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MAKING THE RIGHT CHOICE FOR A FIRE PUMP DRIVER AND POWER SOURCE, DIESEL ENGINE, OR ELECTRIC MOTOR

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I. ABSTRACT

The conventional wisdom within the fire protection industry is that an electric motor driven fire pump is almost always cheaper than a diesel engine driven pump, therefore, electric motor driven fire pumps are utilized except when reliable electric power is unavailable or when a backup fire pump is required to provide increased reliability.

The purpose of this study is to review the advantages and disadvantages of both electric motor driven and diesel engine driven fire pumps, and when each is the appropriate choice. NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection,* also recognizes steam turbine driven fire pumps, however, very few locations have a reliable source of steam, thus, steam turbine driven fire pumps are rare and will not be considered in the article.

II. INTRODUCTION

Selecting the appropriate fire pump rating is beyond the scope of this study, so it is assumed the appropriate pump size is known. The cost of fire pump maintenance and operation is factored into this analysis, while the requirements for fire pump maintenance is beyond its scope. Discussions of reliability are based on the following assumptions:

- Fire pumps are installed according to NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection.*
- Fire pumps are maintained according to NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems.*
- Emergency generators are installed according to NFPA 110, *Standard for Emergency and Standby Power Systems.*

The primary considerations in selecting a fire pump driver are reliability, exposed value, life safety protection needs, initial cost, maintenance cost, operating cost, safety, and other design issues. Each of these are considered in this analysis.

III. RELIABILITY

The cause of most fire protection system failures can be eliminated by installing the fire protection system and components in accordance with the appropriate NFPA standards, maintaining the fire protection systems in accordance with NFPA 25, and providing remote supervision in accordance with NFPA 72, *National Fire Alarm Code*.

Inadequate data is available to quantify reliability to a high degree of certainty. However, it is beneficial to understand the effect of the fire pump driver and its power source on the expected fire loss. Although subjective, reliability factors are presented for discussion and used in this analysis. The reliabilities used in this exercise are the author's best estimate.

A. Reliability of an Electric Motor Driver for Fire Pumps

For the purpose of calculating the expected loss in the event of a fire, it is assumed that an electric motor driving a fire pump will fail one out of every 10,000 fires, 0.01% of the time.

B. Reliability of a Diesel Engine Driver for Fire Pumps

Diesel engine driven fire pumps are not affected by power outages, and are designed to be more reliable than automotive, truck or standby diesel generator set engines. Most of the reasons that engines fail to start are minimized or eliminated in a fire pump installation. The fire pump diesel engine is not subjected to cold temperature, and backup batteries are a part of every fire pump installation, batteries are monitored, and the engine is tested weekly for 30 minutes. The fuel level is supervised. For purposes of calculating the expected loss in the event of a fire, it is assumed that a properly installed and maintained diesel engine driven fire pump will fail one out of 1,000 fires, 0.1% of the time.

C. Reliability of a Fire Pump

Fire pumps are highly reliable but may fail because of cavitation, rocks entering the impeller, or mechanical failure. Testing can eliminate most of these problems. For purposes of calculating the expected loss in the event of a fire, it is assumed that a fire pump will fail one out of 5,000 fires, 0.02% of the time.

D. Reliability of Single Source Electric Power for an Electric Motor

NFPA 20 requires the power supply to an electric motor driven fire pump to be reliable, but does not define reliable. The reliability of the electric power is affected by many things, including natural disasters, transformer or sub-station failure, utility grid maintenance, etc. In August 2003, much of the northeastern grid covering parts of New York, New Jersey, New England, Pennsylvania, Ohio, Michigan, and several Canadian provinces was blacked-out up to several days. Hurricane Isabel caused massive power outages the following month, up and down the east coast. Since 1999, the utility company serving Chicago, Illinois, has experienced various outages, some lasting three to four days. Downtown Chicago recently experienced outages involving multiple substations.

The loss of power and the start of a fire cannot be viewed as entirely independent events, i.e., there is a higher likelihood of having a fire during a power outage. Storms, lightning strikes, tornados, hurricanes and terrorism may cause both a power outage and a fire. The reaction to a power outage may also result in a fire, as when using candles during a power outage may lead to a fire. For purposes of calculating the expected loss in the event of a fire, it is assumed that a single source electric power supply will fail one out of 100 times, i.e., power will not be available for the fire pump one out of every 100 fires, 1% of the time.

E. Reliability of Electric Power from Two Substations for an Electric Motor

Providing a backup power source can increase the reliability of electric motor driven pumps. Backup power can be from a different substation or from an onsite generator. Theoretically, if one power source is 99% reliable (fails one out of 100 times), two totally independent power sources would be 99.99% reliable (both fail simultaneously one out of 10,000 times). However, while backup power from a second substation improves reliability, substations are not totally independent. Events that cause the loss of power at one substation may cause loss of power at other substations, as with the northeast outage. Storms, lightning strikes, tornados, hurricanes, generator and grid outages are examples that may cause power outages at multiple substations. For purposes of calculating the expected loss in the event of a fire, it is assumed that power supplied from two substations will fail one out of 200 fires, 0.5% of the time.

F. Reliability of Electric Power from a Utility and an On-Site Emergency Generator for an Electric Motor

Properly installed and maintained emergency generators increase the reliability of an electric motor driven fire pump. However, there are significant differences between NFPA 20 diesel engine fire pump drivers and NFPA 110 emergency generator drivers, summarized in Table 1.

The difference in installation and testing requirements make a diesel engine driven fire pump more reliable than an emergency generator. For purposes of calculating the expected loss in the event of a fire, it is assumed that an on-site generator will fail one out of 100 times, 1% of the time.

G. Summary of Reliability and Expected Loss

Statistically, the probability of two totally independent events occurring simultaneously is the product of the probability of each event. So if a utility fails one out of 100 fires (99% reliable), and an emergency generator fails one out of 100 fires (99% reliable), the probability of both failing at the same time is one out of 100 x 100 or 10,000 (99.99% reliable).

For simplification in this exercise, it is assumed that if the fire pump operates, the loss is zero, and if the fire pump fails to operate, the loss is total. Table 2 translates the above failure probabilities into reliability percentages, then compares the various fire pump drivers and power sources in terms of expected losses for a $10 million exposure. The reader may adjust these assumptions, should a more detailed analysis be desired.

Table 1
COMPARISON OF REQUIREMENTS FOR DIESEL ENGINE DRIVERS FOR FIRE PUMPS AND EMERGENCY GENERATORS

Requirement for Diesel Engine Fire Pump Drivers (NFPA 20)	Requirement for Emergency Generator Drivers (NFPA 110)
Dual Battery Sets	Single Battery Set
Dual Battery Chargers	Single Battery Charger
Engine Cranking Time – 90 seconds	Engine Cranking Time – 45-75 seconds
Manual Operation – Completely bypasses all control panel circuits and interconnects.	Manual Operation - Dependent on the control panel circuits.
Run to Destruction Operation – Shutdown only on overspeed condition, will otherwise run to destruction to save the facility.	Will Not Run to Destruction – Will shutdown on overspeed, high water temperature, and low oil pressure to save the engine.
Engine Reliability - Only otto ignition (diesel) engines allowed.	Engine Reliability - Spark ignition engines allowed.
Fuel Supply - A separate supply, containing a minimum eight hours' supply dedicated to each fire pump.	Fuel Supply – Dependent on classification, can be as little as five minutes. Allows sharing of fuel supply with other loads. Allows utility gas supply (for spark ignited natural gas engine)
Dedicated Purpose – Fire pump only allowable load.	Not Dedicated to Fire Pump – Can supply multiple loads in addition to the fire pump and may depend on load dumping logic to provide sufficient capacity to power the fire pump.
Run Testing - Weekly testing required.	Run Testing – Monthly testing required.
Reserve Power - Requires 10% reserve power.	Reserve Power - No reserve power requirement.
Performance Assurance - Required to be listed by independent 3rd party confirming performance.	Performance Assurance - No 3rd party confirmation of performance.
Testing Under Load – Annual flow test under full flow pump load.	Testing Under Load – No requirement to ever test the fire pump at full flow pump load while powered by the emergency generator to verify capability.
Engine Heater – Maintains engine at 120°F for quick starting.	Engine Heater – Not Required.
Automatic Transfer Switch - Not Required.	Automatic Transfer Switch - Additional component in the system with it's own additional Reliability factors.
Circuit Breaker - Not Required.	Circuit Breaker - Unsupervised and is an additional component in the system with it's own additional Reliability factors.

Reliabilities are assumed for a diesel engine driven fire pump, an electric motor driven fire pump, an on-site emergency generator, and two substations, and the anticipated loss in the event of a fire is calculated as a percentage of the total value at risk.

Table 2 **FAILURE PROBABILITIES AND EXPECTED LOSSES WITH DIFFERENT PUMP DRIVERS AND POWER SOURCES**			
Fire Pump Driver and Power Source	Failure Probability	Reliability Percentage	Expected Loss with $10,000,000 Exposure[2]
Power Supply Reliability			
Power from Single Utility	1.000%[1]	99.000%	
Power from Two Substations	0.500%[1]	99.500%	
Emergency Generator	1.000%[1]	99.000%	
Pump Reliability	0.020%[1]	99.900%	
Pump Driver Reliability			
Diesel Engine Fire Pump Driver	0.100%[1]	99.900%	
Electric Motor Fire Pump Driver	0.010%[1]	99.990%	
Reliability of Power Supply and Electric Motor Driven Fire Pump Combination			
Single Utility	1.0297%	98.9703%	$102,970
Two Substations	0.5298%	99.4702%	$52,985
Utility and Emergency Generator	0.0400%	99.9600%	$4,000
Reliability of Diesel Engine Driven Fire Pump (Engine and Pump)	0.1200%	99.8800%	$11,998
Dual Electric Motor Driven Pumps with Emergency Generator Backup	0.0100%	99.9900%	$1,001
One Diesel and One Electric Pump Without Emergency Generator Backup	0.0012%	99.9988%	$124
Dual Diesel Engine Driven Pumps	0.0001%	99.9999%	$14

[1] Failure probability based on author's best estimate.
[2] Expected loss for a single fire, assuming a negligible loss if the fire pump operates, and a total loss if the fire pump fails to operate. The expected loss is presented to aid in evaluating reliability issues. The exposed value includes the building, contents, and business interruption potential and liability exposure.

In summary, a highly reliable (greater than 99.75% reliable) fire pump can be provided by either:

1) Using a properly installed and maintained diesel engine;
2) Connecting an electric pump to both a public utility and an emergency generator.

For high value facilities, dual fire pumps provide significant reduction in the expected loss, with dual diesel engine driven fire pumps providing the lowest expected loss.

IV. FIRE PUMP DESIGN PHILOSOPHY

Before reviewing the selection considerations, it is appropriate to discuss fire pump design philosophy. When a fire pump is called upon to run under emergency conditions, it must be given every opportunity to run, even when it may be damaged by continued operation. NFPA 20 considers a fire pump "expendable", and the requirements are focused on getting the pump started and running continuously, and only secondarily on protecting the pump from damage.

V. INSTALLATIONS EVALUATED

Table 3 shows a representative sample of fire pump installations that were used for this cost comparison.

Table 3
SAMPLE FIRE PUMP INSTALLATIONS

	Sample Installations I.D.					
Pump Ratings	1	2	3		4	5
Flow – gpm	1,500	1,500	1,000	1,000	2,500	750
Pressure - psi	100	150	150	150	150	150
Pump – hp	125	200	130	130	330	70
Electric Motor - hp	125	200	125	125	300	75
Diesel Engine - hp	127	200	130	130	330	72
Application	Big Box retail store, i.e. Wal*Mart, Target, Lowe's	High-rise application	Two fire pumps arranged in series for high-rise application		Ware-house storage or industrial application	Retail store without high piled storage
Typical Exposed Value (Millions of Dollars)	30-50	20-80	80-100		10-200+	1-50

VI. DESIGN/COST CONSIDERATIONS

A. Power Supply

When the site's transformer is installed and owned by the utility company, (typically a larger transformer is required to supply an electric motor driven fire pump), the additional cost of the transformer is built into the rates charged by the utility company. If the owner is required to pay for the transformer, it is likely that a diesel engine fire pump will cost less that the total cost of the electric motor driven fire pump including transformer.

There are too many variables in determining the cost of utilizing a second substation to supply backup power to the fire pump to provide a cost comparison that is representative of all installations. However a comparison is provided assuming a transmission distance of ½ mile of flat terrain with the cost borne by the owner. If the electrical usage for the project is sufficient high, it may be possible to negotiate with the utility company to pay the initial cost of the second feed. For this exercise, the transformer included in the cost was sized for the fire pump only. An emergency generator provides a more reliable, and in most cases, a more economical backup power supply.

The yearly cost for electricity is the charge for the actual electricity used at a typical cost of $0.07 per kilowatt hour, plus the demand usage charge. For this analysis, the demand usage was assumed to be $0.00/kw for 0-35 kw, $3.32/kw for 35-115kw, and $6.67/kw above 115kw, and it is assumed that the demand charge is on a monthly basis. The demand charge could be reduced by testing during off-peak hours, however, even if the testing is done during off-peak hours, the peak demand charge cannot be completely eliminated because there will be times when the fire pump is required to run during peak hours. For this analysis, calculations have been made for testing the fire pump during peak usage and during off-peak usage.

B. Power Supply Feeder

The significant variable in the installation cost of an electric motor driven fire pump is the length of the electric feeder from the transformer to the fire pump. The cost of electrical feeds used for this study is shown in Table 4.

Table 4
INSTALLED COSTS OF ELECTRICAL FEEDERS FOR FIRE PUMPS

Pump Example Reference	1	2	3 (2) pumps	4	5
Rated Flow (gpm)	1,500	1,500	1,000	2,500	750
Rated Pressure (psi)	100	150	150	150	100
Horse Power	125	200	125	300	75
Feeder Size (amps)	150	250	150	400	100
Feeder Cost/ft	$33	$44	$33	$62	$24

Table 5 shows the approximate feeder lengths at which the installed cost of an electric driven fire pump, supplied from a single utility without emergency generator backup, and the cost for a diesel engine driven fire pump are the same for different fire pump examples.

Table 5
APPROXIMATE LENGTH OF FEEDER WHEN THE INSTALLED COST OF ELECTRIC MOTOR AND DIESEL ENGINE DRIVEN FIRE PUMPS EQUALIZE

Pump Example Reference	1	2	3 (2) pumps	4	5
Rated Flow (gpm)	1,500	1,500	1,000	2,500	750
Rated Pressure (psi)	100	150	150	150	100
POWER SUPPLY	Length of Feeder (feet)				
Single Source Power Supply, Across the Line Controller	579	405	578	474	760
Single Source Power Supply, Reduced Voltage Starter	388	279	387	316	603

C. **Cost Tables**

The following tables show the installed, maintenance and operating cost for the representative sample of fire pumps.

- Table 6a - Installed and Current Value Costs for Electric Motor Driven Fire Pump With Single Utility Source
- Table 6b - Installed and Current Value Costs for Electric Motor Driven Fire Pump With Two Substation Utility Source
- Table 6c - Installed and Current Value Costs for Electric Motor Driven Fire Pump With Generator Back-Up
- Table 6d - Installed and Current Value Costs for Diesel Engine Driven Fire Pumps

1. Cost Table 6a Electric Pump With Single Utility Power Source

Table 6a INSTALLED AND CURRENT VALUE COSTS FOR ELECTRIC MOTOR DRIVEN FIRE PUMP WITH SINGLE UTILITY SOURCE							
Pump I.D.			1	2	3 (2 pumps)	4	5
Rated Flow (gpm)			1,500	1,500	1,000	2,500	750
Rated Pressure (psi)			100	150	150	150	100
Base Cost Fire Pump with Across the Line Starter Controller[1]			$18,870	$23,145	$37,920	$29,378	$14,205
Installation Cost			$6,800	$7,650	$13,600	$8,500	$5,950
Cost 200 ft. of Feeder			$6,600	$8,800	$13,200	$12,400	$4,800
Total Installed Cost	w/Across the Line Starter		$32,270	$39,595	$64,720	$50,278	$24,955
	w/Reduced Voltage Starter[1]		$38,570	$45,135	$77,320	$60,098	$28,725
Electricity for Weekly Test (kilowatt hours)			$21	$35	$71	$56	$85
Yearly Cost for Electricity Usage @ $0.07/kwH[3]			$189	$302	$377	$452	$113
Yearly Demand Charge [3] @$6.37/kw	Peak Usage Testing		$2,574	$4,290	$8,580	$6,864	$10,296
	Off-Peak Usage Testing		$90	$842	$2,977	$2,338	$4,693
Annual Test			$850	$850	$800	$900	$750
Yearly Maintenance[2]			$807	$990	$1,618	$1,257	$624
Total Yearly Cost	Peak Usage Testing		$4,252	$6,165	$11,069	$9,078	$11,755
	Off-Peak Testing		$1,768	$2,717	$5,465	$4,551	$6,151
Present Value of Installation and Yearly Maintenance and Operating Cost Over 20 Years @ 10% Interest	**Peak Usage Testing**	**Across the Line Starter**	$68,471	$92,084	$158,954	$127,560	$125,030
		Reduced Voltage Starter	$74,771	$97,624	$171,554	$137,380	$128,800
	Off-Peak Usage Testing	**Across the Line Starter**	$47,325	$62,725	$111,249	$89,027	$77,325
		Reduced Voltage Starter	$53,625	$68,265	$123,849	$98,847	$81,095
	No Demand Charges	**Across the Line Starter**	$46,557	$55,561	$85,907	$69,123	$37,374
		Reduced Voltage Starter	$52,857	$61,101	$98,507	$78,943	$41,144

Table 6a INSTALLED AND CURRENT VALUE COSTS FOR ELECTRIC MOTOR DRIVEN FIRE PUMP WITH SINGLE UTILITY SOURCE
(1) The controller cost is based on the utility having sufficient power to support an across the line starter. Reduced voltage starters will add 30-100% to the controller cost. A Wye Delta Closed Transition reduced voltage starter is used for this price comparison. (2) Yearly maintenance cost assumed to be 2.5% of installation cost. (3) Demand charge based on $0.00kW for 0-35kW, $3.32/kW for 35-115kW, and $6.67/kW above 115kW. Peak usage testing based on $6.67kW. Weekly churn test for 10 minutes requires 50% of full load, yearly test requires full load.

2. Cost Table 6b Electric Pump With Power From Two Substations

Table 6b
INSTALLED AND CURRENT VALUE COSTS FOR ELECTRIC MOTOR DRIVEN FIRE PUMP WITH TWO SUBSTATION UTILITY SOURCE

Pump I.D.			1	2	3 (2 pumps)	4	5
Rated Flow (gpm)			1,500	1,500	1,000	2,500	750
Rated Pressure (psi)			100	150	150	150	100
Cost 200 ft. of 2nd Feeder			$6,600	$8,800	$13,200	$12,400	$4,800
Cost to bring 2nd substation feeder to premises and feeder switching equipment (1)			$39,810	$43,410	$43,410	$47,510	$39,810
Transfer Switch			$12,146	$12,514	$24,292	$13,568	$11,284
Total Additional Installed Cost			$58,556	$64,724	$80,902	$73,478	$55,894
* Present Value of Installation and Yearly Maintenance and Operating Cost Over 20 Years at 10% Interest	Peak Usage Testing	Across the Line Starter	$127,028	$156,808	$239,856	$201,038	$180,924
		Reduced Voltage Starter	$133,328	$162,348	$252,456	$210,858	$184,694
	Off-Peak Usage Testing	Across the Line Starter	$105,881	$127,449	$192,151	$162,505	$133,219
		Reduced Voltage Starter	$112,181	$132,989	$204,751	$172,325	$136,989
	No Demand Charges	Across the Line Starter	$105,114	$120,285	$166,809	$142,601	$93,268
		Reduced Voltage Starter	$111,414	$125,825	$179,409	$152,421	$97,038

(1) Assumes cost is borne by owner to bring power from 2nd substation located ½ mile from site, terrain is flat.

* Includes the incremental cost from this Table and the total cost from Table 6a.

3. Cost Table 6c Electric Pump With Generator Back-up

Table 6c INSTALLED AND CURRENT VALUE COSTS FOR ELECTRIC MOTOR DRIVEN FIRE PUMP WITH GENERATOR BACK-UP							
Pump I.D.			1	2	3 (2 pumps)	4	5
Rated Flow (gpm)			1,500	1,500	1,000	2,500	750
Rated Pressure (psi)			100	150	150	150	100
Base Generator Size (kw)			350	350	350	350	350
Generator Size with Pump (kw)			350	350	450	450	350
Generator Cost Differential			$0	$2,000	$25,000	$25,000	$0
Cost for Feeder (200 ft)			$6,600	$8,800	$13,200	$12,400	$4,800
Transfer Switch			$12,146	$12,514	$24,292	$13,568	$11,284
Total Additional Installed Cost	w/Across the Line Starter		$51,016	$62,909	$127,212	$101,246	$41,039
	w/Reduced Voltage Starter		$57,316	$70,449	$139,812	$111,066	$44,809
*** Present Value of Installation and Yearly Maintenance and Operating Cost Over 20 Years at 10% Interest**	**Peak Usage Testing**	**Across the Line Starter**	$119,487	$154,993	$286,166	$228,806	$166,069
		Reduced Voltage Starter	$125,787	$162,533	$298,766	$238,626	$169,839
	Off-Peak Usage Testing	**Across the Line Starter**	$98,341	$125,634	$238,461	$190,273	$118,364
		Reduced Voltage Starter	$104,641	$133,174	$251,061	$200,093	$122,134
	No Demand Charges	**Across the Line Starter**	$97,573	$118,470	$213,119	$170,369	$78,413
		Reduced Voltage Starter	$103,873	$126,010	$225,719	$180,189	$82,183

* Includes the incremental cost from this Table and the total cost from Table 6a.

4. Cost Table 6d Diesel Engine Driven Fire Pump

Table 6d INSTALLED AND CURRENT VALUE COSTS FOR DIESEL ENGINE DRIVEN FIRE PUMPS					
Pump I.D.	1	2	3 (2 pumps)	4	5
Rated Flow (gpm)	1,500	1,500	1,000	2,500	750
Rated Pressure (psi)	100	150	150	150	100
Horsepower	127	200	130	330	72
Base Cost	$37,298	$40,298	$75,406	$58,095	$31,785
Installation Cost	$6,800	$7,650	$13,600	$8,500	$5,950
Installed Cost of Pump	$44,098	$47,948	$89,006	$66,595	$37,735
Cost of Diesel Engine Exhaust	$600	$709	$1,200	$1,170	$255
Fresh Air Louvers	$65	$77	$130	$127	$46
Total Installed Cost of Diesel Engine Fire Pump	$44,763	$48,613	$89,671	$67,260	$38,400
Fuel for Weekly Test (gals.)	8.9	13.1	18.8	22.5	4.5
Yearly Cost for Fuel	$740	$1,090	$1,564	$1,872	$374
Yearly Maintenance	$850	$850	$800	$900	$750
Total Yearly Cost	$1,590	$1,940	$2,364	$2,772	$1,124
Present Value of Installation and Yearly Maintenance and Operating Cost Over 20 Years @ 10% Interest	$58,304	$65,250	$110,463	$91,492	$47,609

VII. SUMMARY

Table 7 provides a comparison of the present value cost of installation, maintenance and operating costs, for each of the 5 sample installations, each with the following fire pump driver and power source and electric cost combinations:

1. Electric Motor Driven

   - o Single Utility Source
     - Testing During Peak Demand
     - Testing During Non-Peak Demand
     - No Demand Charges

   - o Dual Utility Source from Two Subststions
     - Testing During Peak Demand
     - Testing During Non-Peak Demand
     - No Demand Charges

   - o Single Utility Source with Generator Back-up
     - Testing During Peak Demand
     - Testing During Non-Peak Demand
     - No Demand Charges

2. Diesel Engine Driven

A. Cost Summary Table 7

Table 7

COMPARISON OF PRESENT VALUE INSTALLED, OPERATING AND MAINTENANCE COSTS FOR ELECTRIC MOTOR DRIVEN, ELECTRIC MOTOR WITH GENERATOR BACKUP, AND DIESEL ENGINE DRIVEN FIRE PUMPS

	Pump I.D.	1	2	3 (2 pumps)	4	5
	Rated Flow (gpm)	1,500	1,500	1,000	2,500	750
	Rated Pressure (psi)	100	150	150	150	100
When Testing During Peak Demand Rates	**Electric Motor with Across the Line Starting**					
	with Single Utility	$68,471	$92,084	$158,954	$127,560	$125,030
	with Two Utilities	$127,028	$156,808	$239,856	$201,038	$180,924
	with Gen Back-Up	$119,487	$154,993	$286,166	$228,806	$166,069
	Electric Motor with Reduced Voltage Starting					
	with Single Utility	$74,771	$97,624	$171,554	$137,380	$128,800
	with Two Utilities	$133,328	$162,348	$252,456	$210,858	$184,694
	with Gen Back-Up	$125,787	$162,533	$298,766	$238,626	$169,839
	Diesel Engine					
		$58,304	$65,250	$110,463	$91,492	$47,609
When Testing During Non-Peak Demand Rates	**Electric Motor with Across the Line Starting**					
	with Single Utility	$47,325	$62,725	$111,249	$89,027	$77,325
	with Two Utilities	$105,881	$127,449	$192,151	$162,505	$133,219
	with Gen Back-Up	$98,341	$125,634	$238,461	$190,273	$118,364
	Electric Motor with Reduced Voltage Starting					
	with Single Utility	$53,625	$68,265	$123,849	$98,847	$81,095
	with Two Utilities	$112,181	$132,989	$204,751	$172,325	$136,989
	with Gen Back-Up	$104,641	$133,174	$251,061	$200,093	$122,134
	Diesel Engine					
		$58,304	$65,250	$110,463	$91,492	$47,609
No Demand Charges	**Electric Motor with Across the Line Starting**					
	with Single Utility	$46,557	$55,561	$85,907	$69,123	$37,374
	with Two Utilities	$105,114	$120,285	$166,809	$142,601	$93,268
	with Gen Back-up	$97,573	$118,470	$213,119	$170,369	$78,413
	Electric Motor with Reduced Voltage Starting					
	with Single Utility	$52,857	$61,101	$98,507	$78,943	$41,144
	with Two Utilities	$111,414	$125,825	$179,409	$152,421	$97,038
	with Gen Back-up	$103,873	$126,010	$225,719	$180,189	$82,183
	Diesel Engine					
		$58,304	$65,250	$110,463	$91,492	$47,609

Design, reliability, installation cost, and current value cost issues have been reviewed for diesel engine and electric motor driven fire pumps. Reliability is summarized in Table 2 based on the author's best estimate and assumptions as outlined in this article.

Diesel engine driven fire pumps are more reliable than electric motor driven fire pumps with power from a single utility, or two substations. The reliability of a diesel engine driven fire pump is slightly less than an electric motor driven fire pump with power available from both a utility and an emergency generator. The simplified expected loss shown in Table 2 provides a way of evaluating reliability. When exposed values exceed $10 million, increased reliability (diesel engine driven fire pump or electric motor driven fire pump with emergency generator back-up) is clearly justified.

VIII. CONCLUSIONS

A. In general, when the transformer is supplied by the utility and the feeder is not too long, electric motor driven pumps with a single utility power source and utility furnished transformer can be installed for less than diesel engine driven pumps. The cost differential is less when a reduced voltage starter is required for the electric motor driven fire pump. The other significant variable in the total installed cost is the length of the electric feed from the transformer to the electric motor. This can quickly make the electric motor driven fire pump more expensive than the diesel driven fire pump. When the exposed value is low ($10 million or less) the decreased reliability of an electric motor driven fire pump with power from a single utility may be acceptable (expected loss increases by $90,972).

B. Diesel engine driven pumps provide a better value when considering installed cost and expected loss when the exposed value is moderate ($10 million to $100 million).

C. The installed cost of diesel engine driven fire pumps is less than electric motor driven fire pumps with a dual power source (i.e., an emergency generator or two substations), and provides nearly the equivalent reliability to a system with an emergency generator and greater reliability than two substations.

D. For high exposed value (>$100 million), dual pumps (two diesel engine driven or one diesel engine driven and one electric motor driven) with independent water supplies, are needed to provide suitable reliability.

E. Some events that cause a power outage may also cause a fire (i.e. lightning, tornados, hurricanes). This effect is not factored into the numerical estimates of this analysis.

F. In areas that may be subjected to prolonged power outages, the reliability of an electric fire pump supplied from a utility without emergency power decreases and the expected loss increases accordingly. The cost justification of installing a more reliable pump may be realized at significantly lower exposed values than identified in Conclusion A.

G. Increased reliability should also be provided whenever there are significant life safety considerations. Many health care facilities, i.e. nursing homes and assisted care living facilities, have immobile patients who are difficult to evacuate. Assembly occupancies have high population densities where crowd control and evacuation issues necessitate increased fire pump reliability.

H. Lastly, the electricity demand charge has a significant impact on yearly maintenance and present value cost for electric fire pumps. In general, in areas with significant demand charges for electricity, present value cost for a diesel engine is less than for an electric motor driven fire pump when the pump's electrical demand exceeds electrical demand for other uses. Caution should be exercised when selecting a fire pump driver based upon No Demand Charges for electricity. Most utility companies will have some demand charge in their rate structure. It may also be difficult, in actual practice, to limit fire pump testing to Non-Peak Demand hours.

The break points between low, medium, and high exposed values used for this article are somewhat arbitrary and should be reviewed with the loss prevention department and the insurance company for the facility under consideration.

IX. REFERENCED DOCUMENTS

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection.*
NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems.*
NFPA 72, *National Fire Alarm Code.*
NFPA 110, *Standard for Emergency and Standby Power Systems.*