Performance Improvement

Programs at

Louisiana Power & Light Company

Energy Incorporated
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ABSTRACT

Two performance improvement programs are currently underway at Louisiana Power & Light Company. The Component Performance Deviation Program was developed to provide management with detailed data on sources of a unit's performance degradation. This program involves the development of a set of standardized PEPSE models for each subject unit, and test procedures development.

The Middle South Utility System Power Plant Productivity Improvement Program (PPPIP) includes the procurement of a mobile testing facility (MTF). The MTF, which will include a data acquisition system, precision instrumentation, and metrological standards, will be used for the company's major testing programs.

1.0 Introduction

Currently Louisiana Power & Light Company is engaged in two performance improvement programs. The first, the Component Performance Deviation Program, involves the development of a set of standardized PEPSE models for each subject unit, and the development of comprehensive test procedures. The scope of the second program, the Power Plant Productivity Improvement Program, includes the development and acquisition of a mobile testing facility for the company's major equipment testing efforts.

2.0 The Component Performance Deviation (CPD) Program

The CPD program was conceived in March, 1985 to evaluate power plant equipment performance. The initial scope of this program includes the development of standardized PEPSE models and test procedures development. The General Office Plant Performance and Results Section was assigned the task of program implementation.

2.1 Test Procedures Development

The first step in developing performance test procedures is the determination of the types of results we desire. Do we want detailed information on the turbine, boiler, feedwater heater, etc.; or do we only need information on the gross turbine heat rate? How accurate should the test be? These are the types of questions which must be answered prior to test procedures development. Generally speaking the more detailed results we require, the more complex the test, the calculations, and the analysis. Cost may become an important item. A full conformance ASME turbine acceptance test may run upwards of several hundred thousand dollars.

The ASME Performance Test Codes serve as an excellent source from which to develop a testing program. The codes contain a great deal of information on different test types, instrumentation, statistical analysis of data, and the effects of measurement uncertainties on test results.

For the CPD program test, management wanted detailed performance information on the turbine sections, boiler, condenser, feedwater heaters, condenser, and major pumps.

After reviewing applicable ASME Performance Test Codes and other material, we decided upon a test which would concentrate on a high accuracy enthalpy-drop test of the superheated turbine stages with a heat losses method boiler test. Additional cycle information would be used to calculate the other components' performance. Since we are able to measure fuel accurately (all the units are natural gas or fuel oil) the overall unit heat rate uncertainty is about ± 1%. The boiler efficiency uncertainty is approximately ± 0.5%. Thus, we are able to obtain fairly accurate unit heat rate, boiler efficiency, and turbine heat rate data.

PEPSE was used to examine the effects of measurement uncertainties on superheated turbine section efficiencies. These are listed in Table No. 1. As can be seen from the table to obtain a turbine section efficiency test result accuracy of about ± .5% would require a temperature measurement uncertainty of better than 1°F. Pressure measurements of better than 1% would also be required. An important concept is illustrated by this example; to obtain certain test accuracies will require a certain set of instrumentation and hookup procedures.

As a part of our test procedures we have developed generic instrument uncertainty tables and worksheets for calculating the effects of the measurement uncertainties on the test results. We have also developed worksheets to statistically analyze our test data. The test procedures also include instrument hookup, data collection, and cycle isolation requirements.

Figure No. 1 depicts typical test procedures development methodology.

TEST PROCEDURES DEVELOPMENT METHODOLGY

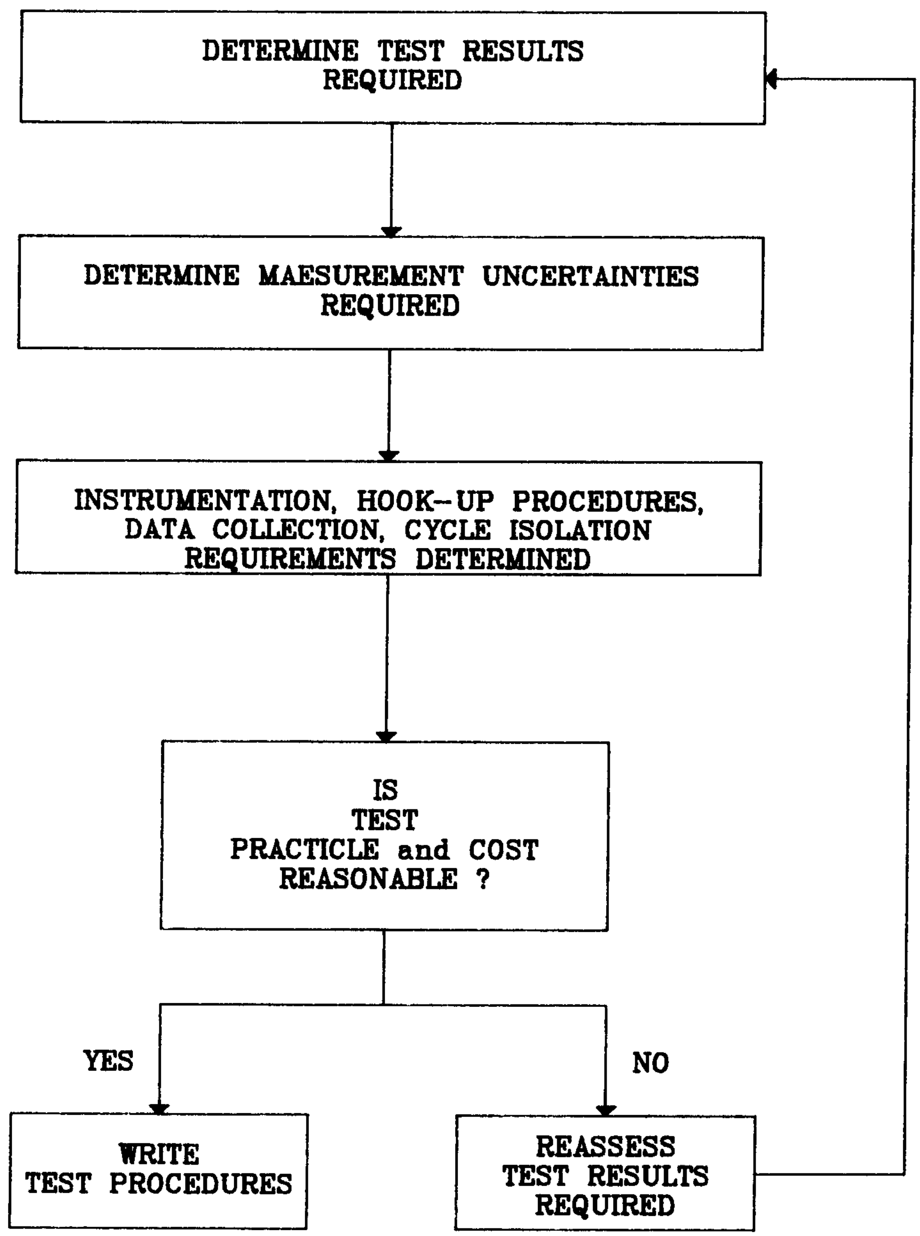


Figure 1

Table No. 1

*Inlet and Exhaust Steam Conditions in psia and F	Effect of Test Measurements on Determination of Turbine Efficiency			
	Inlet T, %/F	Inlet P, %/psi	Exh. T, %/F	Exh. P, %/psi
H.P. Turbine				
3690P, 1000°F -- 766.1P, 601F	.428	-.0337	-.526	.141
3515P, 1000°F -- 700.3P, 585F	.366	-.0322	-.482	.142
2415P, 1000°F -- 602.3P, 642F	.356	-.043	-.43	.156
1505P, 1000°F -- 478.7P, 731F	.434	-.0732	-.483	.206
I.P. Turbine				
731.3P, 1000°F -- 170.1P, 639F	.246	-.092	-.302	.378
630.3P, 1000°F -- 178.9P, 679F	.281	-.123	-.336	.422
541.8P, 1000°F -- 178P, 720F	.327	-.161	-.453	.486
435.6P, 1000°F -- 54.2P, 503F	.149	-.0932	-.207	.731

*Use the closest inlet and exhaust steam conditions in the table.

2.2 Standardized PEPSE Models

PEPSE model development closely follows a method presented at the 1984 PEPSE User's Group meeting. For each subject unit, five models are constructed. These models are: Vendor Verification, Benchmark, Benchmark with Condenser, Performance, and Component Improvement Evaluation.

2.2.1 Vendor Verification Model

This model verifies the original vendor's heat balances. The main purpose of this model is to convince personnel PEPSE can duplicate the vendor's heat balances.

Typical modeling philosophy follows.

1. Use of general turbine sections for non-G.E. units.
2. Closing of input-output loop. Reheater components are used to simulate the boiler. For drum units this enables the matching of blowdown enthalpy values.
3. Use of controls to match enthalpies on non-ASME 67 steam table heat balances during initial model development.
4. All other cycle data as per vendor heat balance.

With perseverance and good modeling techniques we have been able to very closely simulate the vendor's heat balances as illustrated in Table No. 2.

2.2.2 Benchmark Model

This model was developed to provide a more detailed and realistic heat balance than that of the Vendor Verification Model. The base Vendor Verification Model deck is modified to more closely simulate the unit's as-built condition. Pump shop test curves, system head curves, and piping heat loss data are typical of the as-built information we include in these models. A comparison of the Benchmark versus the Vendor Verification and vendor heat balances is listed in Table No. 2.

2.2.3 Benchmark with Condenser Model

This model is identical to the Benchmark Model with the exception of the condenser. PEPSE operations are used to calculate the condenser performance using the Heat Exchange Institute's methods.

2.2.4 Performance Model

The Performance Model is used to calculate as-is component performance based upon the test input data. Output data from this model can be input in the Evaluation Model for a detailed test versus design component performance deviation study. PEPSE Special Options 2 (or a mimic) or 3 are available for use. Special Option 2 may assist in determination of the UEEP for the condensing turbine or in test data validation.

Special Option 3 is the primary method used for the test performance calculations. The following procedure is used when Special Option 3 is run:

1. Test data points are used to construct the turbine expansion line to the vendor's base pressure.

2. "Corrected" data from the expansion line is input in the Performance Model.

3. Run Option 3.

4. Compare calculated feedwater flow rate to the test value. Compare the input/output boiler efficiency to the losses method value.

5. If the calculated flow is not acceptable, redraw the expansion line and rerun Option 3.

TABLE NO. 2 VENDOR/PEPSE COMPARISON

Vendor Sheet No	1	2	3	4	5	6	7	8	9
Vendor									
Net MW	84.330	199.651	306.295	310.280	396.741	398.460	413.235	414.735	437.041
Net HR	11864	9985	9625	9501	9537	9495	9539	9506	9673
PEPSE LG2 VEND									
Net MW	84.337	199.894	306.147	310.242	396.800	398.472	413.357	414.711	437.400
Net HR	11858.2	9973.3	9625.4	9498.3	9529.8	9489.8	9534.5	9503.3	9669.4
DEV from Vendor									
NET MW	(0.007)	(0.243)	0.148	0.038	(0.059)	(0.012)	(0.032)	0.024	(0.359)
NET HR	5.8	11.7	(0.4)	2.7	7.2	5.2	4.5	2.7	3.6
% DEV									
NET MW	(0.008)	(0.122)	0.048	0.012	(0.015)	(0.003)	(0.008)	0.006	(0.082)
NET HR	0.049	0.117	(0.004)	0.028	0.076	0.055	0.047	0.028	0.037
PEPSE BENCH MARK									
NET MW	84.190	199.601	305.795	309.847	396.471	398.130	413.145	414.478	436.842
NET HR	11930.9	10008.0	9648.8	9522.6	9544.9	9505.3	9545.3	9514.6	9682.6
DEV FROM Vendor									
NET MW	0.140	0.050	0.500	0.433	0.270	0.330	0.180	0.257	0.199
NET HR	(66.9)	(23.0)	(23.8)	(21.6)	(7.9)	(10.3)	(6.3)	(8.6)	(9.6)
% DEV FROM Vendor									
NET MW	0.166	0.025	0.163	0.140	0.068	0.083	0.044	0.062	0.046
NET HR	(0.564)	(0.230)	(0.247)	(0.227)	(0.083)	(0.108)	(0.066)	(0.090)	(0.009)

2.2.5 Component Improvement Evaluation Model

The Component Improvement Evaluation Model is used to compare the effects of substituting design components in place of the as-is (test) components. Design components derived from the Benchmark Models are substituted cumulatively (using PEPSE stacked cases) so that the final case is a Benchmark run. A listing of a typical model follows.

Case No. 1

This case duplicates the original test run. General Turbine Type 8 sections are used for the entire turbine. The solution methods are Type 3 (efficiency and flow coefficient) for all sections except the last L.P. stage which uses Type 1 (efficiency and pressure). Feedwater heater data are input as TTDs and DCAs. Pump data are input as efficiencies and pressure rises. Generally speaking, data is input in a "flexible" format so that model may use PEPSE Special Option 1 (constant control valve setting) in the following runs.

Case No. 2

The design H.E.I. condenser calculations are substituted in place of the test data. A new backpressure is calculated and the cycle is corrected to this new backpressure.

Case No. 3

This case corrects the original test case to "Standard Conditions." Typically, these are referred to as "Group 1

Corrections", see ASME PTC 6 "Steam Turbines", 1976. These items are primarily variables which affect the turbine performance. The cycle is corrected to the design values of throttle temperature and pressure, reheat temperature and reheater % pressure drop, turbine back pressure, power factor, and generator hydrogen pressure, etc.

Case No. 4

The design values of TTD and DCA for the No. 7 feedwater heater are substituted in place of the test data.

Case No. 5

The design values of TTD and DCA for the No. 6 feedwater heater are substituted in place of the test data.

Case No. 6

The design values of TTD and DCA for the No. 5 feedwater heater are substituted in place of the test data.

Case No. 7

The design values of TTD and DCA for the No. 4 feedwater heater are substituted in place of the test data.

Case No. 8

The design values of TTD and DCA for the No. 3 feedwater heater are substituted in place of the test data.

Case No. 9

The design values of TTD and DCA for the No. 2 feedwater heater are substituted in place of the test data.

Case No. 10

The design values of TTD and DCA for the No. 1 feedwater heater are substituted in place of the test data.

Case No. 11

The design condensate pump values are substituted in place of the test data.

Case No. 12

The design boiler feedpump values are substituted in place of the test data.

Case No. 13

The design H.P. turbine values are substituted in place of the test data.

Case No. 14

The design I.P. and L.P. turbine values are substituted in place of the test data.

Case No. 15

The design auxiliary value is substituted in place of the test datum.

Case No. 16

The design value of boiler efficiency is substituted in place of the test datum.

Case No. 17

This case is a verification step. Special Option 1 is removed such that the output from this run should be a duplicate of the previous run.

Table 3 shows test versus design data from a recent test. Table 4 illustrates the results of an evaluation study performed on this same data. An example of a typical test result uncertainty analysis, for a test utilizing high accuracy instrumentation, is provided in Example No. 1.

Table 3
Test Summary

Item	Description (Units)	Test Data	Corr. To Std. Cond.	Design Data At Test Flow
1	Throttle Steam Flow (KLBH)	2939.3	2965.0	2965.0
2	Throttle Pressure (PSIA)	2404.6	2415.0	2415.0
3	Throttle Temperature (DEGF)	1007.6	1000.0	1000.0
4	Hot Reheat Temperature (DEGF)	996.7	1000.0	1000.0
5	Turbine Exhaust Pressure (INHG)	3.16	2.5	2.50
6	H.P. Turbine Efficiency (%)	79.2	XXX	85.8
7	I.P. Turbine Efficiency (%)	87.6	XXX	86.9
8	L.P. Turbine Efficiency (%)	82.9	XXX	88.1
9	F. W. Heater No. 1 TTD/DCA (DEGF)	13.7/18.4	XXX	1.0/17.2
10	F. W. Heater No. 2 TTD/DCA (DEGF)	3.6/16.1	XXX	1.2/17.3
11	F. W. Heater No. 3 TTD/DCA (DEGF)	14.5/32.9	XXX	6.0/35.8
12	F. W. Heater No. 4 TTD/DCA (DEGF)	11.9/17.8	XXX	6.0/17.3
13	F. W. Heater No. 5 TTD/DCA (DEGF)	7.8/10.9	XXX	6.2/17.3
14	F. W. Heater No. 6 TTD/DCA (DEGF)	5.9/7.7	XXX	6.3/17.2
15	F. W. Heater No. 7E TTD/DCA (DEGF)	5.2/10.1	XXX	6.3/17.5
16	F. W. Heater No. 7W TTD/DCA (DEGF)	---	XXX	---
17	Boiler Feed Pump Power (KW)	9330	XXX	10028
18	Boiler Efficiency (%)	85.1	XXX	85.0
19	Gross Generator Output (KW)	426000	425327	443779
20	Auxiliary Usage (KW)	7450	7439	7646
21	Net Generator Output (KW)	418550	417888	436133
22	Net Unit Heat Rate (BTU/KWH)	10114	10091	9559

Table 4

Component Improvement Study

Case No.	Item	HR BTU/KWH	HR Dev. +	Gen. MW	Gen. Dev. +
1	Base Test	10112.54	-	418.371	-
2	Condenser	10128.48	+15.94	417.719	-0.652
3	Base Test Corr. To Standard Conditions	10090.69	—	417.888	-
4	No. 7 Heater	10092.93	+2.24	417.782	-0.106
5	No. 6 Heater	10093.75	+0.82	417.748	-0.034
6	No. 5 Heater	10092.30	-1.45	417.808	+0.060
7	No. 4 Heater	10089.22	-3.08	417.951	+0.143
8	No. 3	10084.45	-4.77	418.200	+0.249
9	No. 2 Heater	10082.54	-1.91	418.375	+0.175
10	No. 1 Heater	10051.88	-30.66	413.898	-4.477
11	Condensate and Htr. Drn. Pumps	10051.64	-0.24	413.881	-0.017
12	Boiler Feed Pump	10061.50	+9.86	413.501	-0.38
13	H. P. Turbine	9923.22	-138.28	423.740	+10.239
14	IP - LP Turbine	9551.26	-371.96	435.960	+12.220
15	Auxiliaries	9548.74	-2.52	436.075	+0.115
16	Boiler Efficiency	9559.14	+10.40	436.132	+0.057
17	Verification	9559.14	+0.00	436.132	+0.000
18					
19					
20					

NOTE: Values of improvement are theoretical, based upon design components under test flow conditions. Actual improvements realized may be slightly less.

Example No. 1

Uncertainty Analysis of the
H.P. Turbine Efficiency

Step 1. Calculate Standard Deviation on the test data.

H.P. Throttle Temp °F

Test Data

1.	1000.0	6.	1000.5
2.	1001.2	7.	999.2
3.	1000.3	8.	1001.1
4.	999.7	9.	1001.8
5.	1003.2	10.	1000.4

Mean = 1000.7°F

Sample Standard Deviation = ± 1.1°F

Apply 99% Confidence Factor

± 1.1°F x 2.5 + 1000.7°F = 998.0 to 1003.5
Acceptable Test Data Range

Step 2. Calculate Process Uncertainty

$$P.U. = \frac{S.D.}{\sqrt{N}} \times 2 \text{ (95\% C.F.)}$$

$$= \frac{1.1}{\sqrt{10}} = \pm .70$$

Step 3. Instrument Uncertainty Evaluation

Throttle temp uses calibrated 4 wire platinum RTD.
Assume ± 1.0°F uncertainty

Step 4. Calculate Measurement Uncertainty

$$M.U. = \pm\sqrt{(I.U.)^2 + (P.U.)^2}$$

$$= \pm\sqrt{(1.0)^2 + (.70)^2}$$

$$= \pm 1.2°F$$

Repeat Above Steps for Each Data Point

Example No. 1 Continued

Step 5. Calculate H.P. Turbine Efficiency
Uncertainty Using Table No. 1

Measurement	Effect on Turbine Efficiency Uncertainty	Measurement Uncertainty	Turbine Efficiency Uncertainty	Square of Turbine Efficiency Uncertainty
(A)	(B)	(C)	(D) = (B) X (C)	(E) = $(D)^2$
H.P. Inlet Steam P	-.043	± 2.5	± .1075	.0116
H.P. Inlet Steam T	.356	± 1.2	± .4272	.1825
H.P. Exh. Steam P	-.430	± .6	± .2580	.0666
H.P. Exh. Steam T	.156	± 1.1	± .1716	.0294

H.P. Eff. Uncertainty = $\pm\sqrt{\text{Sum Column E}}$ = ± .54%

Apply to test value 79.2% ± .54%
= 78.7% to 79.7%

3.0 The Power Plant Productivity Improvement Program

The goal of the Middle South Utility System Power Plant Productivity Improvement Program (PPPIP) is to develop recommendations for a System-wide strategy, which utilizes existing System resources, to improve overall power plant productivity. The Productivity Strategy Team determined that a generating unit's availability, heat rate, and operating and maintenance expenses are the fundamental, measurable parameters required to monitor improvement in power plant productivity. The strategy team also identified six (6) functional areas which affect these productivity yardsticks. They include

- Maintenance
- Training
- Availability
- Materials Management
- Unit Efficiency
- Reporting

The prototype plant selected for program implementation is Louisiana Power & Light Company's Ninemile Point Station. The Unit Efficiency Program implementation of Ninemile encompasses four major task categories - performance monitoring, performance testing, energy loss survey and thermal analysis/improvement. The detailed tasks within each major task category are discussed below:

1. Performance Monitoring - The scope of this task category includes:
   a. the development of generic functional requirements for on-line performance monitoring systems,
   b. evaluation of alternatives and acquisition of on-line performance monitoring systems for Ninemile Units 4 and 5.
   c. survey and upgrade of Ninemile Units 4 and 5 instrumentation used for the on-line performance monitoring system.
2. Performance Testing - The tasks comprising this area are:
   a. the development of test procedures and a performance procedure manual,
   b. the development and acquisition of a mobile testing facility for the company's major equipment testing program.

3. Energy Loss Survey - The scope of this task category involves identification and monitoring of power plant controllable loss items.

4. Thermal Analysis/Improvement - This task encompasses the development of standardized test data and cost benefit analysis techniques.

Development of the Mobile Testing Facility is discussed in the following section.

3.1 The Mobile Testing Facility (MTF)

The MTF will be used as an integral component of LP&L's Unit Efficiency and Component Performance Deviation Programs. Use of the MTF, which will be equipped with precision test equipment, will provide better quality test data, and thus better confidence in the test results. Testing cost reductions will be achieved through the use of common test and calibration equipment. Key elements of the MTF include:

1. A customized trailer
2. Data acquisition equipment
3. Precision instrumentation
4. Metrological standards.

3.1.1 Customized Trailer

A customized trailer will be utilized to transport the instrumentation to each of LP&L's plants. The trailer will also serve as a calibration lab and base of operations when tests are conducted. Trailer details are illustrated in Figure Nos. 2 and 3.

3.1.2 Data Acquisition Equipment

The use of automated data acquisition equipment has gained wide acceptance with the major turbine vendors and several utilities for conducting turbine performance test. The data acquisition system will initially be used for the turbine enthalpy-drop testing. Additional data points may be incorporated at a later date. A mini-computer will be utilized to assist in test data reductions and calculations. Examples of the types of calculations which may be done include statistical checks on the test data to see if a sufficient quantity has been accumulated, and turbine enthalpy-drop efficiency calculations. An illustration of the hardware configuration is given in Figure No. 4.

3.1.3 Precision Instrumentation

Instrumentation for the MTF were carefully evaluated to ensure a successful program. Parameters such as accuracy, repeatability, measurement uncertainty, traceability to recognized standards laboratories, and conformance with elements of the ASME Performance Test Codes were considered during the course of the instrumentation evaluation. The instrumentation includes:

1. Four wire platinum RTDs
2. .1% span pressure transmitters
3. Flue gas analysis instrumentation.

Additional instrumentation such as flow metering or digital watthour equipment may be considered at a future date.

3.1.4 Metrological Standards

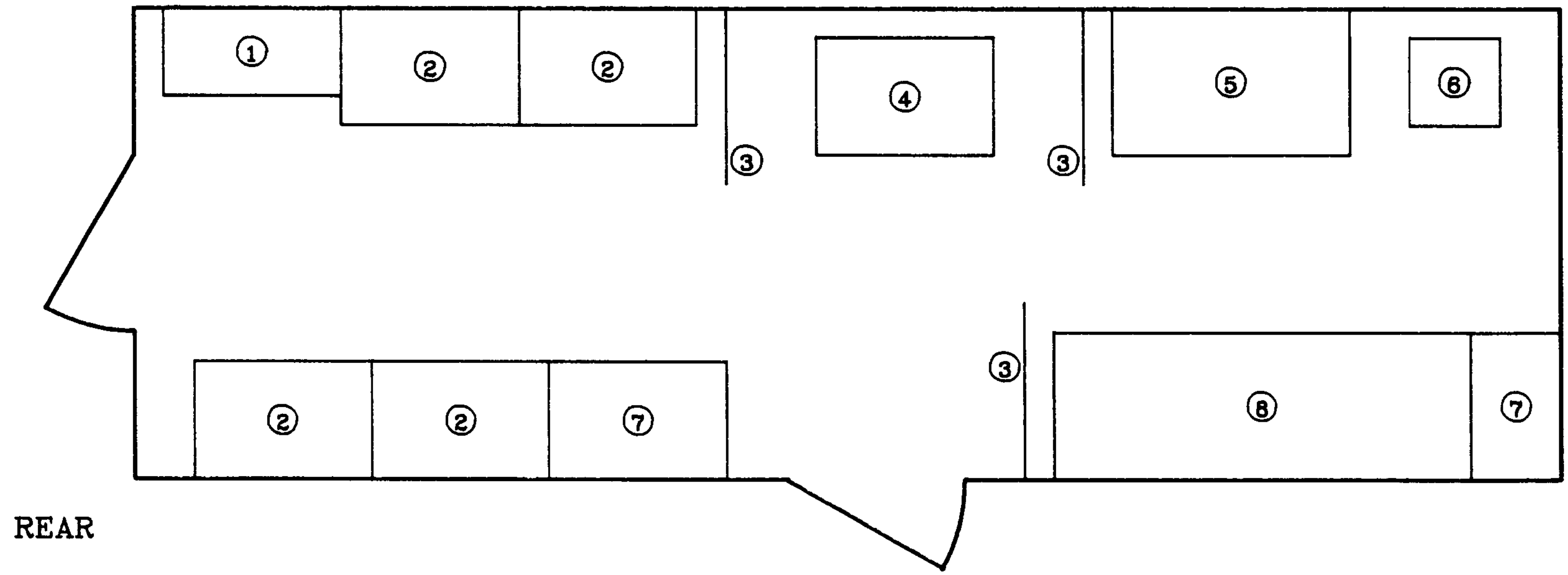
The metrological standards used in the Mobile Testing Facility will ensure the actual field testing instrumentation maintain their accuracy, repeatability, and precision; and that these parameters are directly traceable to recognized national standards laboratories (such as the National Bureau of Standards). The significance of the establishment of a metrological program for power plant testing will be in increased repeatability and accuracy in test results, conclusions drawn therefrom, the ability to meet various parameters, set forth in the ASME Performance Test Codes, and improved credibility between the vendor and the company when test results are examined.

Metrological standards for the MTF will include:

1. A temperature standards system
2. A precision deadweight tester.

The temperature standards system consists of a fluidized bath, a Standard Platinum RTD, and a precision digital indicator. System worst case accuracy is better than ± .13°F. The system will be used to calibrate test RTDs.

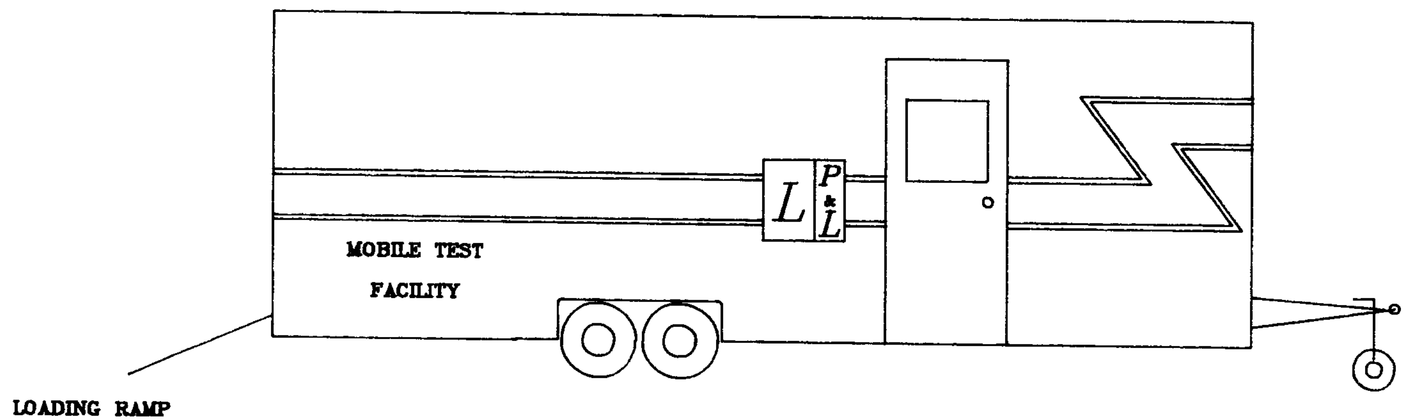
The deadweight tester will be used to check and calibrate field pressure transmitters or gauges. The deadweight tester accuracy is ± .01% of the indicated pressure. This will allow us to maintain a 10:1 accuracy ratio between the standard and the field test equipment.



TOP VIEW

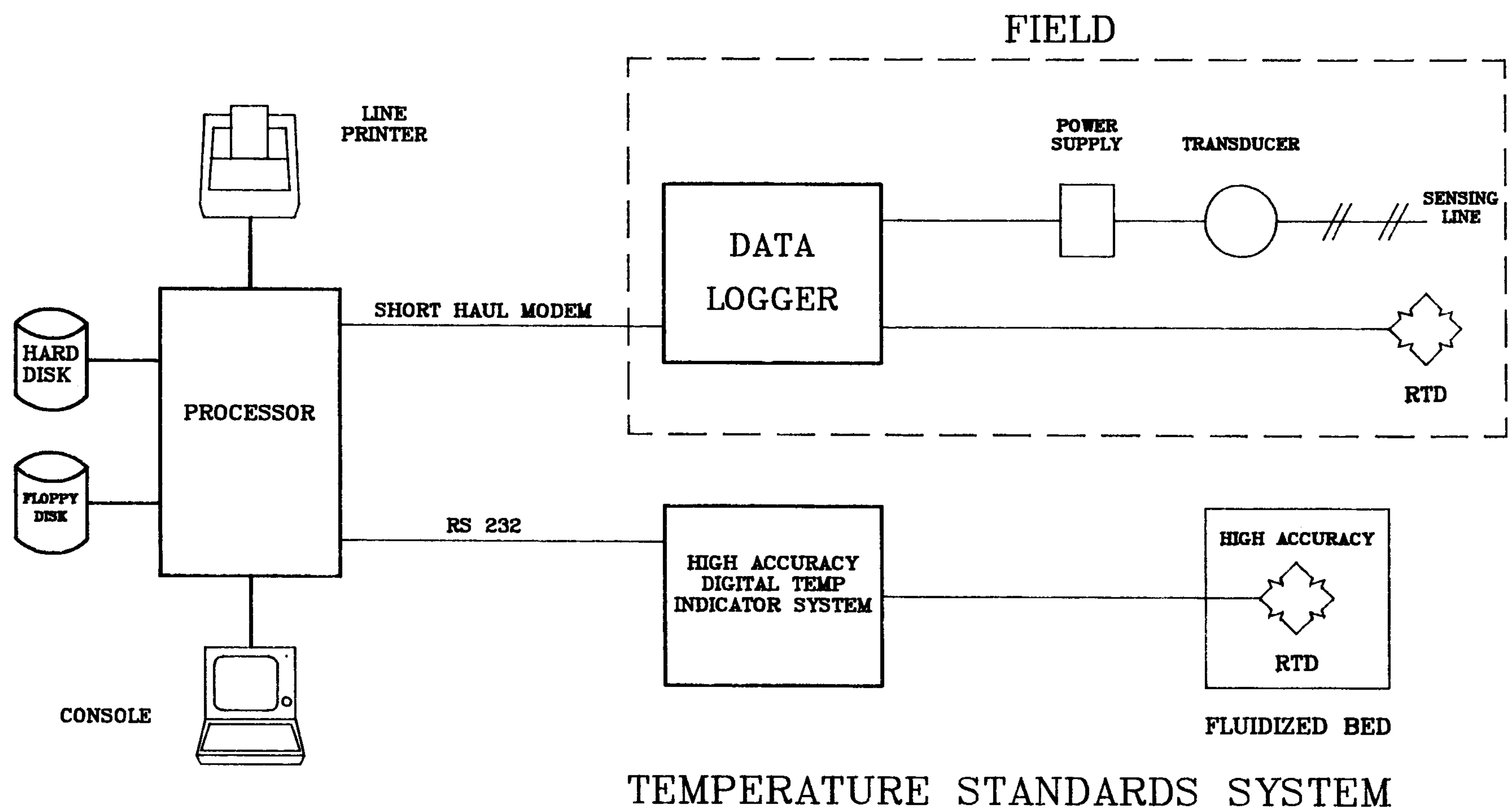
1. 36" X 18" 78" CABINET WITH BINS
2. 36" X 24" X 78" CABINET
3. PARTITION 36" X 2" X 84"
4. FLUIDISED BATH
5. WORK BENCH
6. RACK MOUNTED DATALOGGER
7. DEADWEIGHT TESTER CABINET
8. LAB DESK

GENERAL LAYOUT
FIGURE 2



TRAILER SIDE VIEW

FIGURE 3



SYSTEM HARDWARE CONFIGURATION FOR MOBILE TEST VAN

FIGURE 4

4.0 Summary

PEPSE has become a core component of Louisiana Power & Light Company's performance improvement programs. Current and future developments such as a standardized PEPSE modeling system and a mobile testing facility will enhance the productivity of our company.

LP5-0022

C. P. D. PROGRAM
OBJECTIVES

OBTAIN ACCURATE and REPEATABLE MEASUREMENTS of the FOLLOWING PARAMETERS

* UNIT HEAT RATE
* TURBINE HEAT RATE
* BOILER EFFICIENCY
* SUPERHEATED TURBINE SECTION EFFICIENCES

PROVIDE ADDITIONAL PERFORMANCE DATA ON THE:

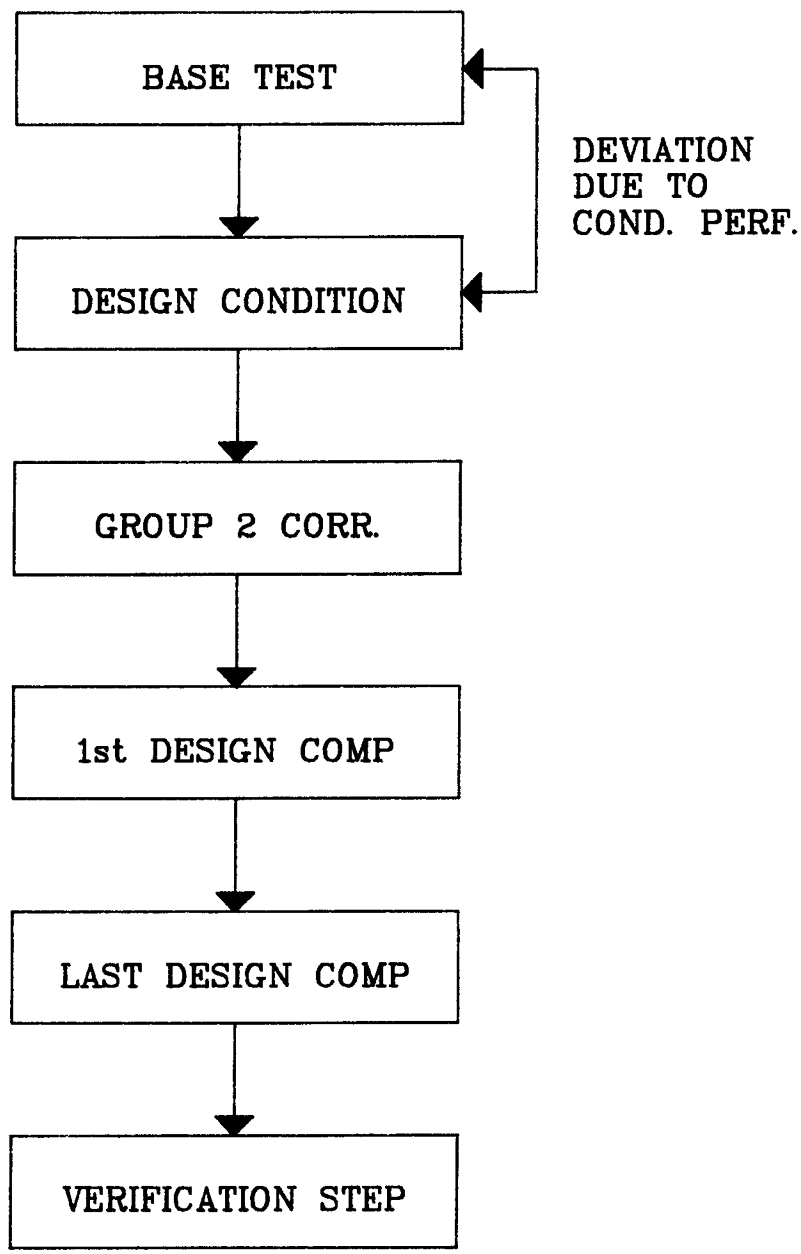
* CONDENSER
* F. W. HEATERS
* MAJOR PUMPS

UTILIZE STANDARD PEPSE MODELS TO PERFORM THE TEST CALCULATIONS

C. P. D. PROGRAM
STANDARDIZED PEPSE MODELS

* VENDOR VERIFICATION
* BENCHMARK
* BENCHMARK W/ CONDENSER
* PERFORMANCE
* COMPONENT IMPROVEMENT EVALUATION

COMPONENT IMPROVEMENT EVALUATION MODEL



MSUS PPIP PROGRAM
UNIT EFFICIENCY

* PERFORMANCE MONITORING
* PERFORMANCE TESTING
* ENERGY LOSS SURVEY
* THERMAL ANALYSIS/IMPROVEMENT

MOBILE TESTING FACILITY

* DATA ACQUISITION EQUIPMENT
* PRECISION INSTRUMENTATION
* METROLOGICAL STANDARDS