

Performance Monitoring of an Aging AMR Meter Population: One Approach

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The Problem

NSTAR was formed in 1999 through the merger of three utilities:

- ***Boston Edison***
- ***Cambridge Electric***
- ***Commonwealth Electric***

Each of the three original utilities started an AMR program prior to the merger:

- ***Boston Edison:***

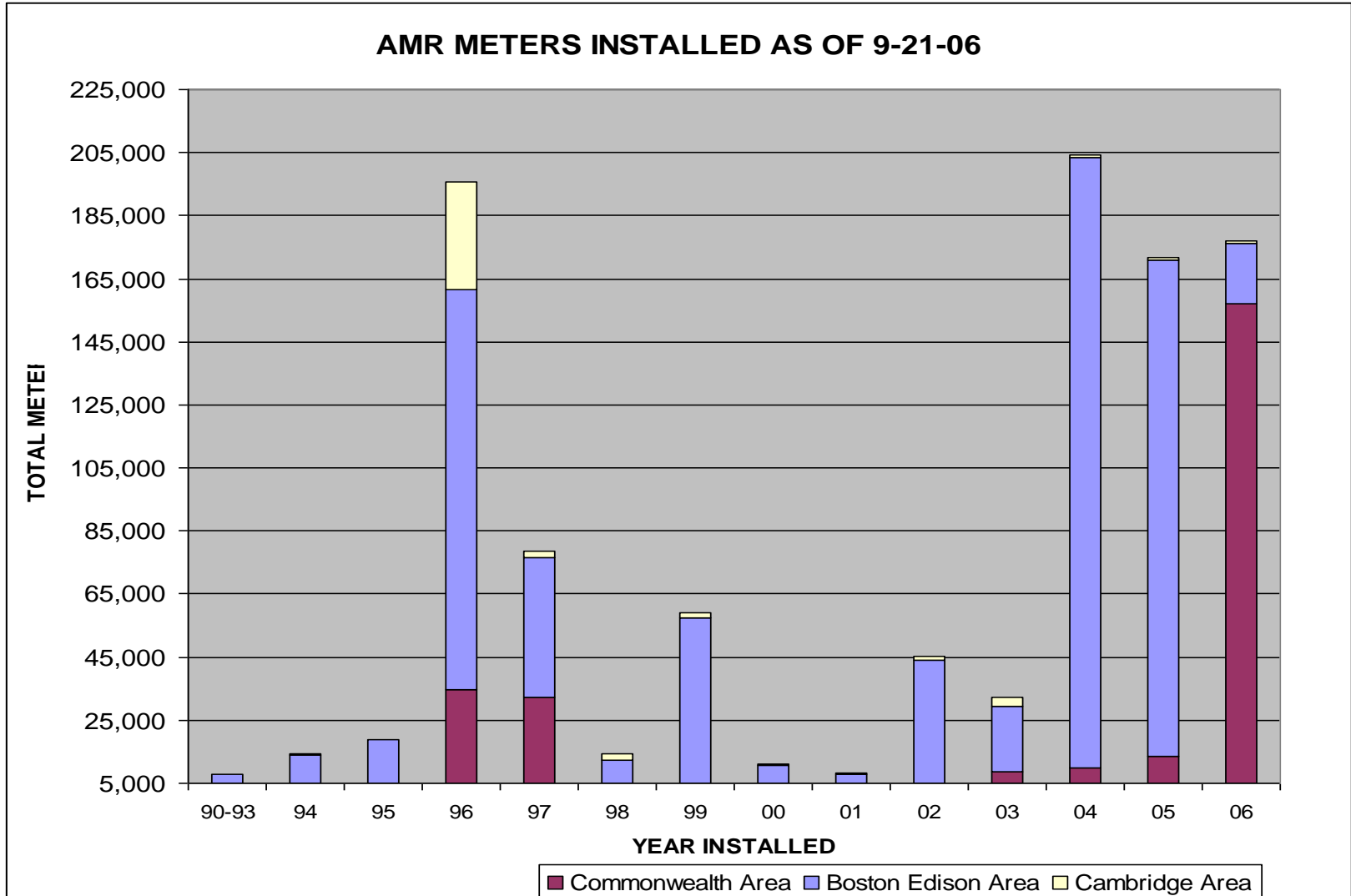
AMR deployments started in 1990 and continued into 2006 with major deployments in 1996, 1997, 1999, and 2002 to 2006

- ***Cambridge Electric:***

Near full AMR deployment in 1996

- ***Commonwealth Electric:***

Partial AMR deployment made in 1996 & 1997 with remaining meters switched to AMR meters in 2006



The result of these sporadic AMR deployments was:

- ***a wide range of meter types in use:***
 - ***existing electro-mechanical meters retrofitted with AMR modules***
 - ***new electro-mechanical meters with AMR modules***
 - ***new solid state electronic meters with AMR modules***
- ***a wide range of AMR module types in use***
- ***AMR meters nearing the end of their projected life***

Therefore, in 2006 NSTAR was faced with the problem of an aging, mixed AMR meter population with no method of monitoring the performance of the various segments of the meter population.

The Solution

Faced with this situation, NSTAR engaged TESCO, a division of Advent Design, in late 2006 to develop a monitoring program and related software for tracking and checking NSTAR's aging AMR meter population.

The first step in the process of developing a monitoring program was to determine what factors needed to be monitored. Discussions with NSTAR personnel led to this list:

- meter accuracy***
- detection of the meter's AMR signal at normal drive-by distance***
- verification of the meter's display reading against the AMR reading***

The second step in the process of developing a monitoring program was to review the available guidance and regulations for in-service meter testing to determine what minimum standards needed to be met. Available guidance for Massachusetts:

- No applicable state regulations***
- ANSI C12.1-2001, American National Standard for Electric Meters, Code for Electricity Metering***

Since a statistical picture of NSTAR’s meter population needed to be developed, the obvious choice was to use a statistical sampling program for monitoring. ANSI C12.1 provides this guidance for statistical sampling programs:

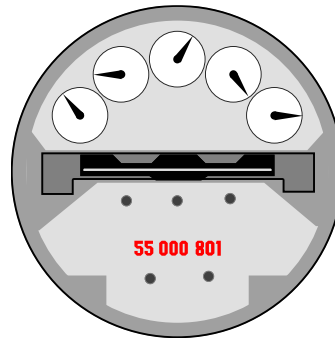
Paragraph 5.1.4.3.3 Statistical sampling plan

“The statistical sampling plan used shall conform to accepted principles of statistical sampling based on either variables or attributes methods. Meters shall be divided into homogeneous groups, such as manufacturer and manufacturer’s type. The groups may be further divided into subdivision within the manufacturer’s type by major design modifications.”

NOTE - Examples of statistical sampling plans can be found in ANSI/ASQC Z1.9, the ANSI version of MIL-STD-414 and ANSI/ASQC Z1.4, the ANSI version of MIL-STD-105.

What is Statistical Testing?

Statistical testing is the testing of a population or group for specific characteristics or parameters using a valid statistically-derived sampling plan.



Features of a Statistical Testing Plan:

- ***Homogeneous Population(s)***
- ***Sample(s) of a Suitable Size for the Plan***
- ***Random Sample Selection of Items to Be Tested***
- ***Expectation that the Group or Population Being Tested Fits the Statistical Model***

ANSI C12.1 references the two primary statistical sampling plans commonly used for in-service meter testing:

- ***ANSI ASQ Z1.4, Sampling Procedures and Tables for Inspection by Attributes***
- ***ANSI/ASQ Z1.9, Sampling Procedures and Tables for Inspection by Variables for Percent Nonconforming***

ANSI/ASQ Z1.4:

- Based on MIL-STD-105
- Uses attributes (pass/fail, yes/no, etc.) as the basis for its analysis
- Variety of special and general inspection levels
- Various sampling plans (single, double, & multiple)
- Wide range of Acceptance Quality Limits (AQL's)

ANSI/ASQ Z1.9:

- Based on MIL-STD-414
- Use variables (a measured parameter or characteristic) as the basis for its analysis. This is normally weighted average for electric meters.
- Variety of special and general inspection levels
- Selection of Acceptance Quality Limits (AQL's)

For the list of factors to be monitored on NSTAR's meters, the attribute or variable categorization is as follows:

- ***meter accuracy - attribute or variable***
- ***detection of the meter's ERT signal at normal drive-by distance - attribute***
- ***verification of the meter's display reading against the ERT reading - attribute***

Based on the factors to be monitored, it is clear that a statistical sampling plan based on attributes was needed. This would be a plan based on the standards of ANSI/ASQ Z1.4

However, since the sample sizes for ANSI/ASQ Z1.4 are larger than those needed for an ANSI/ASQ Z1.9 plan, it was decided to use a hybrid plan where all factors would be monitored using an ANSI/ASQ Z1.4 plan and meter accuracy would also be monitored using an ANSI/ASQ Z1.9 plan.

With the type of plan and the sample sizes determined, the next step was to develop the meter groupings to be used for the plan. It was agreed to base the meter groups on the following parameters:

- ***meter manufacturer and type***
- ***meter form***
- ***AMR module type***

Based on NSTAR's meter population and with the combining of similar form meters (Forms 1, 2, & 12 and Forms 15 & 16), the population divided up into 100 different combinations of meter type, form, and AMR module type.

When groups with only 1,000 or more meters were considered, the number of groups was reduced to 26, which covered 98.6% of NSTAR's 1.2 million meter population.

The meter groups ranged from:

***Form 1 & 2 C1SR meters with an ERT –
521,721 meters***

to

***Form 1 & 2 MX meters with an ERT –
1,117 meters***

With the test plan selected and the meter groups determined, the final step in developing the monitoring program was to decide on how meters would be selected for test.

After extensive discussion, it was agreed to use meters pulled for cause for meter groups with more than 10,000 installed meters. For groups with fewer than 10,000 installed meters (13 of the 26 groups), a random sample of meters would be selected to ensure that a sufficient sample of meters was being obtained.

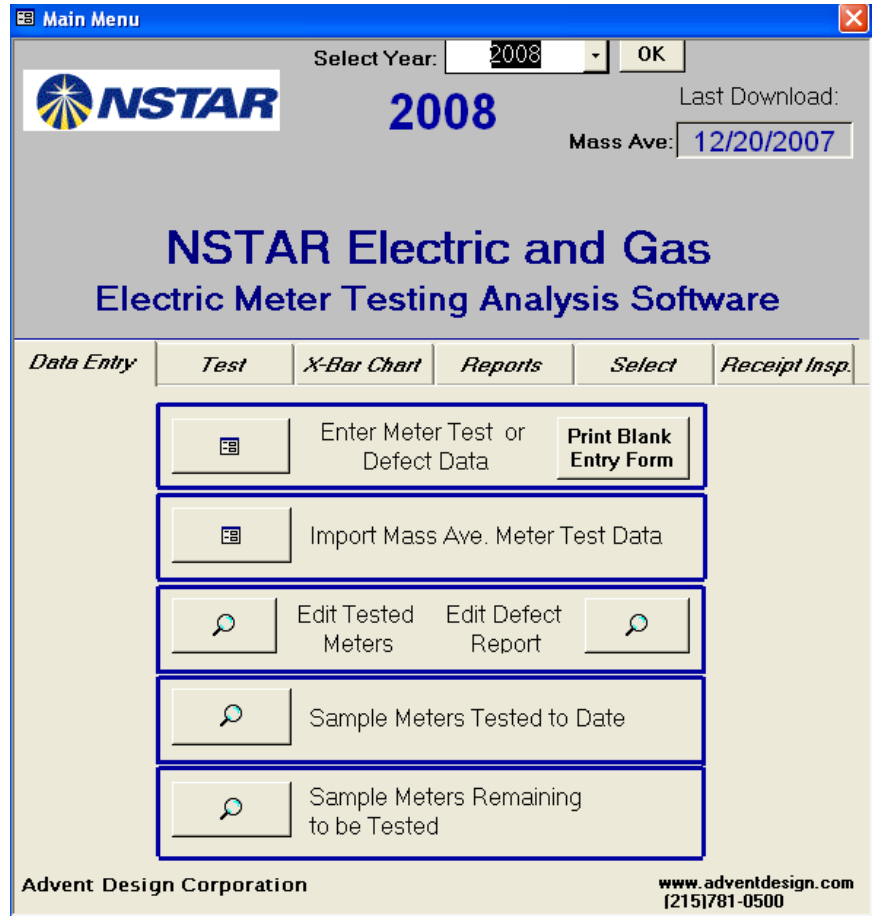
Statistical Testing Plan Features:

- ***Homogeneous Population(s) - yes***
- ***Sample(s) of a Suitable Size for the Plan - yes***
- ***Random Sample Selection of Items to Be Tested – yes but with the use of meters pulled for cause***
- ***Expectation that the Group or Population Being Tested Fits the Statistical Model – yes for the Z1.4 plan & maybe for the Z1.9 plan***

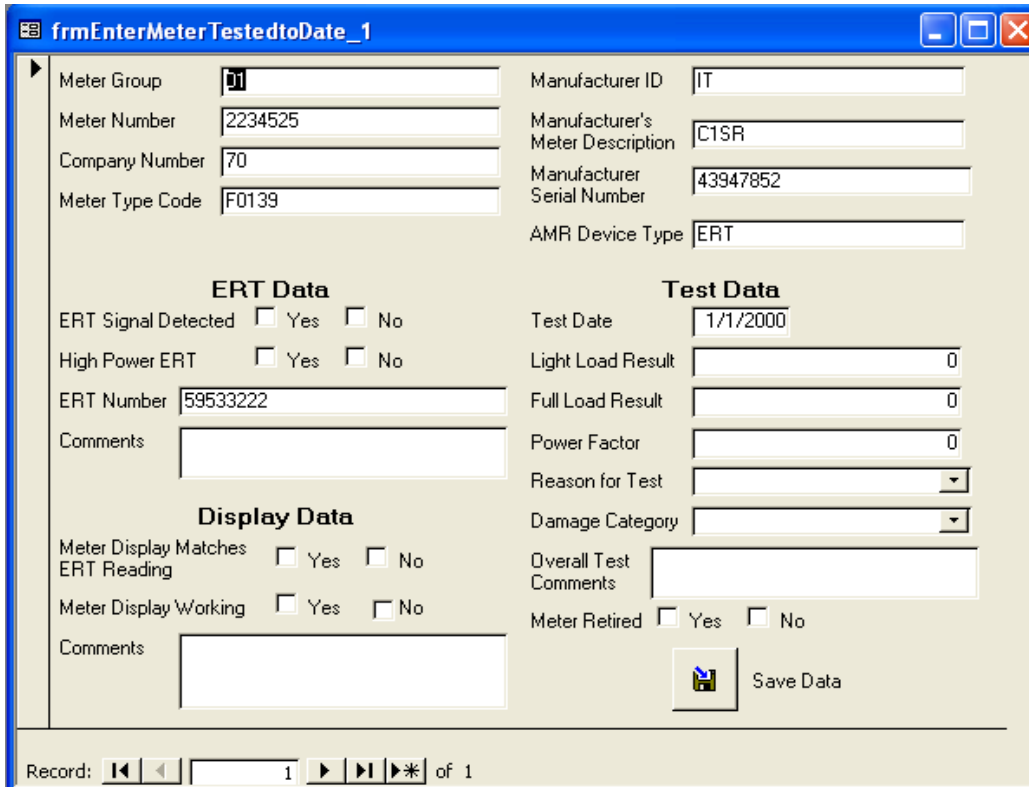
The Results

With the monitoring plan developed, the next stage of the project was to create a software program to run the plan.

TESCO took on this work and developed an MS Access program to collect and analyze the meter test results.



The screenshot shows a software window titled "Main Menu" with a blue header. The NSTAR logo is in the top left. The year "2008" is displayed in large blue text. To the right, there are fields for "Select Year:" (set to 2008), "OK", "Last Download:", and "Mass Ave:" (set to 12/20/2007). The main title is "NSTAR Electric and Gas Electric Meter Testing Analysis Software". Below this is a navigation bar with tabs: "Data Entry", "Test", "X-Bar Chart", "Reports", "Select", and "Receipt Insp.". The "Data Entry" tab is active. The main area contains several buttons: "Enter Meter Test or Defect Data" (with a document icon) and "Print Blank Entry Form"; "Import Mass Ave. Meter Test Data" (with a document icon); "Edit Tested Meters" and "Edit Defect Report" (each with a magnifying glass icon); "Sample Meters Tested to Date" (with a magnifying glass icon); and "Sample Meters Remaining to be Tested" (with a magnifying glass icon). At the bottom, it says "Advent Design Corporation" on the left and "www.adventdesign.com (215)781-0500" on the right.



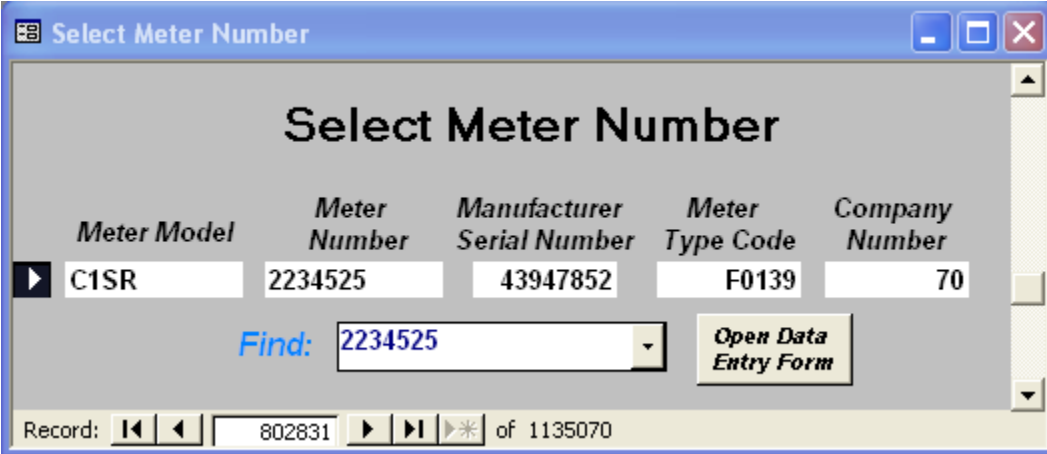
The screenshot shows a software window titled "frmEnterMeterTestedtoDate_1" with a blue title bar and standard Windows window controls. The interface is divided into several sections:

- General Information:** Meter Group (01), Meter Number (2234525), Company Number (70), Meter Type Code (F0139), Manufacturer ID (IT), Manufacturer's Meter Description (C1SR), Manufacturer Serial Number (43947852), and AMR Device Type (ERT).
- ERT Data:** ERT Signal Detected (checkboxes for Yes/No), High Power ERT (checkboxes for Yes/No), ERT Number (59533222), and a Comments text area.
- Test Data:** Test Date (1/1/2000), Light Load Result (0), Full Load Result (0), Power Factor (0), Reason for Test (dropdown menu), Damage Category (dropdown menu), Overall Test Comments (text area), and Meter Retired (checkboxes for Yes/No).
- Display Data:** Meter Display Matches ERT Reading (checkboxes for Yes/No), Meter Display Working (checkboxes for Yes/No), and a Comments text area.

A "Save Data" button with a floppy disk icon is located at the bottom right of the form. At the bottom of the window, a record navigation bar shows "Record: 1 of 1" with navigation icons for first, previous, next, and last records.

The software allows the user to manually enter test or defective meter data and to download test data directly from meter test boards.

The software maintains a database of installed meters in order to reduce the amount of data required to be entered with each test result.



The screenshot shows a software window titled "Select Meter Number". Inside the window, there is a table with the following columns: Meter Model, Meter Number, Manufacturer Serial Number, Meter Type Code, and Company Number. The first row of data is: C1SR, 2234525, 43947852, F0139, 70. Below the table, there is a search field labeled "Find:" with the value "2234525" entered. To the right of the search field is a button labeled "Open Data Entry Form". At the bottom of the window, there is a record navigation bar showing "Record: 802831 of 1135070".

Meter Model	Meter Number	Manufacturer Serial Number	Meter Type Code	Company Number
C1SR	2234525	43947852	F0139	70

Find: 2234525


Record: 802831 of 1135070

The software can create a wide variety of reports for use by NSTAR personnel and management in assessing the state of their meter population and the various meter groups.

Meter Group		Manuf. Model	Meter Type Code	AMR Device	Meter Population	Tested Amount	Required Amount	Z1.9 Current %NCF	Z1.9 Allowed %NCF	Z1.9 Status	Mean	Std Dev	Z1.4 Allowed Failures	Accuracy Failures / Status	ERT Failures / Status	Display Failures / Status	ERT / Display Mismatch Failures / Status
01	C1SR	F0139	ERT	525040	114	1250	0.006	4.39	pass	100.1	0.0806	21	1 / pass	1 / pass	1 / pass	1 / pass	
03	CN1SR	F0209	ERT	69714	189	500	0.006	4.42	pass	100.0	0.0454	21	1 / pass	1 / pass	1 / pass	1 / pass	
06	A3T	F8000	DEMERT	43484	490	500	0.008	4.42	pass	99.99	0.0433	21	5 / pass	0 / pass	0 / pass	0 / pass	
07	C1SR	F0139	R300	38816	260	500	0.008	4.42	pass	100.0	0.0755	21	0 / pass	0 / pass	0 / pass	0 / pass	
08	ABS5	F0209	ERT	38691	1	500	0	4.42	pass	100.4		21	0 / pass	0 / pass	0 / pass	0 / pass	
12	A3T	F8000	ERT	15885	150	315	0.006	4.67	pass	99.97	0.0448	14	0 / pass	0 / pass	0 / pass	0 / pass	
25	ABS3	F0229	ERT	1429	10	80	0	5.21	pass	100.4	0.2887	7	0 / pass	0 / pass	0 / pass	0 / pass	

Main Menu

Select Year: 2008 OK

 **2008** Last Download: Mass Ave: 1/9/2008

NSTAR Electric and Gas Electric Meter Testing Analysis Software

Data Entry Test X-Bar Chart Reports Select Receipt Insp.

Receipt Inspection Analysis

First Meter Number	5103114
Last Meter Number	5103179
Test Start Date	3/2/2007
Test End Date	3/3/2007

- Select Test Data
- Review Test Data
- Analyze Test Results
- Test Report

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12151781-0500

The software can also be used to analyze receipt inspection results for shipments of incoming new meters.

Implementing the software and getting it into use has been challenging. Among the issues that have impacted its start are:

- ***Slow network access speeds forcing the purchase of a special server just for the software***
- ***Difficulty interfacing with older meter test boards***
- ***With no active meter records database with which to interface, the software's installed meter database has to be periodically refreshed***

Overall, the development of the monitoring program and the creation and challenge of implementing the software has been a fairly long and, at times, tedious effort.

However, the information and data that have been and will be resulting from the program and software are expected to have great impact in helping NSTAR make future decisions on meter purchasing and replacement.



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