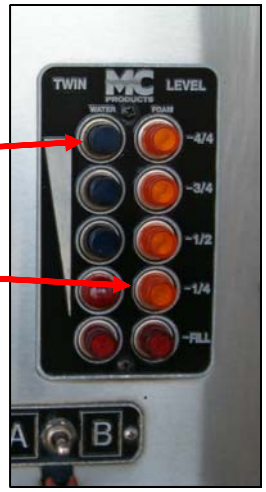
Flow meters read discharge flow in gallons per minute (gpm)

- Flow meters replace the standard pressure gauge for setting flows.
- There are two basic types of flow meters.
- The differential flow meter operates by comparing pressure in upstream and downstream facing tubes inserted in the flow line.
- Turbine sensor flow meters operate by a paddle wheel device inserted along the edge of the flow line measuring the paddle wheel rotation.
- You may have a combination flow meter and pressure gauge.

NOTES

Water/Foam Level Gauge

Indicates the level of product in the corresponding tank.



Water

Foam

Pump Hour Meter

- Records the total time that the pump has been operated.

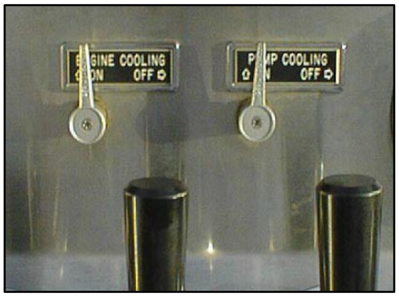
- It provides accurate information for scheduling of preventative maintenance for the pump

Remote Engine Gauges

On the pump panel you will also find remote engine gauges. These should include a tachometer, ammeter, voltmeter, engine temperature, oil pressure, fuel gauge, and pump hour meter. Oil pressure and coolant temperature now require audible and visual alarms.

Auxiliary Cooling Controls –

Engine Cooler/Auxiliary Cooler



The engine temperature is extremely important for safe and efficient operation. The normal vehicle cooling system may be inadequate to cool the engine during stationary pumping operations. The auxiliary cooler acts as a heat exchanger. Cool pump water circulates through coil units to cool the radiator fluid. The pump water does not mix with the radiator fluid.

Older engines may have a radiator fill control as an emergency device. Pump water will replace fluid in the radiator to cool the engine. The radiator fluid must be replaced during restoration of the vehicle to normal service. Failure to do so may cause the engine to freeze in cold weather causing the engine to crack.

Pump Cooler/Booster Cooler or Recirculator

Centrifugal pumps tend to overheat when turning rapidly and discharging little or no water. Modern equipment is available to warn of overheat conditions. These may be electric sensors attached to the pump housing that activate warning lights and audible alarms. You may detect an overheating condition by feeling the pump housing or intake.

Overheat prevention includes the circulation of water through the pump. This can be accomplished by the following methods:

Open pump cooler/circulating valve
Discharging water to flowing lines
Dump water to the ground
Circulate tank-to-pump and pump-to-tank continually
Put road transmission in neutral when water is not needed or no water is flowing (this disengages the pump drive).
Some pumps are equipped with a cooler valve that is automatically activated by a thermal sensor.

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NOTES

UNIT 2

Lesson 2

Maintenance, Inspections, & Testing

Objectives

At the conclusion of this unit, the student will:

- Understand specialized tests, inspections, and basic maintenance functions
- Be able to perform routine inspections, tests, and maintenance functions on pumping apparatus
- Document pumper inspections and tests
- Perform a walk-around inspection of pumping apparatus
- Perform a vacuum (dry prime) test

NOTES

UNIT 2

LESSON 2

Introduction

It is of the utmost importance that fire department pumping apparatus function at their full capabilities during emergencies. Apparatus that do not operate properly could permit a small fire to reach major proportions. Continuous reliable operation of pumping apparatus depends directly on a human component, with the driver/operator serving as a key component in this process.

Every fire department must have a policy specifying what constitutes maintenance and repair, and who performs these functions. Because fire apparatus are more complex today, it is imperative that the driver/operator have a thorough understanding of all the components of the apparatus.

In order for apparatus to operate as designed, certain inspections, tests, and maintenance functions must be performed. Many pumper failures can be traced to a lack of preventive maintenance and proper repair. Importantly, NFPA standard 1002 requires driver/operators to have basic skills in apparatus maintenance, inspection, and testing. This unit will cover basic inspection procedures and skills needed by the driver/operator.

Maintenance vs Repair

It is important for driver/operators to differentiate between the terms maintenance and repair. Maintenance usually means keeping the unit in a state of readiness. Repairs are generally defined as replacing or fixing that which is not operating properly. A good preventative maintenance program will help to ensure unit reliability, lessen out of service time, and will help reduce the overall cost of fire department operation.

The purpose of preventive maintenance is to try to reduce unexpected failures, which could threaten life and property. It should always be remembered that anything mechanical can fail, but with a good maintenance and repair program in place, the odds of a failure are greatly reduced.

Preventive maintenance starts with the driver/operator. He or she is the person most familiar with the unit and should know when the apparatus is operating at full capability, and when it is not. Some departments may have a maintenance officer who receives the driver/operator reports. This individual may routinely check and service the apparatus, or may only coordinate needed repairs with department mechanics or outside service companies. The driver/operator should be able to perform minor maintenance; however, major repairs should be left to properly qualified mechanics and repair personnel.

Maintenance and Repair Programs

Every fire department maintenance and repair program should include the type of inspection procedures used, the type of repairs done and by whom, as well as the process for proper documentation. This program should be included in the department's standard operating guidelines (SOGs).

A department's SOGs should specify which items the driver/operators are responsible for checking, and which items the operator can correct on his/her own. Departments generally allow driver/operators to check fluid levels (and top-off if needed), tighten loose nuts, bolts, and screws, and replace bulbs. More serious repairs are referred to qualified mechanics. Large departments may have their own mechanics and repair shops, smaller departments may send their units out to qualified repair facilities for maintenance.

The individual performing the repair work on fire apparatus should be qualified to repair heavy trucks as well as the associated pump(s) and equipment on the apparatus. The schedule for checks and maintenance functions varies greatly in departments, from career organizations requiring driver/operators to perform daily maintenance checks and inspections, to volunteer departments checking equipment on a weekly or

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monthly basis. The apparatus checks and maintenance should be outlined in SOGs to ensure that the equipment is properly checked and that those checks are properly documented.

Proper record keeping results in a running history of the apparatus's reliability, assists in planning for replacement, and also is important for warranty claims. In the event that the unit is involved in an accident, investigators will certainly review these records. All operators should be very familiar with their department's maintenance record keeping system.

NOTES

Apparatus Inspections

It is highly important that the operator have a systematic method of checking the apparatus, this ensures that all items and functions are checked and noted each time inspections are carried out. Many departments use the inspection requirements outlined in NFPA 1002, or the pre-trip inspection requirements used in the federal Department of Transportation (DOT) or state commercial driver programs. These are the types of inspections that career firefighters should use on a daily basis, and volunteer personnel should use on a weekly or monthly basis. Individual departments will need to establish their own program based on response information, apparatus usage, and other local factors.

New York State Heavy Equipment Safety Inspections are not required for fire apparatus. However, this procedure is highly recommended and many departments have adopted this standard.

Changes in NFPA Standards –

As of 2007, the NFPA 1911 standard was rewritten to contain three previous stand-alone documents: NFPA 1911, NFPA 1914, and NFPA 1915.

The new NFPA 1911 standard is now called the "Standard for the Inspection, Maintenance, Testing, and Retirement of In-Service Automotive Fire Apparatus, 2007 edition."

Pre-service Inspection

The Pre-service Inspection, sometimes called an operator's check, pre-duty check, or general walk-around, all accomplish the same goal—to assure that to the best of the operator's knowledge, the unit is ready to respond if needed.

There are a number of obvious items that are checked on all apparatus, including:

- Battery condition
- Fuel and fluid levels
- Booster tank water level
- Tire condition, and any other related items

A methodical approach to the inspection procedure permits all critical areas to be checked. If records are available from a previous inspection, the operator should review these to see if any problems were noted and if repairs were made.

Walk-around Inspection

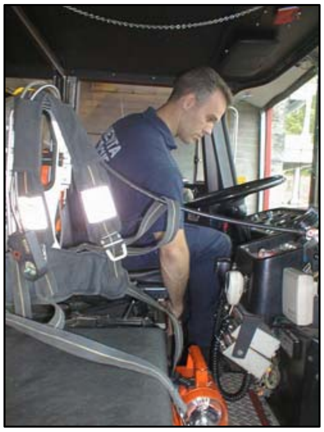
The walk-around inspection is a good method for operators to use to inspect their units. As the operator approaches the unit he will begin the inspection by observing the overall appearance of the vehicle and looking for any obvious problems, such as low tire pressure, vehicle damage, or puddles of fluid under the vehicle. Other conditions, such as the unit leaning to one side, may indicate a suspension problem. The driver will then start the inspection from the driver's door and work around the unit in a clockwise direction.

The Overall Inspection Process

As the operator circles the unit, all important areas are checked, including all of the assigned equipment. The final step of the inspection will be for the operator to return to the cab of the engine start the unit, and perform an operational check on all the unit's systems.

Cab Interior

The first thing the operator should do upon entering the apparatus cab is to adjust the seat and mirrors properly. It is imperative that the driver has the seat and mirrors adjusted for safe and comfortable operation. Many accidents have occurred because the operator failed to adjust these critical items before driving the apparatus. Check and adjust the seatbelts and occupant restraint devices if needed.



If the apparatus is equipped with a tilt and telescoping steering wheel, adjust it now. The operator should then check all equipment carried in the cab including portable radios, flashlights, etc. for proper storage. All equipment should be stowed properly so as not to interfere with response.

Practical Tip → Loose equipment rolling around the interior of the cab can become a lethal projectile if the unit is involved in an accident or makes a sudden direction change.

According to NFPA 1901 and NFPA 1500, **all** equipment in the cab must be secured in mounting brackets.

The driver should inspect the road-to-pump shift mechanism for proper positioning. The transmission selector lever, or shift lever for manual transmissions or mechanical linkage automatic transmissions, should also be checked for neutral position. All apparatus should have operable neutral safety switches that will not allow the engine to start in gear. The operator should check all other switches in the cab for proper positioning. This includes emergency lights, headlights, radio controls, heating and air-conditioning levers or switches, and all other controls and switches.

Under the Hood

Once the operator has completed checking the cab interior the engine compartment can be checked next. Most engine and other related component checks should be done prior to the operational check, which will be discussed later.

NOTES

The **Engine oil** level should be checked first when inspecting the engine compartment. All engines have a dipstick to measure the amount of oil in the crankcase. If the reading is low, the proper amount and type of oil required should be added. If the unit has just been running, the driver/operator should wait to allow the oil to settle in the oil pan before measuring the level.

The operator will check the **radiator coolant** (antifreeze) level next. This is done by removing the cap on the fill opening usually located on the coolant system recovery or overflow reservoir, or by viewing the fluid level through the sight glass, if supplied. There will usually be at least one or two marks on the side of the reservoir to indicate the proper level of the antifreeze. The driver/operator should also inspect the condition of the radiator hoses at this time. The front of the radiator should be free of leaves, papers, and other objects that would restrict the flow of air through the unit. Some engines also have automatic cooling fans, so extreme care should be taken when working around the cooling fan systems to avoid coming in contact with a moving fan assembly. If the coolant fluid level is low, add the proper coolant.

Practical Tip → Because these systems are pressurized when the engine is at operating temperature, caution should be used when working around cooling systems when the engine is warm.

NOTES

Power steering fluid levels, as well as **brake fluid** levels (on vehicles equipped with hydraulic brake systems) should be checked at this time. Check power steering levels by using the dipstick in the reservoir or by a method specified by the manufacturer. Some systems require the unit to be checked with the engine running and the fluid at normal operating temperature.

Check the brake fluid level in the master cylinder by using the procedure recommended by the manufacturer.

The **Automatic transmission** fluid level should be checked in the same general manner as the engine oil level. The transmission should be at operating temperature and on level ground, according to the manufacturer's specifications. A dipstick is usually provided for this check, and the proper level noted. Some newer pumpers have transmissions with electronic readouts of the fluid level. In this case, the fluid level check is accomplished by pushing specific buttons on the electronic transmission control pad in the designated sequence.

All **belts**, including water pump, air compressor (if equipped), fan, and alternator, should be inspected for wear and proper adjustment. The operator should be familiar with the proper feel for tightness of each belt when properly adjusted.

Electrical wiring **should** be inspected in the engine compartment at this time. The general condition of the wiring should be good with no signs of frayed, loose, or cracked wires or connections.

At the conclusion of the engine compartment inspection, the driver/operator should look for leaks of any fluids used in the vehicle's engine or transmission. Look for oil, transmission fluid, water, hydraulic oil, power steering fluid, or any other fluid that may be leaking. All engine hoses, tubing, pressure lines, and fittings should be checked for their overall condition and indication of leakage.

NOTES

Walk-Around Inspection

Left Front Side

By beginning at the driver's door, the operator will check the door, the latches, and window glass for proper operation and cleanliness. All handrails and mounted equipment should be checked for proper attachment. If the unit has saddle-style fuel tanks, the fuel caps should be secure and any evidence of leaking or damage noted.

The next items of importance are the wheels and tires. A visual inspection of the wheel should be made to check for cracks, loose or missing lug nuts, bent or broken studs, and unusual amounts of brake dust on the wheel. The wheel should also be inspected for any gear oil or grease, in particular if signs of trailing show on both the wheel and tire.

The unit's tires should be inspected for cuts, sidewall damage, tread separation, uneven wear, or other problems that may require maintenance. Tire inflation should be at the pressure recommended by the tire manufacturer, and is usually found on the sidewall of the tire. The valve stem should also be checked for cuts, cracks, tightness, and leaking air.

The operator can then look behind the wheel at suspension components and the steering gear. Look for obvious problems involving springs, spring hangers, u-bolts, shocks, and shackles. Most power steering units are frame-mounted in this area, so look for evidence of fluid leaks on the floor or on the power steering unit itself.

Vehicle Front

As for all areas of the apparatus, the operator will check for any obvious damage to the front of the unit. The condition of the windshield, and wiper blades and arms should be inspected.

If the unit has any warning devices mounted to an extended bumper, or an intake or discharge fitting located in this area, these should be checked for proper attachment and visible damage. For units with front intake fittings that are normally capped, make sure the cap is tight enough to prevent air leaks when attempting to draft, but not so tight as to make it difficult to remove. Any hose attached to pre-connected intake or discharge fittings should be in good condition and stowed properly. If a valve is provided, it should be in the closed position. Importantly, all nozzles should be clean and in their proper place.

Many apparatus today are equipped with winches, hydraulic rescue tools, and other systems mounted on the front of the unit. These should also be inspected to ensure proper stowage, operation, and cleanliness, as well as to note any damage.

Some apparatus are equipped with front-mounted pumps, these can be checked at this time. Once the front inspection is complete, the driver can proceed to the right front of the vehicle.

Right Front

The right front inspection of the apparatus would be the same procedure as used when inspecting the driver's left front side. Again, general condition is noted of all right front components, wheels, tires, and all associated suspension parts. Once the right front inspection is completed, the operator can continue on the right side of the apparatus, working towards the rear of the apparatus.

Right Side

This part of inspection process covers all areas from the rear of the cab to the tailboard area of the apparatus.

As in the front inspection, the operator shall look for any obvious damage that may have occurred since the last inspection. Tires, wheels, and suspension components are checked. Most fire apparatus have dual rear wheels/tires on the rear axle or axles. These should be checked for condition, as is done with the front inspection. Importantly, any dual tires should not be touching each other or coming in contact with any part of the axle or vehicle.

Units should be equipped with mud flaps and these should be properly attached and in good condition. None of the flaps should be hanging loosely or dragging on the ground.

Many fire apparatus are equipped with automatic tire chains. This equipment should be inspected by the operator at this time. The driver should make sure that all links of the chains are present and in good condition. The automatic chains should be lubricated as per the manufacturer's specifications, and should be operated by the driver at least once per month. Many departments remove the hub and chain units during the summer months, and then reinstall the units in the fall.

NOTE: These devices are generally turned on and off from the cab by the driver. When activated, a rotating hub with lengths of chain swings into place in front of the drive wheels. The chains are swung in a rotating motion so they fall under the rear wheels as the unit moves forward or backward, providing enhanced traction in snow or ice.

The operator should check all compartment doors, hinges, hold-open devices, and latch mechanisms. Inspect the equipment carried in the compartments at this time, which should be present and properly stowed. Some departments will inspect each piece of equipment carried at this time, others will only check for presence, cleanliness, and if the equipment is properly placed in the compartment.

If the apparatus is equipped with side-mounted ladders, they should be checked for cleanliness and for proper securing to the apparatus. Hard suction hose carried in trays should be checked for condition and proper securing. Any hose or other equipment carried on the exterior sides or running boards of the apparatus should also be checked at this time, including pre-connected hose lines that go across the midship area of the unit or those stowed on top of the fender compartments.

Once all compartments and equipment on the right side of the apparatus have been checked, the driver can then proceed to the rear and top areas for inspection.

Top and Rear

Starting at the rear of the unit, the operator will check the tailboard for any damage. All equipment mounted in this area, should be secured properly and in working order. Portable extinguishers, hydrant valves, and portable master stream devices are examples of tools and appliances found at the rear of apparatus.

If the unit is equipped with a rear compartment, this should be checked in the same manner as the right side compartments. All equipment contained in the compartment should be inspected for operation, cleanliness, and its proper stowage.

The operator should then check the main hose bed area, ensuring that the hose is properly packed and finished off. Driver/operators must know the quantity of hose carried on their pumpers and be able to recognize shortages of any hose lays. If the unit is equipped with a hose bed cover, it should also be checked at this time for condition, placement, and security. Some apparatus are equipped with solid covers. If these are used they should be checked to ensure that they stay open when necessary.

NOTE: A recent NFPA 1901 amendment now requires that any hose must be restrained to the apparatus to prevent accidental deployment while in motion (1901 Temporary Interim Amendment (TIA)).

All other equipment that is stored in the hose bed area should be checked at this time. This includes ground ladders, portable tanks, hose, pike poles, and other equipment. Some apparatus today are equipped with rear-mounted pumps.

After the top rear of the unit is checked, the driver/operator can then proceed to the top front to check the top of the pump enclosure, if the apparatus is a midship pump design. Any equipment stored in this area should be inspected like all other areas of the apparatus. Visually inspect the booster tank water level at the filler opening at this time.

After the inspection of the top of the pumper is complete, the operator can proceed to the left side inspection.

Left Side

Inspect the left side of the pumper in the same way as the right side. After completing the left side inspection, proceed to the pump panel inspection.

NOTES

Pump Panel

The driver/operator will now check all pump controls at the panel and associated areas. This inspection is best done after the vehicle inspection is completed.

The first items to check are the master pump gauges, which are usually located in the upper section of the pump panel. After these, check the individual gauges for each discharge. Check any duplicate gauges in the cab or other areas to make sure that they both display the same value. Gauge glass should be clean, not cracked, and have no fluid leaks. After checking the gauges on the unit, proceed to inspect all valves on the discharges and intakes. The driver/operator may wish to open and close each valve to ensure proper operation with no binding or sticking.

If the unit is equipped with a multistage pump, the operator can check the transfer valve next. The valve can be changed from one position to the next and then back to the original setting. Keep in mind that operating the pump transfer valve may require the pump to be in gear.

If the unit has an external intake relief valve, this can be checked after the transfer valve inspection. Depending on department policy, the air bleeder should be checked to see if it is in the proper position (open or closed). The valve itself should be opened and then closed to check for proper operation.

The operator will then check all water drains located either at the pump panel or other locations to ensure that they are fully closed.

NOTE: Depending upon individual department's procedures, pumps can be kept "wet" or "dry."

NOTES

The operator now should check any pressure control devices, such as relief valves, pressure governors, and any auxiliary cooling systems to ensure proper setting. If the unit has auxiliary fire suppression systems, such as foam or dry chemical, they should also be inspected for proper fluid amount, leaks, corrosion, or any obvious damage. The level of the priming fluid can also be checked at this time.

NOTES

Undercarriage

To complete the walk-around inspection, the driver/operator should now do a general inspection under the unit. Any obvious signs of damage or loose or missing parts should be noted. This would include, but not be limited to the suspension, driveline, and auxiliary systems (tire chains, for example).

The operator should now check for any unusual oil leaks from the fire pump gear case and note them accordingly. Also be sure to check for any water leaking from the fire pump.

After the operator has completed the undercarriage inspection, the operational inspection can now be done.

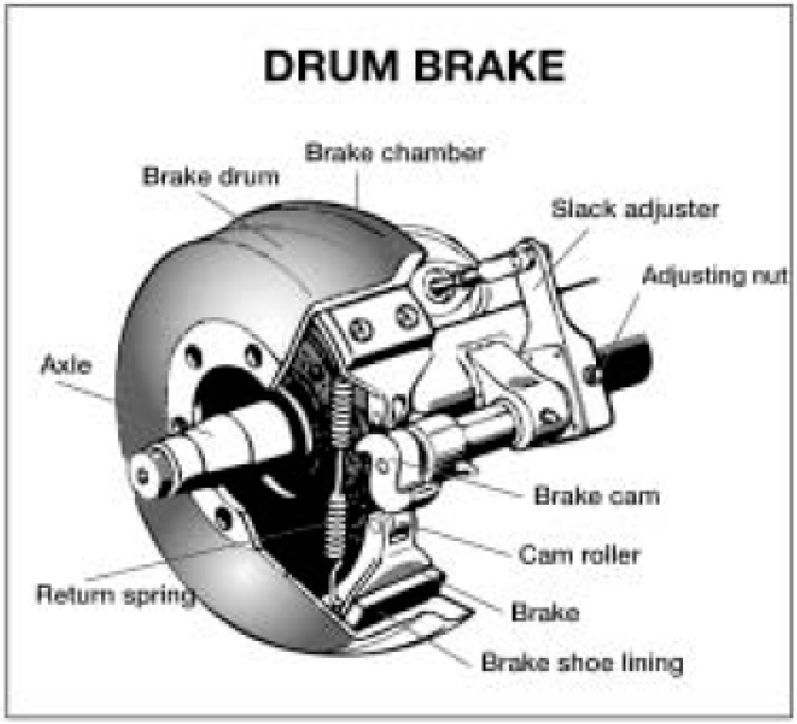
Brake System Inspection

Fire department pumpers may be equipped with air brakes. The major components of air braking systems are: an air compressor, a compressor governor, air storage tanks (with drains), an air drier, a safety relief valve, the brake pedal, the brake mechanism and its parts (located at each wheel), an air pressure gauge with low and operating pressure indicators, stop light switch, a low air warning signal, and spring brakes (which are applied when low air pressure exists).

Recent updates in the NFPA 1901 standard now specify that when the parking brake is applied, all forward-facing white lights turn off and ground-illuminating lights turn on. In additon, a variety of safety interlocks controlled by the braking system can be found. The details for these features can be found in NFPA 1901.

NOTES

Behind each wheel is the brake mechanism. This is shown in the following illustration:



Source: New York State Commercial Driver's Manual, p.5-3.

Driver/operators must have a basic understanding of the components of an air brake system. Part of this understanding must be the ability to recognize when air brakes are not properly adjusted.

Although this course is not designed to have each driver/operator make adjustments to air brakes – this must be done according to your department's guidelines and by a properly trained mechanic – driver/operators shall be able to recognize if air brakes are not properly adjusted prior to driving the vehicle.

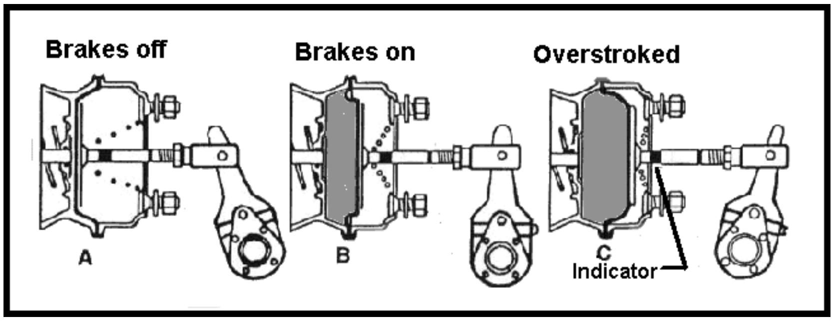
NOTES

During the vehicle inspection, the driver/operator should check the various components of the air brake system. The driver/operator should check the:

- Air compressor
- Air compressor drive belt (if belt-driven)
- Low pressure warning signal
- Air pressure gauge(s)
- Brake drums, hoses, and linings (where possible)
- Parking brake
- Service brakes (can be disc or drum types)
- Slack adjusters on S-cam-type brakes, and
- Spring brake function/application

These system components should be routinely checked and documented according to your department's SOPs, NFPA, and Department of Transportation (DOT) standards.

On vehicles with air brakes, proper adjustment is crucial for safe and effective stopping. The illustration below shows what a properly adjusted brake should look like. If the driver/operator sees that brakes are not properly adjusted, or is not certain if the brakes are properly adjusted, the vehicle should be taken out of service. This finding should be documented and immediately reported in order for corrective maintenance to be done.



Accessed from http://www.e-z.net/~ts/ts/Adjust.htm on 8-8-06; used with permission.

NOTES

Unit 2

Lesson 3

The Operational Inspection

A complete operational inspection of the apparatus includes both a driving and fire pump operational evaluation. Both the road and pump tests shall be conducted according to departmental SOGs. A full pump service test need not be done on every inspection, but shall be scheduled once per year (see NFPA 1911).

To begin the operational inspection the driver/operator will go through the starting sequence for the apparatus. All engine instruments should be monitored during the start to assure proper oil pressure, electrical charging, and air build-up (if equipped with air brakes). It is important that all electrical switches for lights and other systems be in the off position when starting the unit so that an excessive load will not be placed on the batteries and charging system.

After starting, the manufacturers recommend that the engine not be placed under full load before it is up to operating temperature. While the engine is warming up, the operator may choose to check all lights, signaling devices, and warning systems. If proper ventilation systems are not available in the station, the apparatus should be moved outdoors while warming to avoid a build up of fumes in the building. Before the operator moves the apparatus, the air pressure in the braking system should be observed, if so equipped. Apply the brakes to check for adequate braking ability within the first 50 feet of movement.

The operator should drive the apparatus for 20 to 30 minutes. During this time, the steering mechanism, braking system, transmission, and all other systems should be checked for proper function.

If the chassis **air intake system** is equipped with an air filter restriction gauge, it should indicate a “green” condition or another proper indication. If the gauge shows “red” or another color indicating a restriction, then the air filter probably needs to be changed. Because this system requires vacuum to operate, it can only be checked with the engine running.

After the driver/operator has completed the operational road evaluation, the apparatus should be taken to an area where the driver/operator can check the fire pump. The operator will secure the unit by applying the parking brake and wheel chocks, and then proceed to test the pump engagement device, which is the road-to-pump shift. Engagement of the pump should be smooth and the appropriate warning lights should operate as designed to indicate that the pump is properly engaged. When the pump is engaged, the engine's transmission is engaged to the fire pump impeller shaft allowing water to be moved through the pump.

Practical Tip → When the pump is engaged the speedometer will usually indicate a moderate speed. This is a double-check that the vehicle's transmission has engaged the fire pump. Although the speedometer is registering a "speed," the apparatus is not moving and has the parking brake on and the wheels chocked according to the manufacturer's requirements. The operator can then proceed with pumping water. However, it is important to understand that not all speedometers react this way.

A simple fire pump test

The fire pump can be tested by opening the booster "tank-to-pump" valve, operating the priming device, and discharging the water back into the booster tank through the "tank fill" or "pump-to-tank" plumbing. The throttle can be advanced and the appropriate pressure increase can be noted. Depending on the size of the piping in the tank fill system, the operator in most cases should only open the tank fill valve half way to avoid any possibility of causing "cavitation" in the pump. Pump pressure in this test should not exceed 150 psi when filling the tank. The operator can also do a check of the unit's pressure control devices.

Most relief valves and pressure governor systems can be checked while pumping in this manner. Transfer valves should also be operated to ensure proper operation (see Unit 2 Lesson 1, above).

Note: Cavitation occurs when a pump tries to discharge more water than is being taken in. Air bubbles form inside the pump under vacuum where they collapse and fill with liquid, causing shockwaves in the pump. Cavitation is sometimes expressed as the pump "running away from water." See Appendix F for more details about cavitation and its warning signs.

NOTES

The Fire Pump Service Test

A fire pump performance test shall be done on an annual basis in accordance with the NFPA 1911 standard (Standard for the Inspection, Maintenance, Testing, and Retirement of In-Service Automotive Fire Apparatus). This test will assess the function of the priming system as well as the main fire pump and is the only way to tell if the pump is capable of delivering its rated capacity.

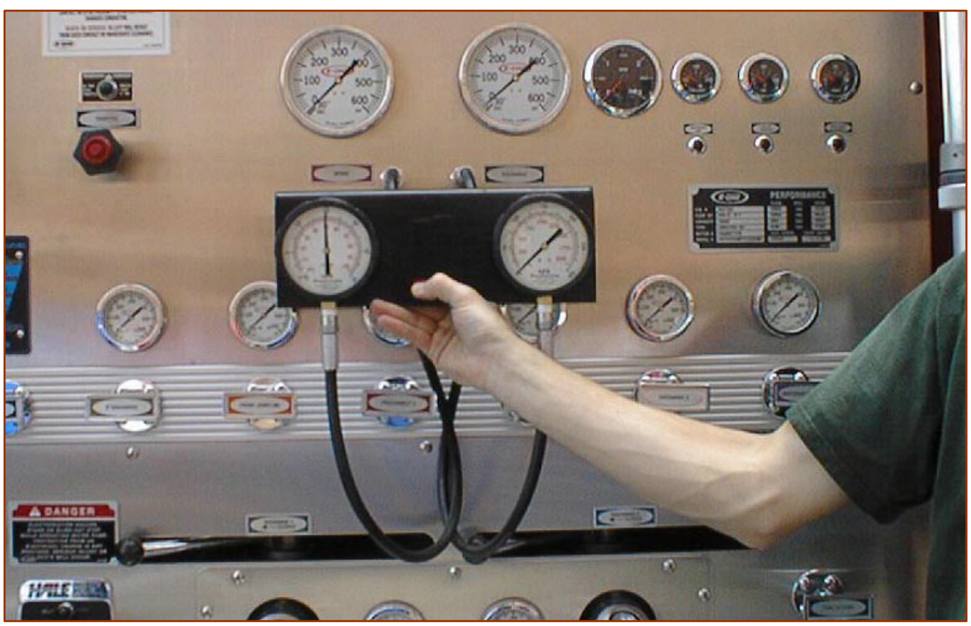
In addition to demonstrating whether the pump can deliver its rated capacity, this test will indicate the overall condition of the pump. The usual cause of a pump not reaching its rated capacity is excess wear of the clearance rings. As the pump ages, the rings wear and the pump becomes more inefficient. This results in the engine using more horsepower for the unit to meet its capacity. As the wear continues, the unit eventually runs out of horsepower and the pump will need to be rebuilt or have its water delivery rating lowered.

Vacuum (Dry Prime) Test

This procedure can be done on a weekly or monthly basis to check the priming system and the pump for any air leaks or other deficiencies.

Conduct this test as follows:

1. Drain the pump of all water
2. Check to see that all drain valves are closed
3. Remove any discharge caps
4. Close all discharge valves
5. Open all intake valves and cap or plug them tightly
6. Activate the primer and observe the master intake gauge until at least 22 inches or more vacuum is obtained
7. Shut off engine and listen for any obvious air leaks while observing the master intake gauge. The pump should not lose more than 10 inches of vacuum in 5 minutes. If the pump fails to hold a vacuum, it must be repaired.



This photo illustrates the use of calibrated test gauges during a dry prime test.

NOTES

DOCUMENTATION

Whether the pumper is inspected and tested on a daily, weekly, or monthly basis, proper documentation must be in place to ensure proper operation. Inspection and test sheets can range from very simple check-off sheets listing fuel level, oil and water levels, booster tank water level, and general condition, to more complex forms, which include pumper-testing results, specific repairs that have been (or should be) completed, and in-depth road test reports that cover all areas of performance.

Proper documentation helps to ensure that any deficiencies will be noted so that repairs can be made. Good inspection practices and record keeping will help maintenance personnel keep the apparatus at full response capability. This will also establish a record of the apparatus' history useful for budget, maintenance, and repair considerations.

STUDENT ACTIVITY

Student will perform a walk-around inspection of apparatus as well as a dry prime test and a basic pump test. See Appendix G for a basic apparatus inspection worksheet.

SUMMARY

Many pump failures can be prevented with proper maintenance and repair. When lives of civilians and firefighters depend on the proper functioning of the apparatus, everything that can be done to assure proper function is imperative. Good inspection, documentation, and testing of fire department apparatus is the first step in maintaining the firefighter's goal of saving lives and property.

NOTES

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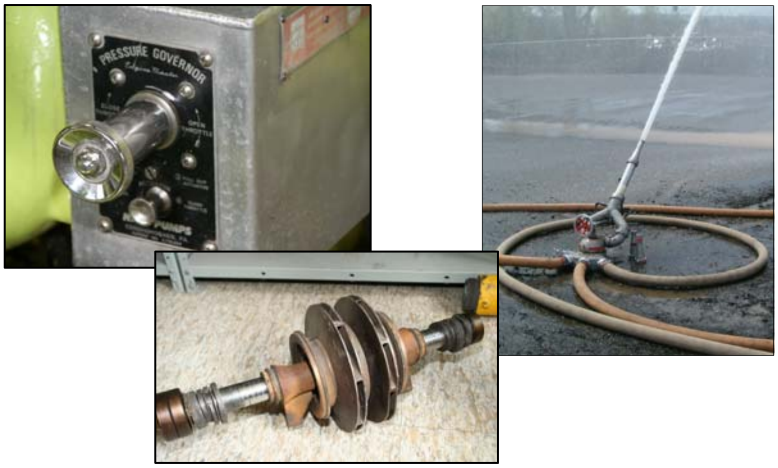
NOTES

UNIT 3 – Hydraulic Principles and Practice



Objectives

At the conclusion of this lesson, students will:

- List and discuss the properties of water
- Explain and define pressure as it relates to fire pump hydraulics
- Discuss the 6 principles of pressure
- Define and describe friction loss and its 4 principles
- Understand the different hydraulic formulas
- Define and understand the NFA fire flow formula
- Understand Fire Pump Ratings
- Perform the needed hydraulic calculations

NOTES

Lesson 1 – Hydraulics

Hydraulics is the branch of science that studies fluids either at rest or in motion.

The "Problem…"

Learning about hydraulics is often perceived as difficult and confusing because of:

- a fear or lack of basic math skills
- not understanding the basic facts about hydraulics
- learning only what have become known as "Rules of Thumb" without learning the underlying principles

The "Solution…"

Learning about hydraulics can be interesting and useful as long as each student:

- learns the basic concepts
- reviews and refreshes basic math skills
- works to apply what is learned to fire pump operation

Physical Properties of Water

Water is made up of hydrogen and oxygen. Together, these components form a substance that is:

- colorless
- odorless
- tasteless
- incompressible

Water can exist in any of 3 states; these are solid, liquid, and gas. Importantly, water expands its volume when it changes from a liquid to a gas (steam). This is known as thermal expansion.

When water expands to steam (at 212°F and 14.7 psi) the volume increased 1,700 times. We say that this is a 1-to-1,700 expansion by volume. This is usually written as 1:1,700 (volume:volume).[1]

Additional facts about water can be found in the IFSTA Essentials of Firefighting, 4th Edition, pages 487-489.

[1]IFSTA Essentials of Firefighting, 4th Edition, p. 488.