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FPL

OCTOBER 1 9 1988

L-88-454

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D. C. 20555

Gentlemen:

Re: Turkey Point Units 3 and 4
Docket Nos. 50-250 and 50-251
<u>Emergency Power System Enhancement Project</u>

Florida Power & Light Company (FPL) has initiated a project to enhance the emergency power distribution system at the Turkey Point Nuclear Plant as described in our report transmitted per letter L-88-269, dated June 23, 1988. As part of this project, two additional safety-grade emergency diesel generators (EDG's) will be installed onsite to increase the capacity of the emergency power supply system. The two new EDG's obtained for this project are similar in design to the existing Turkey Point EDG's and several in service at other nuclear plants.

Our EDG supplier for this project (Morrison-Knudsen Company, Power Systems Division), has determined that the new EDG's do not require a 300 Start and Load Acceptance Test in order to satisfy the qualification requirements of IEEE Standard 387-1984 and Regulatory Guide 1.9. It is our supplier's position that previous qualification testing on EDG's used in other nuclear applications is applicable to the new Turkey Point EDG's. As such, a complete 300 Start and Load Acceptance Test in accordance with Paragraph 7.2.2 of IEEE Standard 387-1984 is not required for qualification of the new EDG's. In lieu of a 300 Start and Load Acceptance Test, our supplier has recommended that a 30 Start and Load Acceptance Test be performed. All other qualification tests (i.e., Load Capability and Margin Tests) in accordance with IEEE 387-1984 will be performed for the new EDG's. The basis for our supplier's recommendation together with a complete description of the testing which will be performed to ensure reliability of the new EDG's is provided in the enclosure.

A015
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FPL has accepted our supplier's recommendation concerning qualification testing of the new EDG's and plans to proceed accordingly to support an EDG delivery date in early 1989. We ask that any questions regarding this matter be identified by November 23, 1988 in order to support the EDG delivery date.

Should you have any questions, please contact us.

Very truly yours,

W. F. Conway
Senior Vice President - Nuclear

WFC/TCG/gp

Enclosure

cc: Malcolm L. Ernst, Acting Regional Administrator, Region II, USNRC
Senior Resident Inspector, USNRC, Turkey Point Plant

ENCLOSURE

TURKEY POINT UNITS 3 & 4

EMERGENCY POWER SYSTEM ENHANCEMENT PROJECT

QUALIFICATION OF NEW EMERGENCY DIESEL GENERATORS

Background

Florida Power & Light Company (FPL) is installing two additional safety-grade emergency diesel generators (EDG's) at Turkey Point as part of an overall emergency power system enhancement project. The main purpose of the new EDG's is to increase the capacity of the on-site emergency power supply system. The new EDG's for this project are similar in design to the existing EDG's at Turkey Point, but have a higher capacity and feature design improvements to enhance resistance to wear and improve overall reliability.

Each new EDG unit is composed of a diesel engine manufactured by General Motors Electro-Motive Division (EMD) and a generator manufactured by NEI Peebles-Electric Products, Inc. The complete EDG assembly is supplied by the Power Systems Division of Morrison-Knudsen Company. The specific diesel for this project is the EMD Model 20-645F4B which replaces the qualified EMD 20-645E4.

Purpose

The purpose of this report is to demonstrate that the qualification on the EMD 20-645E4 engine is applicable to the current, improved EMD 20-645F4B engine.

Qualification Requirements

The qualification requirements for diesel-generator units applied as part of the standby power supply for nuclear power plants are specified in Section 7 of IEEE Standard 387-1984 as endorsed by Regulatory Guide 1.9. Qualification per the Standard is intended to provide verification that the unit will meet all applicable design and application considerations under expected environmental conditions. Qualification tests include Load Capability Tests, Start and Load Acceptance Tests, and Margin Tests as summarized below:

IEEE 387-1984

Section 7, Qualification Requirements
Paragraph 7.2.1, Load Capability Tests

These tests are to demonstrate the capability of the diesel generator unit to carry the following rated loads at rated power factor for the period of time indicated, and to successfully reject load. One successful completion of the test sequence shall satisfy this particular requirement.

1) Load equal to the continuous rating for the time required to reach engine temperature equilibrium.

2) Immediately following 7.2.1(1), the short-time rated load shall be applied for a period of two (2) hours and the continuous rated load shall be applied for a period of twenty-two (22) hours.

3) A short-time rating load rejection test shall be performed.

4) Light or no load capability shall be demonstrated by test. Light or no load operation shall be followed by a load application greater than or equal to 50 percent of the continuous kilowatt rating for a minimum of 0.5 hour.

Paragraph 7.2.2, Start and Load Acceptance Tests

A series of tests shall be conducted to establish the capability of the diesel-generator unit to start and accept load within the period of time to satisfy the plant design requirement. An acceptable start and load acceptance test is defined as follows; however, other methods with proper justification may be found equivalent for the level of reliability to be demonstrated:

A total of 300 valid start and loading tests shall be performed with no more than three (3) failures allowed. The start and load tests shall be conducted as follows:

1) Engine cranking shall begin upon receipt of start signal, and the diesel-generator set shall accelerate to specified frequency and voltage within the required time interval.

2) Immediately following (1), the diesel-generator set shall accept a single step load equal to or greater than 50 percent of the continuous kilowatt rating.

3) At least 270 of these tests shall be performed with the diesel-generator set initially at warm standby.

4) At least 30 tests shall be performed with the engine initially at normal operating temperature.

Paragraph 7.2.3, Margin Tests

Tests shall be conducted to demonstrate the diesel-generator set capability to start and carry loads that are greater than the magnitude of the most severe step load within the plant design load profile. At least two margin tests shall be performed using either the same or different load arrangement. A margin test load of at least 10 percent greater than the magnitude of the most severe single step load within the load profile is considered sufficient for the margin test.

Comparison of E4/F4B Diesel

General Motors EMD has phased out the Model 645E4 diesel and has replaced it with the current Model 645F4B. In the transition from the E4 to the F4B, there has been two intermediary models identified as EB and EC. The methodology for engine model identification is as follows:

(20) - (645) - (F) (4) (B)

First Numbers	=	Number of cylinders - 8, 12, 16 or 20
Second Numbers	=	Displacement of one cylinder = 645 in^3
Next Letter	=	Level of engine evolution
Next Number	=	4 = turbocharger-stationary unit 1 = roots blower-stationary unit 3 = railroad application 7 = marine application
Next Letter	=	Level of improvement

From outward appearance, the Model F4B and Model E4 are indistinguishable. There have been a series of internal engine design improvements to enhance resistance to wear, overall reliability and power output. A comparison between Models E4, EB, EC and F4B is presented in Tables 1 and 2. A more direct comparison between the EMD 20-645E4 and the EMD 20-645F4B is presented in Tables 3, 4 and 5.

The comparison between an EMD Model E4 and F4B diesel shows that there are no changes in bore or stroke and that the vast majority of internal parts and components are the same. There have been design improvements made to improve wear and reliability of the F4B diesel. Each design improvement has been evaluated and determined not to negatively impact the application of the qualification of the Model E4 diesel for the F4B diesel.

<u>Previous Qualification Testing</u>

The Power System Division of Morrison-Knudsen has completed 300 Start and Load Acceptance Tests for tandem diesel generators with 12, 16, and 20 cylinder General Motors EMD Model 645E4 diesels as follows:

1) Hidroelectrica - Spain - 20-645E4 tandem arrangement - 750 rpm

2) TVA - Watts Bar - 16-645E4 tandem arrangement - 900 rpm

3) Laguna Verde - Mexico - 16-645E4 and 12-645E4 tandem - 900 rpm

The three separate qualification tests totaling 900 starts were completed without any failures. Table 6 summarizes the significant information to compare data for each qualification test.

From Table 6, it can be seen that supporting systems, i.e., lube oil, water, fuel oil and air start, were schematically the same even though the component manufacturers in some cases were different because of code requirements. The units for Hidroelectrica and Watts Bar were standard EMD components of the same design as the components to be furnished for the new Turkey Point diesel-generators. The unit for Laguna Verde required components built in accordance with ASME Section III Class 3 which are not standard EMD components. However, the systems are functionally and schematically identical.

The engine control logic was consistent. The control relays used were of the same type for all tests. Therefore, the important portions of the air start system have proven reliability.

The starting relay logic, the engine mounted starting air system and the air start motors are the components that crank and cause the engine to start and accelerate to rated speed. Since the EMD standard components and the relaying are the same in design and function between units that have completed 300 start tests and on the new units for Turkey Point, the starting system has established its reliability and qualification.

There are minor differences for the jacket water system. The engine water can be cooled by means of a shell and tube heat exchanger or a radiator with motor driven fans. In either case, the diesel system is designed to operate for two (2) minutes without the need for service water or to turn on the radiator fan motors. This difference does not impact the ability of the diesel to start and accept load or its qualification.

The air intake and exhaust systems are designed to perform within the EMD specified allowable pressure drop for exhaust or combustion air flow.

The EMD 20-645E4 test was conducted at 750 rpm. The qualfication tests for Watts Bar and Laguna Verde are for 16 and 12 cylinder engine generators operating at 900 rpm. This demonstrates the ability of the EMD 645E4 diesel series to operate reliabily at 900 rpm and, therefore, the qualification also applies to the EMD 20-645E4 engine. The EMD 20-645E4 is also in many nuclear plants operating at 900 rpm where its reliable performance has been established. There are twelve (12) nuclear plants totaling 30 General Motor diesel-generators, which use the EMD model 20-645E4 at 900 rpm. The existing Turkey Point diesels are also EMD Model 20-645E4. Therefore, there is substantial field experience with the diesel-generator operating at 900 rpm.

An EMD 20-645E4 - 900 rpm unit is also utilized for the high pressure core spray (HPCS) pump for General Electric Company (GE) reactors. This unit was intensively tested at the MK/PSD facility in which the EMD 20-645E4 (3600 HP at 900 rpm) started a 3000 HP HPCS induction motor. The tests were conducted from standby conditions. The diesel-generator would start and accelerate to rated speed within 10 seconds at which time the 3000 HP motor was started and brought to rated speed. The motor had a special flywheel to simulate the pump impeller and load.

Testing has demonstrated margin as well as the engine's ability to recover to rated speed. Engine generators furnished to GE for HPCS pump emergency power have passed the 69 start tests per Regulatory Guide 1.108.

Whether the rated speed is 750 rpm or 900 rpm, the cranking and starting requirements are identical. The acceleration to rated speed uses the same governors and control relaying. Only the set points differ. The acceleration time is a function of the engine-generator inertia, which is no different than evaluating generators with different inertias. The EMD diesel is designed to operate at either speed.

In addition to the previous qualification testing, a 10 second start test was conducted on an EMD 20-645F4B-900 rpm unit to demonstrate the ability of the diesel-generator to start and accelerate to rated speed within 10 seconds after the start signal. The test unit accelerated to rated speed and voltage and was ready to accept load in 3.5 seconds. Because the total inertia of the diesel-generator for this project is greater, calculations were performed to show that the acceleration time to rated speed will be 8.01 seconds.

However, because of the change in brake mean effective pressure and diesel-generator arrangement, the following analysis was performed to verify the application of the E4 qualification for the new Turkey Point diesel-generators.

- Brake Mean Effective Pressure (BMEP)

  The following describes the engine modifications to adapt the engine to structurally accept, continuously with additional margin, the higher BMEP:

  The higher BMEP results in a higher cranking torque. The starting air supply (air receivers) has been increased to accommodate the higher torque requirement. The increased air supply maintains a high air receiver pressure for the five start requirements. The higher the starting air pressure, the higher the torque capability of the air start motors. Once the engine fires, the higher BMEP results in a higher net engine torque to enhance the acceleration to rated speed.

  The total stresses in the crankshaft are determined during the torsional vibration calculations which are then added to the load torque stresses. The engine manufacturer is responsible for approving the torsional system and their approval has been given for the new Turkey Point diesel engines. In addition, the stress levels are within the stress limits specified by the Diesel Equipment Manufacturers Association. The main and connecting rod bearings are still conservatively designed to accept the loads imposed by the higher BMEP/firing pressure.

  The design BMEP for all EMD 645E4 models except the 20-645E4 unit is 130 psi. The lower BMEP of 123 psi for the 20 cylinder E4 diesel was limited because of the reduced quantity of combustion air delivered via the turbocharger. Therefore, the 136 psi for the EMD 20-645F4 is only 4.6 percent higher than for the 12 or 16 cylinder E4 series, which have already passed the 300 start and load acceptance tests.

  Engines used for railroad service are the same basic design as engines used for stationary service. Based upon the railroad duty cycle, the full load BMEP is 153 psi for "F" series railroad engines as compared to the BMEP of 136 psi for the stationary engine. The BMEP for the "F" series railroad service is 12.5 percent greater than the BMEP for the EMD 20-645F4 stationary service. Model "F" engines have been in railroad service since 1980.

A significant number of operating hours have been achieved with the "F" series engines in both railroad and stationary services. Approximately 46 "F" engines were produced for stationary service since 1983. This is estimated to total 103,000 operating hours. For railroad service, 714 "F" engines were produced since 1980 with an estimated 23,538 hours of operation per unit. There are no failures related to the basic design. The operating experience is verification of an adequate design.

- Diesel Generator Arrangement

For a tandem drive generator, the generator inertia essentially separates the two driving diesels, one on each end of the generator. Therefore, functionally one diesel does not know that the other diesel is there. Each delivers proportional power to the generator as a result of governor control.

The component systems for starting, water, fuel and lube oil for each diesel of a tandem arrangement are identical to that for a single diesel drive. One can cut through the middle of the generator and essentially have two separate diesel driven generators.

The combustion air intake and exhaust systems are similar; and in each case are designed not to exceed the pressure drop limits specified by the manufacturer.

<u>Starting Systems</u>

Each diesel of the tandem arrangement has two pair of air starting motors; and therefore, the tandem has a total of four pair of air starting motors. The tandem arrangement requires two pair of air start motors for a successful start, while the single diesel requires one pair. Therefore, the torque capability of one pair of air start motors per diesel is required for a successful start. The tandem arrangement has one redundant pair of air start motors for the single engine drive Because the two tandem diesels are connected together through a common generator shaft, it does not matter which two of the four pair of air start motors function.

Similarly for a single engine, it does not matter which of the one of the two pair of air start motors function. What matters is that the engine generator system obtains sufficient cranking torque from the start motors.

For either configuration, the critical phase of starting is the ability to crank the engine generator to a rate of 60 rpm at which time the engine will fire and provide accelerating torque. For a tandem configuration, one engine may fire slightly before the other and may, due to its added acceleration, assist the other engine to fire. However, this is not an important factor because each engine will fire at approximately the 60 rpm rate, and each set of air motors has the capability to accelerate the engine to this speed.

The air start control on the tandem and single diesel drive energizes all the air start motors simultaneously when a start signal is initiated. There are no significant control differences between the two arrangements.

Supporting Systems

The supporting engine systems are identical for each diesel whether in a single or tandem arrangement. Therfore, there is no impact on any of the supporting systems for either arrangement.

Governors

Diesel acceleration, speed and load are controlled by means of a governor which meters the flow of fuel into the combustion chamber.

The governors that are applied to diesels for nuclear applications by Power Systems Division are the Woodward Governor Company electro-hydraulic backup type. With this type of governor, the electric portion is normally in control. Should there be a failure in the electric control section, the hydraulic section will then assume control. The hydraulic section, therefore, "backs up" the electric section.

There are two basic Woodward governors that have been used in the 300 start qualification tests.

a. Actuator Model EG-B13P with the 2301 Control Box

b. Actuator Model EG-B35 with the EGA Control Box

The actuators are essentially mechanically and functionally the same. The difference is in the electric control boxes (EGA or 2301).

For tandem diesel arrangements, either:

a. A single Woodward EG-B35C actuator with a line shaft connecting the injector control rack of both engines through linkage to the actuator terminal shaft. In this manner, a single actuator is used for both engines.

b. A Woodward model EG-13P actuator is mounted on each diesel of the tandem arrangement. The electric section of each governor actuator is connected in series with the electric signal from the 2301 control box and thereby, each actuator responds in identical manner.

For a single diesel arrangement, either type can be used. However, since only one engine injector control rack is involved, the EG-13P actuator is used in place of the EG-B35C.

Therefore, because of the similarity of the governing systems, either type can be applied to any EMD 645E4 diesel arrangement for qualification to the requirements of IEEE 387.

Electric Control

The electric control circuitry that relates to the diesel starting and diesel control, as well as the application of voltage, is basically the same control circuitry whether the arrangement is a single or tandem arrangement.

Therefore, it can be concluded that the 300 start and load acceptance tests conducted on tandem arrangements are valid also for single diesel drives and can be used to qualify single diesel arrangements.

Proposed Testing to Qualify the EMD 20-645FB Diesel-Generator

The following qualification tests on one diesel-generator will be performed to account for the differences between the qualified EMD 20-645E4 diesel and the EMD 20-645F4B diesel:

IEEE 387-1984

1) Load Capability Test - Paragraph 7.2.1

   a) 22 hours at rated speed

   b) 2 hours at short time load

   c) drop short time load in one step for frequency transient test

   d) light or no load capability

2) Start and Load Acceptance Test - Paragraph 7.2.2

   The critical stage in the start sequence is the performance of the air start motor, engine mounted air start valving, governor boost function for governor positioning of the fuel rack and the engine control. All the above components and related systems on the new diesel-generator for the Turkey Point project are the same as those on the qualified diesels. No changes are made to the starting system that affect starting capability. Therefore, there is no need to perform additional 300 start tests to establish reliability of the starting system.

   The next stage is when the engine fires and accelerates to rated speed and voltage and then accept a load step. Examination of all the previous 300 start tests show that the tests results are repeatable for cranking time, accelerating time, and load acceptance over the entire number of tests for the unit being tested. The previous 300 start and load acceptance qualification testing is applicable to the Turkey Point equipment. Therefore, it is not necessary to perform the 300 starts to qualify the engines ability to accelerate to rated speed within the 10 second period and accept the applied load.

   It is proposed to perform 30 start and loading tests, 10 percent of which will be in the "hot" mode with no failures allowed to verify the diesel-generator ability to start and accept load within design limits.

3) Margin Test - Paragraph 7.2.3

   In addition to the 7.2.1 and 7.2.2 tests, two (2) 10 percent margin tests will be performed.

Other Testing

Regulatory Guide 1.108, Positions C.2.a(3) and C.2.a(4) require a complete load capability qualification test based on the machine nameplate rating. These tests will be performed during our planned preoperational testing of the EDG's on site.

The complete set of preoperational testing requirements contained in R.G. 1.108 will be performed on the new EDG's; this includes the 69 in-situ start and load tests to at least 50 percent of the machines' rating to demonstrate the in-situ reliability of the installed units. Thereafter, the normal inservice testing of the EDG's will follow the Turkey Point Plant Technical Specification requirements, which ensure the continued reliability of the EDG's.

Conclusion

The only difference from the qualification testing required by paragraph 7.2 of IEEE 387-1984 is the reduction of the number of start and load acceptance tests (paragraph 7.2.2) from 300 to 30.

The justification to perform 30 starts instead of 300 starts is, in summary, based upon the following:

1) The cranking components, electrical circuits and relays are the same that were used in all previous 300 start tests. Therefore, this system has already been qualified.

2) The higher cranking torque is accommodated by a larger starting air supply. This is considered a minor change.

3) Engine-generator performance was consistently repeatable throughout the 300 starts for each 300 start test conducted. Therefore, 300 starts are not required to demonstrate repeatability.

4) The higher BMEP is reflected in the HP output of the diesel. The load tests required by IEEE 387-1984 (paragraphs 7.2.1 and 7.2.3) will be performed to verify the load carrying capability of the diesel generator.

5) The similarity between tandem and single unit arrangements has been demonstrated. Therefore, the 300 start and load acceptance tests conducted on tandem units are valid for single diesel drives.

TABLE 1

The EMD Model 645E4 (identified as "E" below) has gone through a series of improvements starting in 1979 through 1983. The series of changes were identified as Models EB, EC and FB.

The following table summarizes the evolution of the EMD 645 turbocharged engine from the 645E to the 645EB to the 645EC, to the 645FB. The evolution is a series of improvements to the basic turbocharged engine EMD has been manufacturing since the mid 1960s.

STATIONARY		E	EB	EC	FB
Rated BHP/BMEP	8 cyl.	1525/130	1525/130	1525/130	1700/145
(BHP)	12 "	2305/131	2305/131	2305/131	2550/145
900 rpm	16 "	3070/130	3070/130	3070/130	3400/145
	20 "	3600/123	3600/123	3600/123	4000/136
Nominal Fuel Consumption	8 cyl.	.369	.356	.348	N/A
Full Load	12 "	.359	.353	.344	N/A
900 rpm	16 "	.363	.351	.342	.341
(#/BHP-Hr.)	20 "	.369	.353	.344	.345
Compression Ratio		14.5:1	14.5:1	16:1	16:1
Crankcase		E	E	E	F
Liner		Standard	Laser Hardened Mae West	Laser Hardened Upper Bore	Laser Hardened Upper Bore
Lower Liner Water Seal		Viton/Buma	Viton/Buma	Viton	Viton
Water Outlet Seal		Viton	Viton	Viton	Viton
Lower Liner Insert		Standard	Standard	Standard	Nickel
Cylinder Head		Standard	Thin Deck	Thin Deck	Thin Deck
Cylinder Head Seat Ring		Naval Bronze	Aluminum Bronze	Aluminum Bronze	Aluminum Bronze
Cyl. Crab Retention Sys.		Individual Crabs	Individual Crabs	Plate Crab	Plate Crab
Top Piston Ring Location		1¼"	Fire Ring .75"	FireRing	Fire Ring
Piston Pin Bearing		Silver	Bronze Rocking Pin	Bronze Rocking Pin	Bronze Rocking Pin
Camshaft Material		5046	1080	1080	1080
Injector Plunger		.453"	.500"	.500"	.500"
Rocker Arm Rollers		Standard	Crowned	Crowned	Crowned
Exhaust Valve		Standard	Standard	Heavy Head	Heavy Head
Blade Connecting Rod Matl.		1056	1056	4140	4140
Turbocharger		E	EB	EC	FA
Turbocharger After Cooler		10 row	10 row	10 row	12 row
Turbocharger Screen		See Evolution Section C3-0	Reduced Gradient Screen W/ Trap	Reduced Gradient Screen W/ Trap	Reduced Gradient Screen W/Revised Trap

TABLE 2

IMPROVEMENTS		MODEL		
	FB	EB	EC	FB
Compression Ratio	16:1		X	X
Crankcase	F			X
Liner	Laser Hardened Upper Bore		X	X
Lower Liner Water Seal	Viton		X	X
Water Outlet Seal	Viton	X	X	X
Lower Liner Insert	Nickel			X
Cylinder Head	Thin Deck	X	X	X
Cylinder Head Seat Ring	Aluminum Bronze	X	X	X
Cyl. Crab Retention Sys.	Plate Crab		X	X
Top Piston Ring Location	Fire Ring	X	X	X
Piston Pin Bearing	Bronze - Rocking Pin	X	X	X
Camshaft Material	1080	X	X	X
Injector Plunger	.500"	X	X	X
Rocker Arm Rollers	Crowned	X	X	X
Exhaust Valve	Heavy Head		X	X
Blade Connecting Rod Matl.	4140		X	X
Turbocharger..	FA			X
Turbocharger After Cooler	12 row			X
BMEP	136 PSI			X
Turbocharger Screen	*	X	X	X

* Reduced Gradient Screen With Revised Trap. - F4
Reduced Gradient Screen With Trap. - EB/EC

FB IMPROVEMENTS IMPLEMENTED IN PRIOR MODELS

	20-645E4	20-645F4B
Compression Ratio	14.5:1	16:1
BMEP	123	136
Crankcase	E	F
Liner	Standard	Laser Hrdnd Upper Bore
Lower Liner Water Seal	Viton Buma	Viton
Water Outlet Seal	Viton	Viton
Lower Liner Insert	Standard	Nickel
Cylinder Head	Standard	Thin Deck
Cylinder Head Seat Ring	Naval Brnze	Alum Bronze
Cylinder Crab Retention System	Individual Crab	Plate Crab
Top Piston Ring Location	1-1/4	Fire Ring 0.75"
Piston Pin Bearing	Silver	Bronze Rocking Pin
Camshaft Material	5046	1080
Injector Plunger	.453"	.500"
Rocker Arm Rollers	Standard	Crowned
Exhaust Valve	Standard	Heavy Duty
Blade Con Rod Material	1056	4140
Turbocharger	E	FA
Turbocharger After Cooler	10 Row	12 Row
Turbocharger Screen	See Evolution, Sect.C3-0	Reduced Gradient Screen W/Revised Trap

DIFFERENCES BETWEEN 20-645E4
AND 20-645F4B DIESELS
TABLE 3

TABLE 4

COMPARISON OF DIFFERENCE

ENGINE		20-645F4B	20-645E4
BHP - continuous		4000	3600
BMEP - nominal	PSI	136	123
Torque @ cont. BHP	lb.ft.	23342	21000
AIR AND EXHAUST SYSTEMS			
Intake air at 14.7 psi-90°F.	CFM	10725	10700
Exhaust volume temperature	°F	635	735
Exhaust volume @ exh. temp.	CFM	21350	22000
Firing pressure	PSI	1875	1500

NOTE: The BMEP for the 20E4 diesel of the other number of cylinders is:

No. Cyl.	BMEP
8	130
12	131
16	130

The reason for the lower BMEP of the 20 cylinder is because of the limited combustion air flow from the turbocharger for this specific engine.

TABLE 5

(Page 1 of 2)

COMPARISON OF LIKENESS

Engine Model	20F4B	20E4
Bore & Strokes	9-1/16x10"	9-1/16x10"
Number of Cylinders	20	20
Number of Main Bearings	12	12
Number of Turbo-chargers	1	1
Crankcase/Oil Pan	Welded Steel	Welded Steel
Displacement per Cylinder.	645 cubic inches	645 cubic inches
Piston Speed	1500 fpm	1500 fpm
Fuel Injectors	Needle Valve	Needle Valve
Crank Brg. Dia.	7.50"	7.50"
Crank Pin Dia.	6.5"	6.5"
Piston Pin Dia.	3.68"	3.68"
Piston to Head Clearance	.020/.068	.020/068
Type Engine	2 cycle 45° V	2 cycle 45° V

TABLE 5

(Page 2 of 2)

COMPARISON OF LIKENESS (CONTINUED)

UNIT MODEL (S = Stationary Application)	S20F4B	S20E4
ENGINE MODEL	20-645F4B	20-645E4
RATED RPM	900	900
LUBRICATING OIL SYSTEMS		
Lube pressure flow GPM	229	229
Lube piston cooling flow GPM	109	109
Lube scavenging flow GPM	390	390
FUEL OIL SYSTEMS		
Fuel supply pump - capacity GPM	4.5	4.5
Fuel supply pump - suction lift-max. ft.	12	12
COOLING WATER SYSTEMS		
Total engine water flow GPM	1100	1100
Total system pressure drop PSI	55	55
Allowable pressure drop for external piping & cooling equipment PSI	8	8
Exhaust back pressure (total system) maximum allowable in. H_2O	5	5
Air intake (total system) suction-max. clean filters in H_2O	6	6

NOTE: All system listed pumps for lube oil, fuel oil and cooling water are engine driven and are a standard identical EMD design for the E and F series engine.

TABLE 6

QUALIFIED DIESEL GENERATOR

COMPARISON CHART

	6003 TVA/BE	6001 HIDRO-ELECTRICA	379 TVA WATTS BAR	6020 LAGUNA VERDE	6076 FP&L TURKEY POINT
SERVICE	EMERGENCY STANDBY POWER DEDICATED TO HPCS PUMP	EMERGENCY POWER	EMERGENCY POWER	EMERGENCY POWER	EMERGENCY POWER
CODE/GUIDE	REG. GUIDE 1.108-1977 PARA. 9	IEEE 387-1977 —	IEEE 387-1977 —	IEEE 387-1977	IEE 387-1984
START TEST	69	300	300	300	30
ENGINE/SPEED	20-645E4/900	20-645E4/750	16-645E4/900	16 & 12645E4/900	20-645F4B/900
TYPE	SINGLE	TANDEM	TANDEM	TANDEM	SINGLE
GOVERNOR	WOODWARD EGB-13C	WOODWARD EGB-13C	WOODWARD EGB-35P	WOODWARD EGB-13P	WOODWARD EGB-13P
GOVERNOR CONTROL	EGA	EGA	2301	2301	2301A
TURBO RATIO	18:1	18:1	18:1	18:1	17.9:1
SUPPORTING SYSTEMS					
Lube Oil	EMD STD COMP	EMD STD COMP	EMD STD COMP	*IN ACCORDANCE ASME III CL NOT STAMPED EMD STD SCHEMATIC	EMD ANSI B31-1 STD COMP
Jacket Water	HT. EXCH. & EMD STD COMP.	HT. EXCH. & EMD STD COMP.	HT. EXCH. & EMD STD COMP.	*SAME + HT.EXCH. EMD STD. CKT. DIFF. COMPONENTS	EMD-ANSI B31-1 RADIATOR ASME SECT.VIII & EMD STD COMP.
Air Start Engine Mtd	EMD STD	EMD STD	EMD STD	*SAME EMD STD. CKT. DIFF. COMPONENTS	EMD ANSI B31-1 EMD STD.
Fuel Oil	EMD STD DUPLEX FLTR	EMD STD DUPLEX FLTR	EMD STD DUPLEX FLTR	EMD STD DUPLEX FLTR	EMD STD DUPLEX FLTR
Air Combustion	KITTELL	KITTELL	CYCOIL P01-42	UNIVERSAL FLTR SILENCER SPECIAL SFT-16/SFT-100	DONALDSON SAA30-0011 SILENCER TK000-3000 FILTER
Exhaust	UNIVERSAL UTR-22	KITTELL CCY22-0020 3" H20	UNIVERSAL UT22	UNIVERSAL UTR-20/22	DONALDSON TRX24
Coupling	THOMAS	EMD STD-TYPE A	EMD STD-TYPE A	EMD STD-TYPE A	EMD STD-TYPE A
GENERATOR	ELECTRIC PRODUCTS	BELOIT	ELECTRIC PRODUCTS	ELECTRIC PRODUCTS	ELECTRIC PRODUCTS
Inertia	38,711#/FT2	44,440#/FT2	32,510#/FT2	40,950#/FT2	26,375#/FT2
Configuration	DOUBLE BRG./ SINGLE	DOUBLE BRG./ TANDEM	DOUBLE BRG./ TANDEM	DOUBLE BRG./ TANDEM	DOUBLE BRG. SINGLE
Frequency	60 HZ	50 HZ	60 HZ	60 HZ	60 HZ
KVA	3560/3312	5509	5500	4595	3593
KW	2848/2650	4407	4400	3676	2874
Volt	6900	6600	4160	4160	4160
Phase	3	3	3	3	3
Exciter Voltage Reg.	E.P. STATIC	BASLER STATIC MODEL SER258 9-112000100	E.P. STATIC	E.P. STATIC 72-14000-100	E.P. STATIC
ENVIRONMENT					
Ambient	122 DEG. F	120 DEG. F	110 DEG. F	40 DEG. C	122 DEG.F (INSIDE) 100 DEG.F (OUTSIDE)
Humidity	90%	--	--	65-72%	76-100%
Elevation	1,000 FT	372 METERS	729 FT	10 METERS	18 FT