JOHN CATUOGNO – UPDATE/REBUTTAL
STEAM

Q. Please state your name.

A. John Catuogno.

Q. Have you previously submitted testimony in this proceeding?

A. Yes. I previously provided initial testimony in this proceeding.

Q. What is the purpose of your update testimony?

A. My update testimony addresses the recovery of costs associated with Section 185 ("§ 185") of the Federal Clean Air Act ("CAA").

Q. Mr. Catuogno, please state the purpose of your rebuttal testimony.

A. The purpose of my rebuttal testimony is to respond to the testimonies of Mr. Harvey Arnett, representing the City of New York, Mr. John J. Dowling, representing Consumer Power Advocates, and the Staff Steam Operations Panel as such testimonies pertain to steam line losses (i.e., Steam Variance) and fuel costs.

<u>Update - Clean Air Act ("CAA") §185 Fees</u>

Q. Please describe the Company's proposal for recovery of CAA §185 fees.

A. The Company is proposing to recover the §185 fees for emissions allocable to Steam Operations through its Fuel Adjustment Clause ("FAC"), comparable to the manner of recovery that has been approved by the Commission for Electric Operations' portion of such fees, i.e., through the MSC/MAC. The issue of §185 fees was fully explored in Case 08-E-0539. In that case, the Commission concluded that the fees payable by the Company are recoverable from customers and it also recognized that a portion of these fees is allocable to Steam Operations. (See the Commission's April 24, 2009 *Order Setting Electric Rates* in Cases 08-E-0539 and 08-M-0618, page 324, footnote 552.) This update simply implements that earlier Commission determination with respect to Steam.

Q. What is Steam's estimated share of these fees for the Rate Year?

A. The Company's estimate for the §185 fees for emissions allocable to Steam Operations for the Rate Year is $3 million.

Rebuttal of Mr. Arnett

JOHN CATUOGNO - UPDATE/REBUTTAL
STEAM

Q. Please state your concerns with the testimony of Mr. Harvey Arnett, representing the City of New York.

A. Mr. Arnett recommends (p. 23) that the current Steam Variance target be reduced to 3,501 MMlb and the dead band be continued. Mr. Arnett bases his recommendation (pp. 21-22) on his conclusion that: (1) the Company has not updated its Steam Variance forecast to reflect the recent downward trend; (2) the Steam Variance should continue to decline based on the recent trend; and (3) the high Steam Variance forecast translates into a higher cost of fuel which, in turn, means that the working capital requirement is higher than it should otherwise be.

Q. Did the Company update the Steam Variance forecast as part of its initial filing?

A. No, it did not, since the Company is not proposing a change to the Steam Variance mechanism.

Q. Did the Company recently update its Steam Variance forecast?

A. Yes. In response to discovery requests in this proceeding and Mr. Arnett's testimony, the Company has revised its Steam Variance forecast, which reflects actual data from the last three years. If an updated forecast were required, the Company would forecast a Steam Variance of 4,095 MMlb for the Rate Year, utilizing the same steam sales forecast that was developed by Company Witness Yaegel in this proceeding.

Q. Have you prepared a document which shows the latest result of the Steam Variance forecast?

A. Yes. Under my direction and supervision, Exhibit __ (JC-4), "STEAM VARIANCE FORECAST REVISION" was prepared. This exhibit shows the results of the Steam Variance forecast model by month.

MARK FOR IDENTIFICATION AS EXHIBIT __ (JC-4)

Q. Is Mr. Arnett correct that the Steam Variance has declined and will continue to decline beyond the 3,501 MMlb amount for the period ending September 30, 2009?

A. He is correct that the Steam Variance has declined in recent years, but I do not agree that the available data shows that it will continue to decline. For example, as of the 12 months ending February 28, 2010, the Steam Variance was 3,622 MMlb (13.6%), which represents an increase of 3.5% over the period of 12 months ending September 30, 2009.

JOHN CATUOGNO - UPDATE/REBUTTAL
STEAM

Q. Has Mr. Arnett provided any technical basis or analysis for his claim that Steam Variance should continue at or near the 3,501 MMlb amount, or decline below that amount, for the period ending September 30, 2009?

A. No, he has not. Mr. Arnett's claims (p. 22) that, based on the Company's explanation to NYECC-43, the Steam Variance should continue to decline rather than increase. However, Mr. Arnett ignores the fact that shown in the table provided by the Company (and included on page 21 of Mr. Arnett's testimony), the Steam Variance actually increased by 308 MMlb in the period of 12 months ending September 30, 2007 as compared to the prior year.

The foregoing, coupled with the fact that the Steam Variance shows an increase for the 12 months ending February 2010, and that there are several factors that can occur from one year to another that can drive Steam Variance up or down, demonstrates that there is no basis for assuming that there will be a continuing steady decline in the Steam Variance.

Q. Could you please comment on Mr. Arnett's statement on page 23 of his testimony that the "level of Steam Variance is within Con Edison's control."

A. I disagree with his assertion. A large amount of Steam Variance is fixed due to the laws of Thermodynamics and Heat Transfer, and, as such, no amount of insulation or changes in operating parameters can eliminate such losses. With respect to the level of losses that can change, there are several factors that can occur from one year to another that can drive Steam Variance up or down, many of which are outside the control of the Company. For example, the level of rainfall, water main and sewer leaks, steam load, and unit dispatch all have an impact on the level of Steam Variance and the level of each of these factors can vary from one year to another, thereby causing Steam Variance to increase or decrease.

Moreover, most of the actions that the Company can take to reduce Steam Variance beyond the current level are not cost effective when measured solely from the point of view of reducing losses. For example, as explained later on in my testimony, re-insulating steam piping with pumpable insulation is not cost effective when evaluated solely on the basis of reducing Steam Variance. It is, however, very valuable from a safety point of view.

As discussed below, the recent collaborative effort to evaluate opportunities to reduce thermal losses demonstrated that there is very little, if anything, that the Company can do to economically reduce Steam Variance.

Q. Does the Company recognize that Steam Variance has decreased over the previous two Rate Years?

A. Yes, we do. In seeking to evaluate the lower Steam Variance in recent years, we would attribute this reduction to improvements made in our processes, equipment, and pipe structures to mitigate water intrusion and condensate build up in steam mains.

Q. Why were these improvements made?

A. The Company undertook these improvements in order to mitigate the risk of a water hammer incident. The improvements in Steam Variance were an additional benefit from these improvements.

JOHN CATUOGNO - UPDATE/REBUTTAL
STEAM

Q. Mr. Arnett states (p. 22) that a high forecast of Steam Variance impacts rates. Do you agree?

A. Based on the advice of the Company's Accounting Panel, I do not agree that it would have a material impact on rates. This is because the working capital requirement, with the exception of the fuel oil used in the production of steam, does not recover other steam production costs (*i.e.*, the cost of purchased power and gas used in the production of steam are excluded from the working capital calculation). The associated revenue requirement related to fuel oil is approximately $1.5 million annually, representing less than 0.5 percent of steam base revenues excluding fuel. As a result, assuming that reduced losses result in a reduced amount of fuel oil used, a change in the Steam Variance would have a minimal, if any, impact on the level of this cost reflected in rates.

Q. Does the Company agree with Mr. Arnett's recommendation to lower the Steam Variance target to 3,501 MMlb?

A. No, for the reasons set forth above. If, however, the Commission decides to accept Mr. Arnett's recommendation to reduce the Steam Variance target, the target should not be less than 4,095 MMlb, the Company's updated forecasted level of Steam Variance, with no change to the current deadband.

Rebuttal of Mr. Dowling

Q. What does Mr. Dowling assert regarding the Company's fuel purchasing practices?

A. Mr. Dowling asserts (p. 5) that "if the Company were to retain more of the fuel cost risk, it would not only have a greater incentive to manage fuel purchasing effectively, it would have a greater incentive to reduce thermal losses."

Q. Does Mr. Dowling make a proposal to implement his assertion?

A. No, he does not.

Q. Do you agree with Mr. Dowling's assertion?

A. No, I do not.

Q. Please explain.

A. To begin, Mr. Dowling offers no rationale to support his position, or evidence that the Company's fuel has not been obtained at the lowest reasonable cost consistent with reliability and operational considerations. Nor does Mr. Dowling explain what the

Company should or would do differently if the Company was exposed to greater risk. Indeed, the Staff Panel of Liliya Randt and Nicola Jones (p. 11) states that "the Company has implemented measures to effectively manage the cost of fuel." In addition, as explained elsewhere in this testimony, several factors contribute to the level of Steam Variance, many of which are outside the Company's control, and neither the Company, nor any other party, has identified any cost-effective measure to address thermal losses. Accordingly, Mr. Dowling's assertion should be ignored.

Rebuttal of Staff

Q. What does Staff's Steam Operations Panel say regarding the Steam Variance?

A. The Staff Steam Operations Panel (p. 27) notes that the Company will file an action plan in response to the ABS Thermal Efficiency and Losses Study. Staff then recommends that the pumpable insulation project should not be funded because it is too early to commit funding without the Company's action plan.

Q. Please describe the effort that led to the ABS Study.

A. Pursuant to the Commission's Order in Case 07-S-1315 the Company, in collaboration with other interested parties, retained an independent consultant (ABS Consulting), to review and summarize the findings of previous studies conducted from 1991 to 2002 on Steam Variance, as well as to provide a recommended action plan, which the Company could implement to reduce line losses. Exhibit __ (JC-5), "ABS THERMAL EFFICIENCY AND LOSSES: REVIEW AND ACTION PLAN" ("ABS Study"), is a copy of the final draft of the independent consultant's review and action plan.

MARK FOR IDENTIFICATION AS EXHIBIT __ (JC-5)

A copy of the final ABS Study was distributed to Staff and the other interested parties in May, 2009, although none of the parties to this case submitted any testimony advocating the adoption of any of the recommendations contained in the ABS Study.

Q. Has the Company reviewed the ABS Study and prepared an action plan?

A. Yes, it has. The Company's review and findings of the ABS Study and the Company's action plan are contained in Exhibit __ (JC-6), "REVIEW, ASSESSMENT, AND ACTION

PLAN ASSOCIATED WITH THE THERMAL EFFICIENY AND LOSSES: REVIEW AND ACTION PLAN, PERFORMEND BY ABS CONSULTING, MAY, 2009."

MARK FOR IDENTIFICATION AS EXHIBIT __ (JC-6)

Q. What are the ABS Study's recommendations?

A. ABS recommends that the Company should:

(1) Investigate whether slightly increasing steam sendout temperature, while still maintaining a temperature below the maximum system design temperature limits for the transmission and distribution system, brings about an increase in the amount of superheat (superheated steam is dry steam with a temperature above saturation). In theory, increasing the amount of superheat in the steam increases the distance the steam can travel before a portion of this steam turns to condensate. The expected result is a decrease in the amount of thermal losses.

(2) Investigate whether reducing Steam System pressure, while still maintaining adequate steam pressure to customers, which would result in an increase in superheat, would reduce thermal losses and whether any such reduction is cost effective.

(3) Examine the use of pumpable insulation for re-insulating the Company's High Priority Location List for water intrusion to determine the reduction in thermal losses and to determine if such actions are cost effective.

Q. What are the Company's conclusions regarding the ABS Study?

A. Based on its review of the ABS Study, the Company has drawn the following three conclusions:

(1) There is very little margin for raising the amount of superheated steam by increasing steam temperature. One must also note that by increasing the operating temperature of the steam, there is the potential for a higher heat loss to the outside environment. See Exhibit __ (JC-6).

(2) Re-insulating existing steam piping with pumpable insulation is uneconomic when considered for the sole purpose of reducing heat loss and Steam Variance. See Exhibit __ (JC-6).

(3) Increasing the amount of superheated steam by lowering Steam System operating pressure can and should be examined further to determine the amount of heat that

could potentially be saved as well as the impact on customer service and operations. However, the potential for reduction of heat loss is very limited because of customer pressure requirements. See Exhibit __ (JC-6).

Q. What is the Company's proposal with respect to increasing the amount of superheat by lowering steam operating pressure?

A. As indicated above, although the potential benefits are limited, the action plan calls for the Company to further evaluate this action item. The Company estimates that it will incur up to $50,000 in consultant costs to support this effort and proposes that the consultant's costs be recovered through the FAC as was the case with the ABS Study.

Q. Since the Company's conclusion is that pumpable insulation is not cost effective in reducing thermal losses, do you support the Staff's Steam Operations Panel's recommendation to reject the Company's request to spend $500,000 in 2012, and $500,000 in 2013 on such re-insulation projects?

A. No, we do not. As explained by the Company's Steam Operations Panel, these re-insulation projects are undertaken for important safety reasons and not to address thermal losses. Specifically, pumpable insulation will be applied to steam mains that are direct buried and located in areas that are deep and prone to contact with water from flooding and tidal effects. Such re-insulation will reduce the risk of water hammer by retaining the heat within the steam pipe. This is due to the new layer of insulation forming a thicker boundary between any external water and the hot steam pipe. The effect is additional thermal resistance between the steam in the pipe and any external water, hence impeding the amount of heat lost and thus reducing the amount of condensate formed in the pipe.

Q. Does this conclude your update and rebuttal testimony?

A. Yes.

EXHIBIT__(JC-4)

Steam Variance Forecast Revision

Rate Year		Monthly Forecast Sales (MMlb)	Monthly Forecast Sendout (MMlb)
2010	Oct	1,285	1,638
	Nov	1,817	2,164
	Dec	2,886	3,221
2011	Jan	3,330	3,655
	Feb	2,831	3,161
	Mar	2,395	2,730
	Apr	1,420	1,765
	May	1,142	1,491
	Jun	1,401	1,747
	Jul	1,712	2,054
	Aug	1,652	1,995
	Sep	1,279	1,626
	Total	23,150	27,245

Steam Variance	**4,095**

ABS Consulting
AN ABS GROUP COMPANY

Case 09 - 5 - 0794

EXHIBIT_(JC-5)

Report
2053458-R-001
Revision 0
May 2009

EXHIBIT_(JC-5)

Thermal Efficiency and Losses: Review and Action Plan

Prepared for:
Consolidated Edison of New York, Inc.

Prepared by:
ABS Consulting
Stratham, NH

ABS Consulting

REPORT COVER SHEET

Report No.	**2053458-R-001**
Project:	**Steam System Variance**
Report Title:	**Thermal Efficiency and Losses: Review and Action Plan**
Client:	**Consolidated Edison of New York**
Computer Software Used:	☒ **No** ☐ **YES: Code/Version:**
Quality Assurance:	☒ **ISO 9001 Program (QMS)** ☐ **Nuclear QA Program (NQA)**
Client PO No:	832269
References:	See Section 5.0 of this procedure
Attachments:	As noted on Table of Contents

Total Number of Pages (Including Cover Sheet): **61**

Revision Number	Approval Date	Description of Revision	Originator	Checker	Approver
0	5/15/09	Original Issue	G. Zysk	P. Streeter	For by Telecon T. Roche

RECORD OF REVISION

Revision	Description of Change	Reason For Change
0	Original Issue	

Table of Contents

List of Attachments

Total Pages

1.0 Introduction

Consolidated Edison of New York, Inc. (Con Edison) has requested the performance of a review of previous studies addressing losses and variance. These studies date from 1991 to 2002, and were performed by or for Con Edison for the Steam System serving New York City. Included in these studies are evaluations of the issues that affect losses in the system or the variance, which is defined as the difference between steam produced by Con Edison and steam purchased by customers. Within these reports, specific components of the variance are evaluated and recommendations for addressing these loss components are provided.

This report provides a review of these studies and the conclusions drawn by the previous studies. From the conclusions drawn by these reports, Action Plans to prioritize, implement, and maintain economic projects for reducing overall steam losses/variance are developed.

1.1 Objective

The first objective of this report is to document a review of the previous variance and loss studies.

The second objective of this report is to develop action plans to implement recommendations from these studies.

1.2 Scope

The scope of this paper addresses the following studies.

1. November 1991 – 217 pages – Steam Flow Calculations (not part of the study, provided for reference only)
2. March 1994 – 263 pages - Assessment of the Con Edison Steam System (not part of the study, provided for reference only)
3. April 1995 – 55 pages – Assessment of the Con Edison Steam System–Summary
4. April 1996 – 17 pages – Research study on Steam Meters
5. June 1996 – 36 pages – Methodology of Steam Calculations on 1995 Steam Variance report
6. November 1997 – 11 pages – Effect of Pipe Geometry on Flow Measurement Accuracy
7. November 1997 – 33 pages – Report on Brooklyn Navy Yard Steam Tie Line

8. February 1998 – 15 pages – Shuntflo Meters Weighted Average Error due to Low Flows (1997 data)

9. February 1998 – 9 pages – Steam System Variance

10. March 1998 – 10 pages - Shuntflo Meters Weighted Average Error due to Low Flows (1998 data)

11. August 1998 – 26 pages – Modeling of Heat Losses in the Con Edison Steam System

12. September 1998 – 4 pages – Effect on Steam Variance by Re-insulating manholes

13. September 1998 – 22 pages – Economic Analysis of in-situ on encapsulation of mains using Condufill

14. November 1998 – 63 pages – Steam System Variance in Con Edison Steam Distribution System

15. September 1999 – 78 pages – Steam System Variance Study

16. February 2002 – 13 pages - Steam Variance Study (Factors affecting the Steam Variance)

17. August 2002 – 33 pages – Steam System Variance (Draft)

2.0 Review of Previous Studies

This section provides a summary of the major issues and findings of each of the reports listed in Section 1.2. These reports are referred to herein as the primary reports. Additional reference documents are identified by numbered items in brackets [xx] which refer to numbered items in Section 5.0 of this report.

Figure 2-1, below, is adopted from the August 2002 Litkouhi report (Report 17) and shows the factors affecting steam variance[1]. These fall into two major groups. 1) Metering accuracy issues address the measurement of steam being sent from plants (sendout) or used by customers (sales). 2) Line Losses are thermal losses from the mains and service pipes or leaks from the system attributed to the release of steam during work on the system (repairs), steam used by customers or plants which is unmetered, or actual leaking components.

Each of the primary reports addresses one or more of the variance components provided in Figure 2-1. The primary technical issues and conclusions are summarized within this Section. From these reports, actions were taken to further investigate specific subjects or issues. These actions are described in subsections to each applicable report.

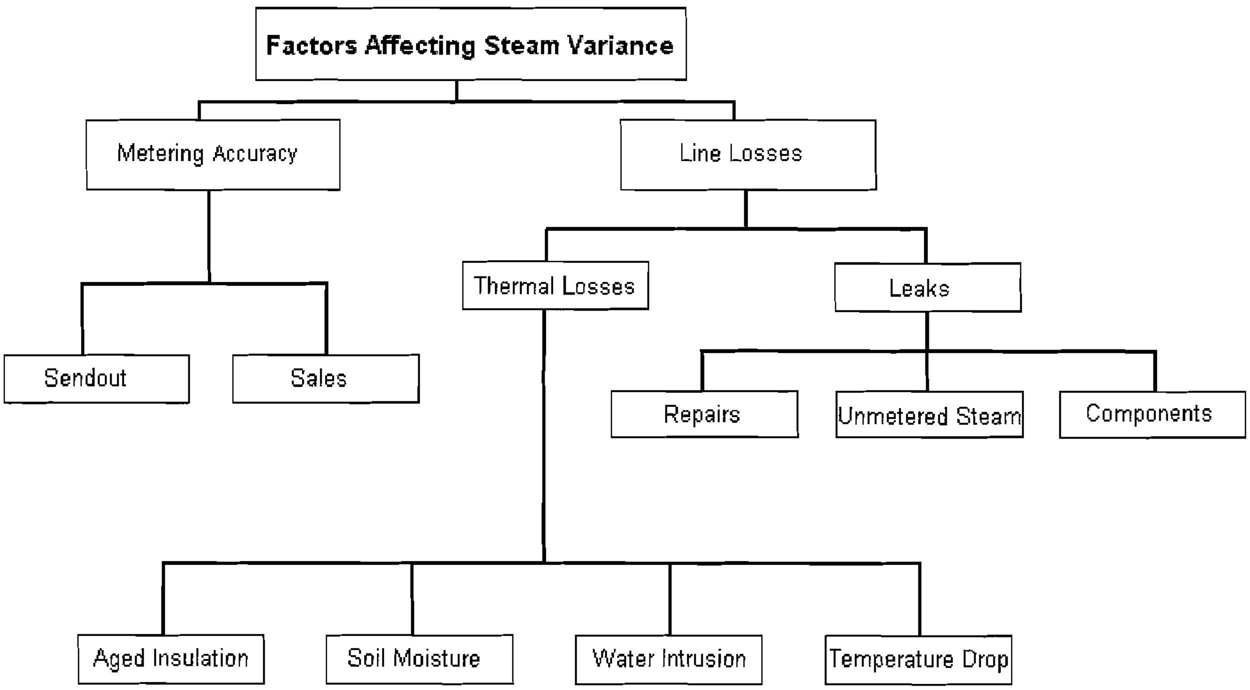

Figure 2-1: Factors Affecting Steam Variance

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[1] It is noted that Report 17 and several other studies identify reporting issues pertaining to the "percentage of steam production" manner in which variance was reported. It is understood that this method is no longer used.

2.1 November 1991 – Steam Flow Calculations

This document addresses metering accuracy issues and includes numerical steam flow calculations for each power station send-out metering station. No conclusions or recommendations are derived in this report and therefore no actions are appropriate based on this report.

2.2 March 1994 – Assessment of the Con Edison Steam System – Sarunac (Lehigh)

This document primarily addresses metering issues. The report provides a review of sendout metering and provides a meter error evaluation for each station. Also included is a brief discussion of other system losses. The report provides a comprehensive investigation of variance statistics and shows that the system loses are relatively constant while demand varies, thus providing a range of variance expressed as a percentage of sendout. Since this report is provided for reference only, and since most of the information is superseded by later reports, no actions are appropriate.

2.3 April 1995 – Assessment of the Con Edison Steam System: A Summary – Sarunac (Lehigh)

This document is a summary report of Item 2, above. Because this information is superseded by later reports (see Section 2.14), no actions are appropriate.

2.4 April 1996 – Summary of Research Study on Steam Meters – Yam (Con Edison)

This document addresses metering accuracy issues and summarizes the testing of new (circa 1996) EDP and vortex meters against older Bailey meters under a range of steady and variable flow conditions. The primary conclusion was that vortex meters were more accurate over the test range. Bailey meters displayed accuracy problems of as much as 26% under low flow conditions.

Further actions taken are described below.

2.4.1 Investigation of Meter Installation

One action was to review the current engineering specifications (EO) regarding vortex meter installation to ensure appropriate control of installation.

The engineering guidelines for installation of the vortex meter are provided by Con Edison on a guidelines website:

http://coned.com/steam/engspecs.asp

The specification for the typical assembly and installation of a vortex flow meter (S-588) requires mounting of the meter with the electronics at the 3 o'clock or 9 o'clock position. An excerpt from the specification is provided below. This installation has been approved by the Vortex meter vendor, Foxboro, as confirmed by Con Edison personnel.

Con Edison personnel also discussed the installation specification requirement for a significant length of straight pipe upstream (approximately 45 diameters) and downstream (approximately 10 diameters) to ensure accurate measurement. The only other potential source of error could be deliberate throttling of a tagged open valve upstream of the meter, although this is considered unlikely since it could reduce the local pressure and therefore the mass flow of steam.

The installation drawings are reviewed by Con Edison Engineering and a walk-through is performed to ensure compliance prior to energizing a steam system.

It can be concluded that appropriate control of installation position is maintained and that the meters should perform within the manufacturer's expected +/-1.5% accuracy. Minimal additional variance improvements are to be obtained from these meter installations.

INSTALLATION POSITION

(1) THE VORTEX FLOW METER SHOULD BE MOUNTED WITH ELECTRONIC HOUSING LOCATED IN THE 3 Ø'CLOCK OR 9 Ø'CLOCK POSITION. EITHER CONDUIT CONNECTION CAN BE USED. TO AVOID ACCUMULATION OF MOISTURE AT THE TERMINAL BLOCK, THE REMAINING CONDUIT CONNECTION MUST BE SEALED WITH ½" NPT PLUG

(2) THE CONDUIT CONNECTED TO THE INSTRUMENT MUST HAVE AN INTERNAL SEAL AND BE CONNECTED TIGHTLY TO EXCLUDE MOISTURE FROM THE TERMINAL BLOCK ENCLOSURE.

(3) PIPING VIBRATION SHALL BE MINIMIZED.

2.4.2 Investigation of Current Metering Status

A second investigation was held regarding the current status of customer steam metering. A discussion of the state of the current metering was held with Con Edison steam engineering personnel (K. Yam, 1/12/09) and is summarized below.

Bailey meters were replaced in the Con Edison system between 1993-1999.

There are approximately 3400 steam meters in the system. Approximately 1900 (55%) are vortex meter, 1500 Shuntflo (43%) and 45 EDP (~2%) meters. However, the larger usage customers have been replaced on a priority basis. As a percentage of steam sales, this provides approximately 81% vortex meters, 7.3% EDP meters, and only 11.4% Shuntflo meters.

The conversion of Shuntflo meters to vortex meters is on going, but is contingent on the payback period with consideration based on a period of approximately 5 years. Assuming a continuation of the current rate of replacement, it will take 8 - 10 years to complete the conversion.

It can therefore be concluded that the previous variance issues regarding the Bailey and Shuntflo meters as discussed in the primary reports are currently being addressed through the replacement program.

2.5 June 1996 – Methodology of Calculations for the 1995 Steam Variance Report – Drilon (Con Edison)

This document addresses thermal losses and leaks experienced in 1995. Only 29.2% of the total variance was accounted for due to known loss mechanisms, and the majority was left unexplained. Of the known losses, the largest factor (23.2% of the 29.2%) was based on thermal losses from the mains.

No actions are appropriate based on this study since the methods presented in this report are superseded by later methods (see Section 2.11, 2.15 below).

2.6 November 1997 – Effect of Pipe Geometry on Flow Measurement Accuracy – Sarunac (Lehigh)

This document summarizes plant send-out meter installation details as found during the 1994 investigation (see Item 2, above), with specific discussion of piping geometry upstream and downstream of the meter stations.

The actions taken were to review the current conditions of plant send-out metering with Con Edison personnel. Interviews of Con Edison personnel are described in more detail below. However, it should be noted that subsequent reports indicate that metering issues have been corrected (see Section 2.14).

2.6.1 Investigation of Current Plant Send-Out Metering

As of 1998, (see Section 2.14) plant send-out meter issues had been resolved. Thus, the current investigation was undertaken to confirm that no significant changes have occurred that could potentially introduce new errors into the system.

The following inquiries were made at the steam plants. A summary Table of the results is provided in Attachment A (in progress).

1) Are there changes to the send-out metering since 1998?

2) When were the current meters installed?

3) Is the meter location geometry the same, in particular the length of upstream piping?

4) Can we obtain a copy of the calibration procedure?

5) How often are the meter factors spot-checked?

6) Is the send-out flow total calculated or automated and by what instrument system?

7) Does the meter meet ASME requirements (% accuracy, calibration period, etc.) ?

8) Any other known issues with the send-out metering?

The plant response to the inquiries, while incomplete, indicated that very few changes to the metering had been made since the 1998 study. It is concluded that little room for improvement is available in this area.

2.7 November 1997 – Report on Hudson Ave.-York-Brooklyn Navy Yard Steam Tie Line – Miller

This document addresses meter accuracy issues by providing an evaluation of the discrepancy between the Brooklyn Navy Yard Cogeneration Partners (BNYCP) meter and the Con Edison meter used to measure steam from the Brooklyn Navy Yard at Hudson Avenue. This report discusses the source of errors in the BNYCP meter installation.

An action was taken, based on this study, to confirm the state of these meters with Con Edison personnel (Conroy, 1/26/09). This Con Edison meter, referred to as the Revenue Meter, is the meter of record and the second BNYCP meter is not considered for official steam measurements, except as discussed below. The Con Edison meter has been replaced in 2007 with a Venturi meter and no further action is required.

Per further discussion with Con Edison personnel, the second (non-Con Edison) BNY meter is used less than approximately 5 days per year as an official measurement. The primary source of error, accounting for as much as 20% under-reporting of steam flow, was a simple calibration error, and is assumed to be corrected. Therefore, due the infrequent use and correction of the primary source of error, the effect of any remaining error (estimated at approximately 3%) on the total variance is expected to be minimal

2.8 February 1998 – Shuntflo Meters Weighted Average Error due to Low Flows (1997 data) – Jordan (Con Edison)

This report addresses meter accuracy by documenting a testing program of Shuntflo meters at four different loads. This testing demonstrated Shuntflo meter inaccuracy (under registering) under low flow conditions. The testing program measured 107 meters at loads as low as 10% flow, and found under-reporting of as 27.1%. This under-reporting of steam use added to the variance at the time of the test.

Shuntflo meters are currently being replaced in the Con Edison system. The action taken was to discuss current metering in the Con Edison system, see also Section 2.4.2.

2.9 February 1998 – Steam System Variance – Jordan (Con Edison)

This memo primarily addresses meter accuracy issues. The memo describes the total fall 1997 variance and discusses corrections for overstatement of the Waterside send-out and planimeter error. The memo also discusses plans for pursuing corrections without specific recommendations in the areas of steam quality, efficiency, and Shuntflo and Bailey meter errors under low loads.

Corrections to the Waterside send-out meter (1.4% of variance) and planimeter (0.35% of variance) were made as discussed in this document.

Customer meter issues were discussed but are being addressed as old meters are phased out (see Section 2.4.2).

No further actions are appropriate.

2.10 March 1998 –Shuntflo Meters Weighted Average Error due to Low Flows (1998 data) – Jordan (Con Edison)

This document addresses meter accuracy and expands upon the testing program described under Item 8. This report uses the testing of 140 Shuntflo meters and a survey of 104 customers' steam use to provide a weighted average of system error of 0.56%.

No further actions are appropriate because Shuntflo meters being phased out (see Section 2.4.2, above)

2.11 August 1998 – Modeling of Heat Losses in the Con Edison District Steam System – Joseph Technology Corporation, Inc.

This document addresses line thermal losses by developing a first principles based heat loss model by Joseph Technology Corporation. This is an important study since the modeling effort shows the significant effect of water intrusion and insulation degradation on heat loss. This model also forms the basis for several later evaluation efforts (see Section 2.13).

An example of the heat losses with water infiltration is shown in the following table for a range of infiltration rates. It can be seen that water infiltration, if large enough, can increase the heat loss by a factor of 100 times. This is significant, since it implies that stopping external water infiltration is the single largest factor for lowering thermal losses.

Influx/1000 ft of pipe	Loss	Condensate
gpm	BTU/hr/ft	lb/hr/ft
0 (dry)	100-200 (approximate)	0.1-0.2 (approximate)
1	485	0.56
2.1	1018	1.18
3	1454	1.69
10	4848	5.62
20	9696	11.24
40	19392	22.48

No specific actions are appropriate because the document provides an evaluation methodology and does not provide specific recommendations for changes to the system.

2.12 September 1998 – Effect on Steam Variance by Reinsulating manholes – Tsang (Con Edison)

This document addresses line thermal losses by providing an estimate of the savings resulting from reinsulating 227 out of 1368 manholes. This savings was reported to be approximately 237 MM lb/year.

The action taken was to follow up with steam engineering to discuss on-going insulation efforts in manholes.

2.12.1 Status of Con Edison Manhole Re-Insulation Effort

The technical subject of this report is largely superseded by an extensive effort to reinsulate steam manholes, undertaken in 2004, to mitigate high temperature conditions at Con Edison manhole covers.

Per investigation with Con Edison personnel (R. Flanagan, J. Catuogno, 3/5/09), approximately 1,000 manholes were re-insulated in 2004. Per further investigation of the total number of manholes in the Steam System, (K. Oh, 3/5/09) the basis for the 1,000 manholes was determined to consist of 790 steam main manholes, including slip joint and main valve manholes, out of a population of 1,370 manholes, and an additional 216 "SV2" or service box/valve manholes, out of a population of 698 were also insulated. This produced a total of 1006 manholes that were reinsulated.

It was also noted that a complete survey of the manhole covers in the Con Edison Steam System was performed at that time. Manholes were prioritized based on the temperature of the manhole cover. For manholes with cooler covers, the insulation condition was inspected and re-insulation was not performed if not warranted. It is therefore concluded that the high heat loss manholes were adequately addressed in 2004.

2.13 September 1998 – Economic Analysis on In-situ Encapsulation of Mains Using Condufill – Tsang (Con Edison)

This document addresses line thermal losses by providing an economic analysis of the re-insulation of 10,000 ft of pipe using Condufill or Ceasefire. The analysis was based on the modeling approach described in Section 2.11, using a range of water in-leakage derived from measured condensate amounts from previous testing efforts. Due to the sensitivity to water intrusion rates, a range of economic benefits is possible.

The conclusion of the economic study was that the use of either Condufill or Ceasefire (both products estimated to cost $250/foot) for a 10,000 ft section of pipe would provide a cost effective method to reduce steam losses. An updated economic analysis was subsequently performed in 1999 (see Section 2.15) which also supports this conclusion.

This document also describes four previous insulation efforts using Ceasefire or Condufill (1984 – Water St., 1985 – Fulton St., 1993 – Ave. D, and 1997 – E27th St.).

The action taken based on this report was to investigate the previous insulation efforts in more detail.

2.13.1 Investigation of Previous Insulation Efforts Using Ceasefire or Condufill

The primary report referenced a second report (Reinsulation Project Summary, 1986 [1]) which was reviewed. This second report describes in detail the installation of Ceasefire (mixes VT-164 and VT-170) at two locations (1984 – Water St., 1985 – Fulton St). This second report also described the condensate collected after the Ceasefire installation and provides additional economic analysis of the effectiveness of the installation.

The economic conclusion from this second report was based on the relatively insignificant change in the volume of condensate collected before and after installation, and thus it was believed that this re-insulation effort was not a cost-effective solution.

However, the primary report dismisses the condensate collection as unreliable due to changes in steam conditions affecting how much condensate was generated. Furthermore, recent work at Con Edison indicates other factors, such as high steam velocities, could affect the flow of condensate to the low point drains. Lastly, the significant improvement in vapor conditions indicates that ground water infiltration was reduced or eliminated, which would indicate significant heat loss improvement.

Therefore, the secondary report (Reinsulation Project Summary) economic conclusions are not considered realistic.

A third referenced report (also called Reinsulation Project Summary, 1994 [2]) was reviewed. This report describes the installation of Ceasefire mix VT-600 at Avenue D north of 13th Street to the East River Station. No detailed heat loss measurements or condensate collection was made to measure the effectiveness of the installation. However, it was noted that "an inspection pit revealed a significant reduction in heat loss from the distribution main to the point of entry at the sump pit". Also, "runoff water which was dumping into the pit during high tide conditions have been permanently stopped". Therefore, it is clear that the insulation effort effectively stopped ground water infiltration and therefore significantly reduced heat transfer.

For the remaining installation of pumped foam material, only the primary report was found. It was noted in the primary reference that the 1997 – E27th Street installation was not performed to eliminate vapor but to test the installation of Condufill material. It was noted that this test installation was successful.

2.14 November 1998 – Steam Variance in Con Edison Steam Distribution System – Levy (Lehigh)

This document provides a summary of prior studies completed between 1989 and 1998, a description of major components of the variance, and a summary of activities underway to further reduce the variance.

The state of the 1998 variance and potential for further improvement, per this study, is provided in the following table (see Figure 2-2).

Based on this report, significant improvements in the variance had been made between 1989 and the 1998, particularly in the area of meter accuracy.

- All plant sendout meter recommended changes had been made, leaving a "negligible" amount remaining for improvement.
- The Shuntflo meters contributed 0.245+.043+0.735+0.8 (estimated) = 2.21%.
- The Bailey meters contributed 0.105+0.315+0.14 = 0.56%.

Furthermore, these results can be extrapolated to current conditions.

At the time of the 1998 report, approximately 70% of the customer steam sales was measured using Shuntflo meters. These have been reduced to approximately 11% of sales. Therefore, the potential Shuntflo error would be reduced to (11/70) x (2.21%) = 0.4%. Bailey meters have been removed, eliminating this 0.56% error. Thus, the only remaining variance attributed to theses types of metering issues is approximately 0.4%

As stated previously, Shuntflo meters continue to be replaced with more accurate Vortex meters. While Vortex meters may have some errors under wet steam conditions, they are generally considered to be more accurate than the Shuntflo meters, and at worst could contribute a similar 0.735% wet steam error for 75% of the meters. Thus the total customer meter error might be estimated as approximately 1.5%. This estimation is not investigated further, since there is little accuracy improvement to be made with these meters.

Contributions to Variance

	Corrected Variance	Remaining Contribution to System Variance
METERS		
SENDOUT METERS	1.4%	Negligible
UNMETERED STEAM	0.1 to 0.2%	
SHUNTFLO METERS		
• District Pressure Correction	0.245%	
• Low Load Errors		0.43%
• Steam Moisture		0.735%
• Damping Liquid, Temperature Error and Other Meter Calibration Issues		Under Investigation
BAILEY METERS		
• District Pressure Correction	0.105%	
• Steam Moisture		0.315%
• Low Load and Cycling Errors		0.14%
SUBTOTAL	1.85%	1.62% Plus Additional Shunt Flo Meter Errors
PIPE LOSSES		
• Main Lines		3.2% Plus Loss Due to Groundwater Effects
• Service Pipes		0.3%
• Leaks		0.2%
• Trap Failures		0.3%
• Repairs and Maintenance		0.03%
SUBTOTAL		4.03% Plus Loss Due to Groundwater Effects

Figure 2-2: State of the Variance, 1998

Based on this study, it can be concluded that metering affects on variance have been or are currently being minimized.

The remaining area of concern is pipe losses, and primarily thermal losses from the mains. As shown above, these are estimated at least 3.2% of the variance and potentially several times greater due to groundwater effects (see Section 2.11, Joseph Technology Report).

It is thus concluded that any appropriate action would be to address thermal losses.

2.15 September 1999 – Steam System Variance Study – Litkouhi

This document addresses line thermal losses and notes that metering issues have largely been addressed at the time the report was issued. The report includes a review of previous studies and provides a detailed investigation of system thermal losses.

The report concludes that previous evaluations of thermal losses based on condensate test data are unreliable. These earlier reports attributed approximately 3-4% of the send-out flow to thermal losses and 3-4% to metering, leaving roughly half of the approximately 13.5-15% variance unaccounted.

An improved explanation of thermal losses was presented, addressing both thermal (heat) losses and the resulting condensate (steam mass or variance) losses. These losses are shown to be affected by plant superheat, and that simple ratios of these two values can be inaccurate by 25%. An estimate of a reduction in heat loss of 6% is required to reduce the variance by 1%.

Reviews of the 1997 thermal infrared imaging project were also provided.

An improved economic analysis of the benefits of Condufill and Ceasefire re-insulation was developed showing payback periods for these products.

The primary conclusions from this report, in agreement with Section 2.14, are that addressing thermal losses would provide benefit under specific circumstances, particularly in areas subject to wet conditions.

2.16 February 2002 – Steam Variance Study (Factors affecting the Steam Variance) – Litkouhi

This document continues the thermal loss model from the previous study and focuses on the environmental factors of soil temperature and moisture with plots provided to show the relative effect of these factors. The relatively constant loss over the range of send-out flows is used to show that a percentage based variance is not appropriate. Further, studies for optimal delivery of superheated steam from the East River Repowering Project are provided.

No new recommendations are provided, and the actions described in Sections 2.14 and 2.15 are appropriate.

2.17 August 2002 – Steam System Variance (Draft) – Litkouhi

This document addresses thermal line losses and expands upon the previous two reports with two MSExcel based models: The first model provides a tool to calculate losses within a specific main and the second model provides a tool to forecast the expected variance. The loss model forms the basis of the discussion of temperature and moisture factors provided in Section 2.16, above.

The variance forecast model shows that improvements Con Edison had made during the mid-1990s period reduced the amount of heat loss. This is verified by comparisons of the variance prediction model with heat loss data from the 1995 to 1999 period which produced more accurate results than the rolling average method. For use as a variance prediction tool, the importance of accurate sales forecasts was shown.

No new recommendations are provided, and the actions described in Sections 2.14 and 2.15 are appropriate.

2.18 Summary of Variance Issues from Reviewed Documents

The Figure 2-1 chart is updated in Figure 2-3 to show the factors affecting the variance with approximate fractions of the total variance obtained from 1998 and 2001 reports and current estimates. The three contributors to variance were previously: metering inaccuracy (4.3%), thermal losses (10.5%), and leaks or unmetered steam (<1%) providing a total variance of approximately 15%. Meter issues were largely corrected to approximately 1.5% of the variance, bringing variance to approximately 13% in 2002. Therefore, the primary remaining opportunity to improve variance is through the reduction thermal losses.

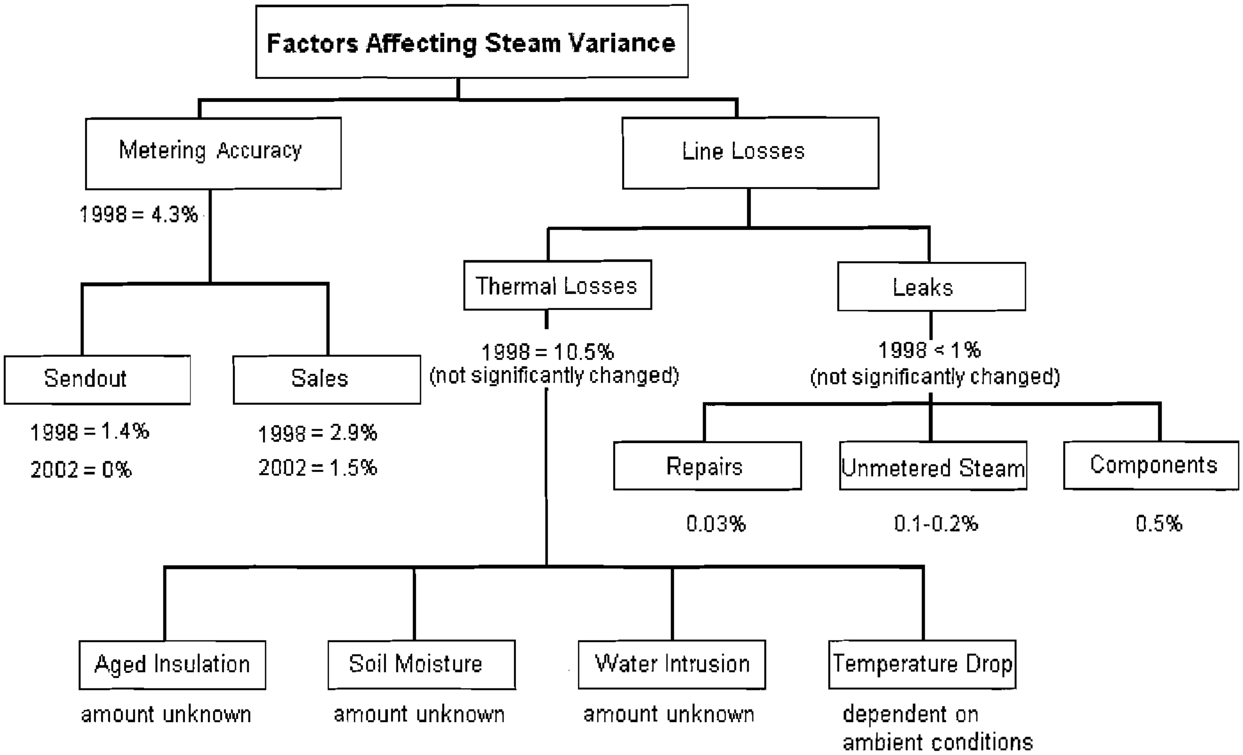


Figure 2-3: Updated Factors Affecting Variance

Considering the reports reviewed in Section 2.0 above, the primary technical subject addressed in each report can be grouped in accordance with the Figure 2-3 loss mechanisms as shown in Table 2-1.

Table 2-1: Report Primary Subject Matter

Metering Accuracy		Line Losses	
Sendout	Sales	Thermal Loss	Leaks
Report 1	Report 4	Report 5	Report 5
Report 2	Report.8	Report 11	Report 14
Report 3	Report 10	Report 12	
Report 6	Report 14	Report 13	
Report 7		Report 14	
Report 9		Report 15	
Report 14		Report 16	
		Report 17	

It should be noted that the constituent parts of the thermal loss cannot be divided as they are inter-related. For example, the thermal loss is a function of the overall temperature gradient divided by the resistances for the heat transfer processes from the steam to the environment. Expressed mathematically:

$$Q = \frac{T_{steam} - T_{amb}}{R_{ins} + R_{soil}}$$

Where:

Q = heat loss (BTU/hr)

T_{steam} = steam temperature (^{o}F)

T_{amb} = ambient or environment temperature (^{o}F)

R_{ins} = Resistance due to insulation (^{o}F/BTU/hr), decreases with aged insulation

R_{soil} = Resistance due to soil (^{o}F/BTU/hr), decreases with moisture

Using the terminology in Figure 2-3, the temperature drop refers to the gradient between the steam and the ground/environment or T_{steam} - T_{soil}. Only the steam temperature portion of this variable can be controlled, and this will be discussed in more detail in Section 3.2. Aged insulation and soil moisture greatly reduce the resistance and therefore increase heat loss.

The resistance conditions cannot be known without significant excavations or test pits to sample pipe and soil conditions. Water intrusion into the housing is also not known, but is indirectly signaled by vapor conditions or wet manholes. As part of the response to the 41st and Lexington incident, these issues have been strongly noted.

A relative view of the change in variance is presented in the pie charts shown in Figure 2-4. These plots show the pre-1998 Variance (approximately 15%) with the post 1998 Variance, estimated as approximately 13% based on the improvements described in the 1998 Lehigh and Litkouhi studies (see Sections 2.14, 2.15).

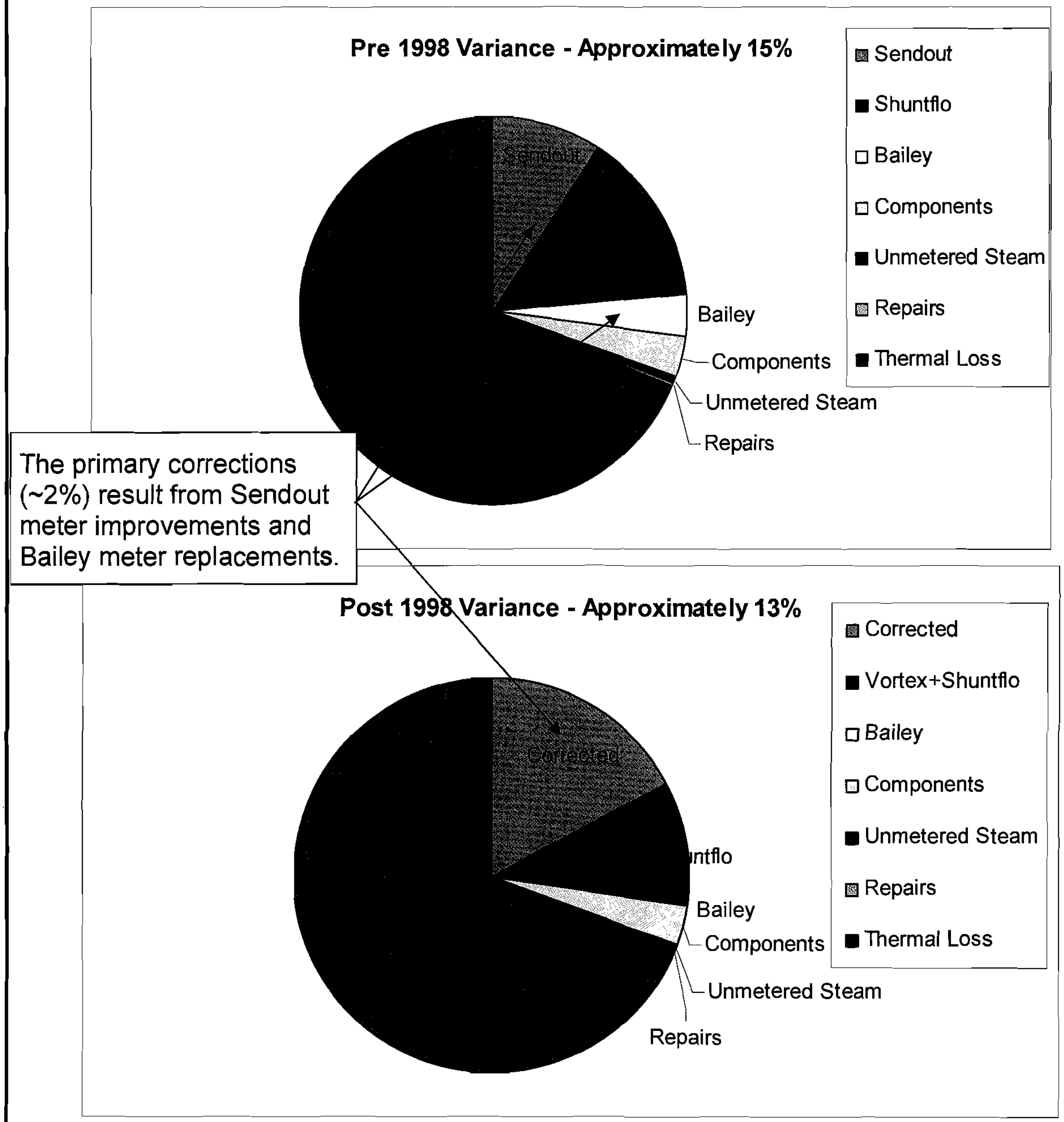


Figure 2-4: Variance Comparison

3.0 Action Plans

Two actions were recommended in the primary reports that are being investigated as potential methods of reducing line thermal losses. These are described below.

3.1 Investigation of Re-Insulation

Re-insulation of buried piping has the potential to lower thermal losses and reduce variance. Previous studies (Reports 15, 17, Litkouhi) estimated that the overall system thermal losses in 1995 were on the order of 3.7×10^{12} BTU/year. To reach this level, an estimated heat loss of 1192 BTU/ft-hr would be required. Using a standard 24" steam main, the insulation thermal conductivity required to achieve this level of loss would be approximately 0.456 BTU/hr-ft-F. This is approximately a factor of 12 higher than new insulation, and represents a significant decrease in insulation quality. However, this is an average for the entire system, which includes both low heat loss sections with dry, non-degraded insulation, and high heat loss sections having wet, degraded insulation.

Additionally, as was shown in (Report 11, Joseph Technology), water intrusion into the housing could increase thermal losses by an even greater amount. Moist soil with 100% degraded insulation could result in a high end estimate for heat loss of up to 2300 BTU/hr-ft for a 24" pipe as demonstrated in Report 15.

It is likely that degraded and wet conditions exist in specific locations, which contribute significantly to the overall heat loss. Because re-insulating the pipe represents a significant cost, the selection of specific locations is an important consideration.

In the following sections, an investigation of the insulation process, a cost/benefit review, and a process for selecting specific locations will be addressed.

3.1.1 Description of the Products

Both Ceasefire and Condufill are initially liquid products that are pumped into the steam main housing. During the pumping process, several constituent parts are mixed that cause the liquid to both expand into a foam and then harden in place.

Condufill (product name, HT-450) is a lightweight closed-cell polyisocyanurate foam that is reported to expand up to 30 times its initial volume to fill insulation gaps in the pipe housing. Condufill is produced by Thermal Science, located in Hanover, Maryland, who also perform the installation work. Because of its closed cell formation, it has very low water absorption (2% by volume) and it has slightly better insulation properties than Ceasefire. However, Condufill is rated for applications less than 400°F for continuous service. This is a potential limit for use in this application.

Ceasefire (product name, Ceasefire 2000) is a dense material containing principally Alumina, Silica, Calcium Oxide and Phosphorous Oxide, Ceasefire is reported to expand up to 1.5

times its initial volume. Ceasefire is produced by Thermal Science of Georgia, distributed locally by Industrial Energy Products (IEP) of Lancaster, PA and installed locally by The Energy Co, Inc. of Westville, NJ. Ceasefire has slightly higher water absorption characteristics (48% by mass per Report 15) but is rated for applications of up to 2000°F.

A summary of the significant characteristics is provided in Table 3-1 and data sheets for both products are provided in Attachment B. As noted in Section 2.13, Con Edison has experience with both these products.

Table 3-1: Pumpable Insulation Characteristics

Property	Condufill (HT-450)	Ceasefire 2000
Thermal Conductivity (K) expressed in:		
BTU-in/hr-ft^2-°F	0.18	0.75
BTU/hr-ft-°F	0.015	0.063
Water Absorption	2% by volume	48% by mass 25% by volume
Temperature Limit	400°F	2000°F

3.1.2 Application Considerations

The cost of the insulation effort is based on the costs of the insulating material and the cost of labor and equipment to install this material. Excavations from the street to the housing are required at relatively close intervals, and this is a major variable in the cost of the project. The number of excavations is dependent on several variable conditions; namely, the type, slope, and condition of the housing and connections to customers, equipment, and sewers. All of these conditions are principally due to the liquid nature of the product and the need to contain yet evenly distribute the product during installation. As a minimum, nozzle insertion lengths are no more than 30-40 feet from each side of an excavation.

The type of the housing surrounding the steam main is typically either a shell type (the steam main pipe is contained in an external carrier pipe) or box type (the steam main is contained in a concrete box section). The shell type can have a smaller annular space between the main and the housing but may have support structures around the steam main that limit the insertion of the pump nozzle. Therefore, the shell type housings may require more closely spaced excavations. Box type housings are generally larger in volume but can vary greatly in age and condition.

Housing condition is very important to the success of an installation because gaps in the housing may permit the undesirable result of the insulating liquid material flowing to other underground structures, customers or the surrounding environment. Housing gaps therefore require repair before these products can be installed.

Housing slope must be considered in the installation plan as the liquid will flow to low points. Piping sections with multiple high points or elevation changes are likely to require multiple excavations.

Connections to customers, sewers, and equipment similarly affect the cost of installation. Each escape path in the housing must be plugged before the pumping can commence. This may require additional excavations to address these locations.

Based on the above, the most likely candidates for successful installation are straight, uniformly sloped pipe housing runs with few branch connections or other potential leak locations.

3.1.3 Cost Benefit Analysis

Costs

Several sources were available to estimate the costs of installation. It is noted that these are estimates. Actual costs would have to be obtained for each project on an individual basis. Additionally, the cost of replacement steam, permitting, and other Con Edison overheads are not included in these estimates. Con Edison estimates these costs (Catuogno, 5/12/09) to increase the project costs by approximately 81% and are included in Section 3.1.3.

Estimate 1: A project using Ceasefire VT-600 was conducted on Avenue D in 2005 with several planned extensions. Con Edison provided estimates of the costs of each extension as shown in Table 3-2 [3]. From these project budgets, a rough cost of $420-$440 per foot (2005 dollars) is derived.

Table 3-2: Estimated Construction Costs for Ceasefire

Year	Length (feet)	Estimated Cost (USD, $)	Cost/foot ($/foot)	Notes
2009	480	200,000	416.67	Ave. D, 10th St to S/O 9th St.
2010	520	200,000	384.62	Ave. D, S/O 9th St. to 6th St.
	170	100,000	588.24	Pearl St. S/O Fulton St.
2011	1,000	400,000	400.00	Ave D, 2nd St. to 6th St.
	280	120,000	428.57	Pearl St. N/O John St.
	450	200,000	444.44	Water St., Broad St. to Coenties Slip
			443.76	Average of above costs per installation
Total	2900	1,220,000	420.69	Average based on overall length, total cost

Estimate 2: Vendor estimates from 2008 for IEP and The Energy Company to install Ceasefire along a 900 foot section of Avenue D were obtained. These costs totaled $316,000 for labor, equipment and materials over a 5 day period. It is estimated that Con Edison would require 5 excavations at approximately $20K per excavation. This produces a slightly higher cost per of $416K/900 = $462 per foot, but is also impacted by the following costs.

In the vendor quotes, specific Con Edison supplied labor and materials were required. These are as follows:

- One Con Edison Site Coordinator
- Two casual helpers
- Secure dry storage of materials
- Transportation of materials from storage to the job site
- Boom truck with Operator
- Fork Lift with Operator
- All excavations, penetrations, and welding
- Air compressor
- Water connections at hydrants
- Waste and waste water disposal
- Lighting, portable toilets
- Damming/blocking of areas not to be pumped

Based on an average labor cost of $150 per hour, and assuming that Con Edison could supply all the required equipment, an additional labor cost of approximately $30,000 (5 people x 8 hours x 5 days x 150 $/hr). This would bring the cost to $446k/900ft = $496 per foot (2008 dollars).

Estimate 3: The total costs associated with the previous re-insulation effort from E13th St to E10th St along Ave. D in November 2005 was approximately $595,000 for 865 ft or $688 per foot (2005 dollars). It is noted that Avenue D was considered by Con Edison to be an easier installation due to limited numbers of customer take-offs and good condition housing.

It is noted that these costs do not include potential additional costs for the use of Con Edison equipment, replacement steam, or other overheads.

Given that a significant component of the cost is for installation of either the Ceasefire of Condufill product, and since the cost estimates provided previously (see Section 2.13) were the same for both products, the revised costs developed herein are assumed to be closely applicable to either product. Both vendors were contacted as part of this study (Thermal Science – Toby Leach, 2/24/09, Thermal Ceramics – Lance Caspersen, 2/25/09). A detailed cost breakdown was only available for the Ceasefire product due to previous quotes obtained by Con Edison.

Benefits

The benefits of steam main re-insulation have been determined both analytically and through field measurements.

Per Report 15, Litkouhi estimated the heat loss for the worst case conditions, fully degraded insulation with moist soil, at approximately 2260 BTU/hr-ft. This would be improved to 787 BTU/hr-ft for Ceasefire and 256 BTU/ft-hr for Condufill.

The benefits of the insulation effort along Avenue D were more closely studied than in previous efforts [3]. Care was taken to measure the steam flow under known operating conditions. Steam was measured during periods of superheat, and thus the heat loss could be directly measured from the change in temperature (in saturated steam conditions, the heat loss results in additional moisture while the temperature remains at the saturation point). These measurements were used to derive heat loss values before and after Ceasefire application and the results of the report [3] are reproduced in Table 3-3. As can be seen, the analytical and measured results for the heat loss, in BTU/hr-ft, before (2260 predicted vs. 2300-2800 measured) and after (787 predicted vs. 770-870 measured) insulation are closely matched.

It is noted that this Avenue D location is considered a very high heat loss location due to the wet conditions surrounding the main and housing. Heat losses vary considerably throughout the system.

Table 3-3: Study of Insulation Thermal Savings

	Pre-Insulation	Post-Insulation	Savings ($/hr-ft)
Date	5/7/2003	7/21/2006	
Mass Flow rate (Mlb/hr)	302	302	
Pressure (psia)	204	202	
Heat Loss (BTU/hr-ft)	2304.13	869.46	
Hourly Cost per foot ($/hr-ft)	0.0258	0.0097	0.0160
Date	3/20/2003	7/21/2006	
Mass Flow rate (Mlb/hr)	433	433	
Pressure (psia)	215	213	
Heat Loss (BTU/hr-ft)	2782.82	868.86	
Hourly Cost per foot ($/hr-ft)	0.0311	0.0097	0.0214
Date	2/5/2003	7/21/2006	
Mass Flow rate (Mlb/hr)	497	500	
Pressure (psia)	226	223	
Heat Loss (BTU/hr-ft)	2792.21	768.86	
Hourly Cost per foot ($/hr-ft)	0.0312	0.0086	0.0226
		Average Savings	0.0200

The hourly cost per foot from the previous report [3] were updated to reflect a current cost of replacement steam of approximately \$9.50 per Mlb (10^3 lb). Costs were calculated based on a steam latent heat of 850 BTU/lb:

Hourly cost per foot = steam cost (\$/Mlb) x thermal loss (BTU/hr-ft) / (850 BTU/lb) = \$/hr-ft

Using the heat loss improvements pre- and post-insulation, the cost/benefit and expected payback period for a wet, degraded insulation region, is calculated as follows.

Savings = (0.020 \$/hr-ft) x (24 hr/day) x (365 day/yr) = 175 \$/yr-ft

Cost = use (Estimate 2) \$500 per foot, increased by 81% for overheads

Payback = Cost/Saving = \$500 x 1.81/\$175 = 5.2 years

It should be noted that areas with low heat loss (i.e. less than that expected with Ceasefire or approximately 800 BTU/hr-ft) will have little room for improvement savings and therefore significantly longer payback periods. For example, heat loss for dry, non-degraded insulation, was determined to be <200 BTU/hr-ft for a 24" pipe (see Report 11) and <500 BTU/hr-ft for dry, degraded insulation (see Report 15). Therefore, the selection of locations that can provide significant heat loss improvement is essential.

3.1.4 Selection of Areas for Potential Re-Insulation

Two issues are addressed in this section. First, a review of the current High Priority locations is performed to assess potential candidates for pumped insulation. Second, a methodology for interpreting the results of Thermal Infrared Scans is developed.

High Priority Locations

A list of High Priority locations is maintained by Con Edison. High Priority Locations are manholes or other structures that have the potential for water intrusion, and they are inspected following rain events of significant intensity or duration.

A review of the piping system in the region of each of these structures was made using Con Edison street map drawings [6]. These drawings provide basic steam main elevation data and were used to identify a drainage region for each High Priority location. Based on the assumption that a re-insulation effort would include the entire local drainage region, an approximation of the scope of the re-insulation effort could be developed.

The re-insulation scope estimate includes the linear length of pipe for the local drainage area for each listed priority location, along with the number of customers, valves, trap stations and elevation changes. As described previously in Section 3.1.2, connections to customers, sewers, and equipment affect the cost of installation. Each escape path in the housing must be plugged before the pumping can commence. This may require additional excavations to address these locations. It is noted that the street plan drawings reviewed for this effort did not include sewer connections.

Based on the review, the data in Table 3-4 was developed. This table provides a rough estimate (in Million US Dollars) of the cost for installing pumped insulation at each High Priority location. From this estimate, decisions pertaining to feasibility of each insulation effort can be made and detailed vendor quotes can be obtained.

Notes on Table 3-4:

1. Each Street/Intersection description was provided by Con Edison to help locate a more specific structure ID (street manhole or service box number). Some judgment was used to identify this location on street maps.

2. The "Description of the Region" was developed to provide the bounds of the drainage region assumed for this estimate. Actual boundaries would have to be developed based on further investigation of each location. The cross street locations, valves, or street addresses nearest to the piping local high points are provided unless the piping is a radial main, in which case the region is identified to include the piping to the "end".

3. Costs are based on the $350 linear foot material cost with overhead, plus field crew labor, ($350 x 1.81 overhead plus $50 for field labor; $350 x 1.81 + 50 = $684) plus $20,000 per additional excavation to address valves, customers, traps, etc. Note that a net cost per foot is higher as shown in the totals at the bottom of Table 3-4.

It is noted that the locations identified on the High Priority list represent potential high heat loss locations because they have previously experienced some water intrusion. From this list, investigations to confirm water intrusion and the source of the water are necessary to further define the insulation scope. Additionally, the condition of the housing and potential leak paths for pumped insulation needs to be investigated. Following these efforts, vendor quotes to install the pumped insulation can be obtained.

Table 3-4: Insulation Scope for High Priority Locations

#	Street/Intersection	Description of Region	Length	Customers	Valves	Branches/Ends	Traps/ blow-offs	Peaks/EL. changes	Cost ($M)
1	160 Water St.N/O Fletcher	Water St - John St	250	1	0	2	1	4	0.33
2	Water N/O Fulton st	Fulton St - Beeckman St	350	0	1	1	0	1	0.30
3	Water St N/O John St	John St - FultonSt	400	0	1	2	0	3	0.39
4	Liberty & Williams	Liberty St - Cedar St	200	2	1	3	0	0	0.26
5	Church St N/O Liberty St	Liberty St - Cortland St	300	0	2	1	1	1	0.31
6	Park Place W/O Broadway	Broadway - 20 Park Pl	150	2	2	2	1	2	0.28
7	Broad St N/O Beaver	Beaver St - end	100	0	0	1	1	1	0.13
8	Broadway N/O Barclay	Park Pl - Barclay St	200	0	1	1	0	0	0.18
9	16 Platt St E/O Gold St.	Gold St - 16 Platt St	100	1	0	1	0	0	0.11
10	Platt St W/O Pearl St	Pearl St - 16 Platt St	200	2	1	1	1	0	0.24
11	Murray E/O West St	Greenwich St - West St	450	0	1	1	1	0	0.37
12	Barclay St E/O Washington	Greenwich St - Washington St	200	0	0	1	1	0	0.18
13	Murray E/O Church	Broadway - Church St	400	3	1	1	1	0	0.39
14	125 Barclay St W/O Washington	Washington St - end	200	2	0	1	1	1	0.24
15	Allen S/O Hester	59Allen St - 23Allen St	500	0	1	2	1	0	0.42
16	4 Columbia St S/O Delancey	Delancy S t- Grand St	600	0	1	2	0	0	0.47
17	15 Madison St E/O St. James	St James - Trap413	150	0	0	1	0	1	0.14
18	Grand E/O Broadway	Lafayette St - Broadway	700	0	0	2	1	0	0.54
19	527 Columbia St S/O Grand	Henry St - Grand St	150	0	1	5	0	0	0.22
20	20 Columbia St N/O Stanton	Stanton St - Houston St	500	1	0	2	1	0	0.42
21	33 Madison St W/O James St	Pearl St - St James	600	0	1	1	1	0	0.47
22	7th Ave I/S W 23rd St.	22nd St - 24th St	600	1	0	3	1	0	0.51
23	7th Ave S/O 11th St.	Perry St - 11th St	300	0	0	2	1	0	0.27
24	41 Seventh Ave N/O 13th St	13th St - 14th St	250	2	1	2	0	0	0.27
25	141 Leonard St E/O Centre	Center St - end	100	1	0	2	1	1	0.17
26	14 St E/O Ave. C	South Steam - Ave C	700	0	2	3	0	0	0.58
27	15 St E/O Ave C	ER station - Ave C	700	0	0	2	0	1	0.54

#	Street/Intersection	Description of Region	Length	Customers	Valves	Branches/Ends	Traps/ blow-offs	Peaks/EL. changes	Cost ($M)
28	14th W/O Ave C	Ave C - Ave B	650	0	1	2	1	0	0.52
29	17th N/O Broadway								0.00
30	128 Ave D N/O 9th St	8th St - 10th St	500	1	0	2	1	0	0.42
31	Ave. A N/O 14th St	14th St - 15th St	250	2	0	2	1	0	0.27
32	545 First Ave S/O 33 St	30th St - 33rd St	1000	4	2	2	2	0	0.88
33	545 First Ave S/O 33 St	combined							0.00
34	319 First Ave S/O 19 St	18th St - 20th St	600	0	0	0	2	0	0.45
35	300 15 St E/O Second Ave	14th St - 15th St(on 2nd) + 2nd - 3rd Ave (on 15th St)	900	4	0	3	2	0	0.80
36	FDR S/O 20th St	540 E20th St - 309 Ave C	1000	1	1	2	2	0	0.80
37	20th W/O FDR	410 E20th St - 540 E20th St	1200	7	1	2	2	0	1.06
38	202 35 St E/O Third Ave	Lexington - 202 E35th St	600	2	1	2	1	0	0.53
39	Lexington Ave N/O 36 St	35th St - 37th St	450	0	1	3	1	0	0.41
40	134 35 St E/O Lexington Ave	Lexington - 134 E35th St	100	0	1	1	1	0	0.13
41	202 35 St E/O Third Ave	see #38							0.00
42	346 35 St W/O First Ave	300 E35th St - 1st Ave	600	2	1	2	0	0	0.51
43	35 St E/O Fifth Ave	Valve 1508 - 16 E34th St	400	1	1	1	1	0	0.35
44	71 35 St E/O Sixth Ave	6th Ave - Valve 1508	800	3	1	2	0	0	0.67
45	150 42 W/O Third Ave	3rd Ave - Lexington	400	0	1	2	1	0	0.35
46	205 41 St E/O Third Ave	2nd Ave - Lexington	1000	7	4	2	1	0	0.96
47	First Ave S/O 41 St	41st St - end	300	0	0	2	1	0	0.27
48	126 41 St W/O Lexington Ave	Park - Lexington	400	4	1	2	1	0	0.43
49	246 41 St W/O Second Ave	2nd Ave - 246 41st St	50	2	1	2	0	0	0.13
50	54th St E/O Fifth Ave	2nd Ave - 1 E54th St	200	2	0	2	1	0	0.24
51	252 52St W/O Second Ave	2nd Ave - 216 E52nd St	400	1	0	2	1	0	0.35
52	140 52 St E/O Lexington Ave	3rd Ave - Lexington	450	4	1	2	0	0	0.45
53	Madison Ave S/O 53rd St	52nd St - 53rd St + 3rd - 12 E53rd St (on 53rd St)	450	2	1	3	0	0	0.43
54	360 57 St W/O First Ave	1st Ave - end	450	5	0	2	1	0	0.47
55	57th between Lex and Park	447 Park - 461 Park + Park-104 E57 (on 57th St)	450	0	1	3	0	0	0.39

#	Street/Intersection	Description of Region	Length	Customers	Valves	Branches/Ends	Traps/ blow-offs	Peaks/EL. changes	Cost ($M)
56	58th St W/O Lexington	Park - 3rd Ave	900	9	3	3	0	0	0.92
57	209 E 58th St	3rd Ave - 223 E 58th St	450	4	0	2	0	0	0.43
58	58th St E/O Third Ave F/O 2	combined							0.00
59	250 58th St W/O Second Ave	235 E58th St - 331 E58th St	600	3	1	2	1	1	0.57
60	63 St I/S Lexington Ave	134 E63rd St- end	200	2	0	2	1	1	0.26
61	64th & Park Ave	Park Ave - end	300	2	0	2	1	1	0.33
62	1114 York Ave N/O 60th St	60th St - 1114York	100	0	1	1	0	0	0.11
63	First Ave N/O 59th St	59th St - Valve 1431	100	0	1	1	0	0	0.11
64	501 60th St E/O York Ave	York - end	150	0	0	0	1	0	0.12
65	1185 First Ave N/O 64th St	65th St - end	300	1	0	2	1	0	0.29
66	823 Madison between 68-69 Sts	821 Madison - 69th St	250	1	0	2	1	1	0.27
67	256 72 St W/O Second Ave	(16"main) 3rd Ave - 2nd Ave	700	4	1	2	1	0	0.64
68	537 71st St W/O FDR	York - end	650	2	2	2	0	0	0.56
69	444 75 St W/O York Ave	York - 1st Ave	750	0	1	2	0	0	0.57
70	1392 Third Ave N/O 79th St	79th St - 84th St + 3rd - Lexington (on 79th St)	1800	3	1	3	1	0	1.39
71	Columbus Circle N/O 58th St	Columbus circle - 60th St	275	1	2	3	0	0	0.31
72	45th St W/O Fifth Ave	5th Ave - end	700	4	0	2	1	1	0.64
73	900 7th Ave S/O 57th St	55th St - 57thSt + Broadway - 7th (on 56th St)	1000	2	2	3	0	0	0.82
74	49th St E/O 7th Ave	6th Ave - 7th Ave	850	1	1	2	0	0	0.66
75	44 St I/S Sixth Ave	across 6th Ave	100	0	0	2	1	1	0.15
76	75 49 St E/O Sixth Ave	6th Ave - end	220	2	0	2	1	1	0.27
	Totals		33345	feet					**$30.41M**
								average cost/ft	**$911.92**

Thermal Scans

Thermal Infrared (IR) scans were discussed with Con Edison Steam Engineering personnel (J. Ng 3/03/09). At this time, a scan of the steam system is being considered. IR scans provide a surrogate picture of the heat losses from the piping system by displaying a light intensity which is scaled to a temperature at the ground surface above the steam main. An example of the results from such a scan is provided in Figure 3-1. In this case, the numerical values of the temperatures from the scan are identified directly on the photo.

Figure 3-1: Example Infra-Red Scan

These street surface temperatures, while important, provide a limited amount of information. The key variable of interest to Con Edison is heat loss, and this is dependent on ambient conditions and other environmental variables the combination of which will result in a surface temperature. Thus, the surface temperature must be considered in the context of these environmental conditions and not as an absolute value.

Expanding on the methodology developed in Report 15 (Litkouhi), a heat loss model showing the losses from the steam main to the environment is developed to evaluate these variables. A sketch illustrating this model is provided in Figure 3-2. In this sketch, it can be seen that a buried pipe at depth Z will produce heat losses (red lines) by conduction through the pipe, insulation, and air gap to the ground, and by conduction through the ground to the surface. These losses are balanced by heat losses at the surface (convection and radiation) to produce a surface temperature (T_s).

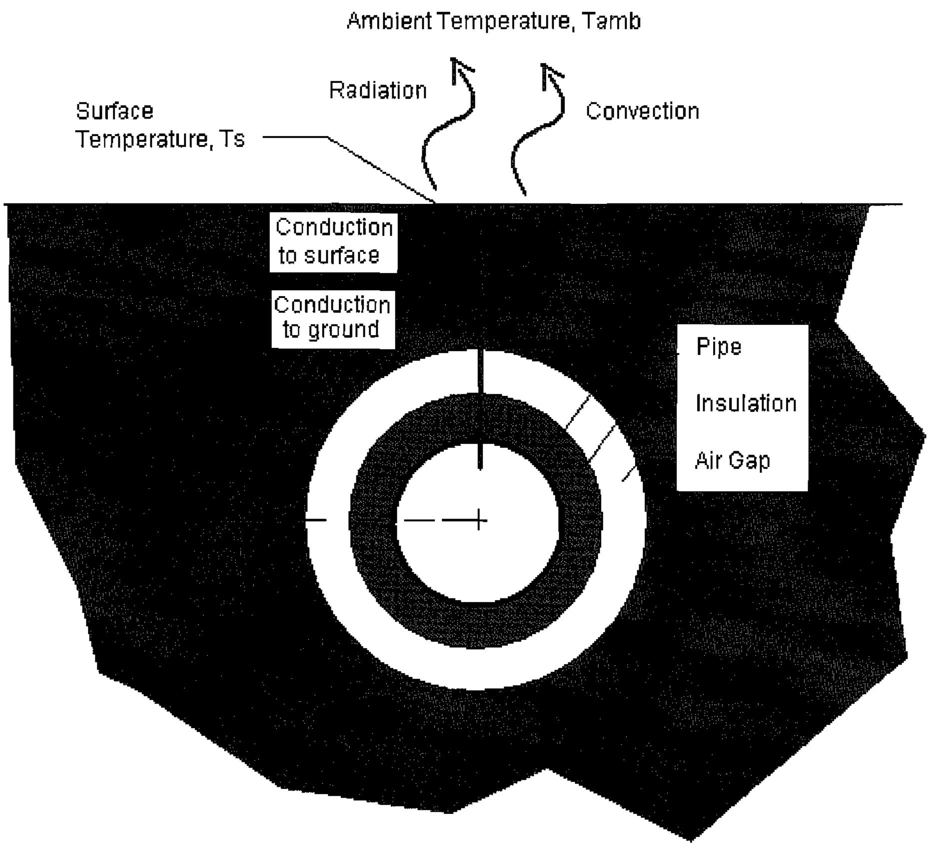


Figure 3-2: Infrared Scan Heat Loss Model

An evaluation of the heat transfer conditions is included in Attachment C to this report, and this evaluation was used to develop plots of the results. The plots are provided in Figure 3-3 and Figure 3-4 and provide the surface temperature (degree Fahrenheit) vs. the depth of the pipe under ground (Z, feet). Figure 3-3 provides surface temperatures for a 24" (solid) and 12" (dashed) diameter main under three ambient temperature conditions, 90°F, 70°F, and 50°F. Figure 3-4 provides surface temperatures for wet (solid) and dry (dashed) soil conditions using soil thermal conductivities of 2.82 BTU/hr-ft-°F and 1.0 BTU/hr-ft-°F, for the same three ambient temperature conditions.

For all these curves, assumptions included an insulation thermal conductivity based on undamaged asbestos (k = 0.12 BTU/hr-ft-F) and a steam temperature of 375°F.

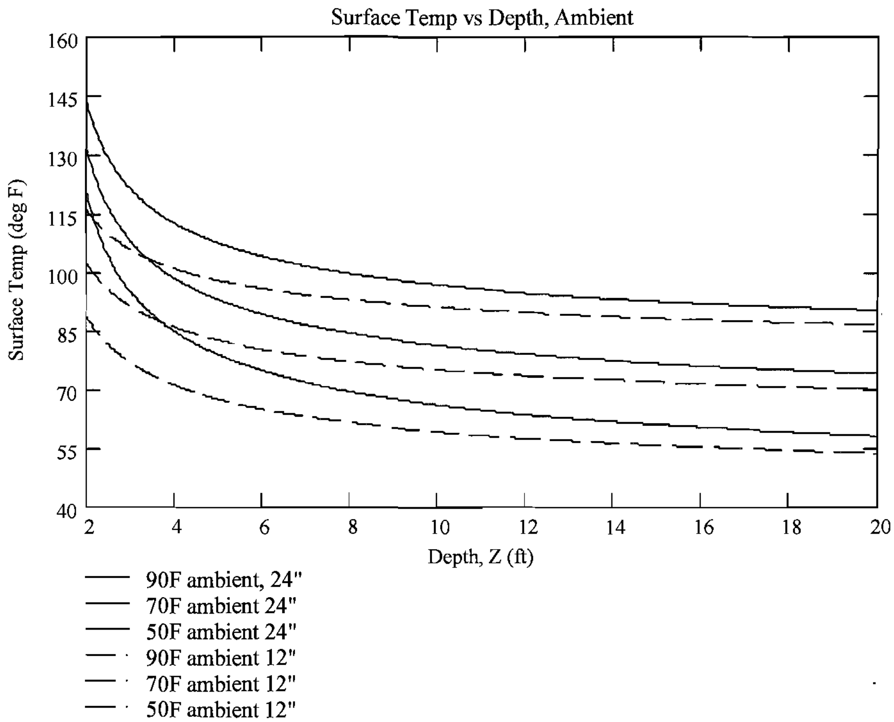


Figure 3-3: Surface Temp. vs. Pipe Depth and Ambient Temperature, 12" and 24" Main

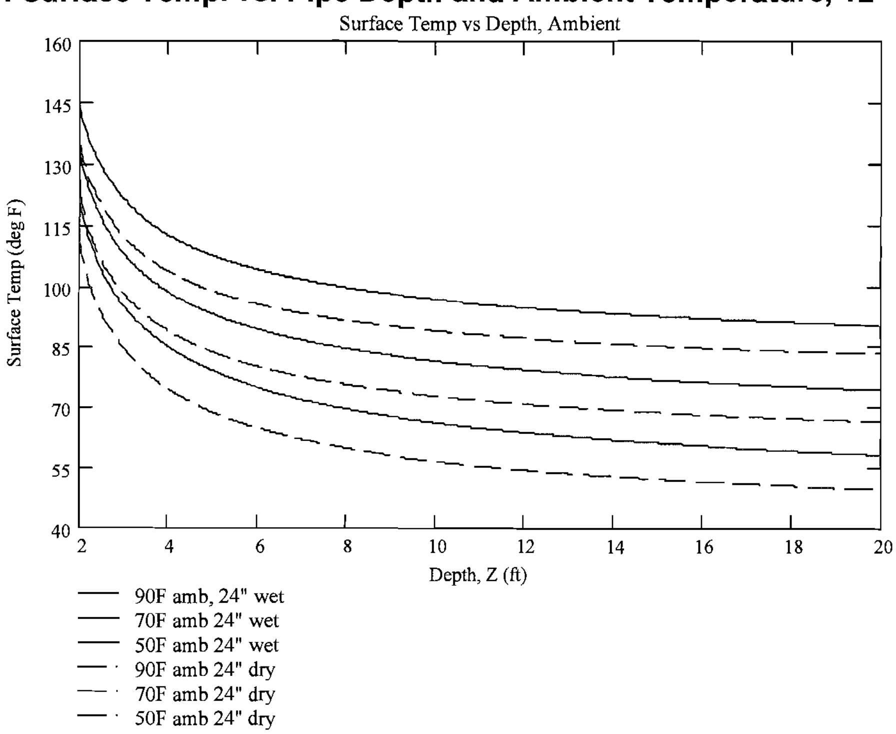


Figure 3-4: Surface Temp. vs. Pipe Depth and Ambient Temperature, Wet and Dry Soil

The curves provided in Figure 3-3 and Figure 3-4 provide a methodology for evaluating the temperature data received from IR scans. If measured temperatures are found above these curves, it is clear that more heat is leaving the system than calculated by the above model, likely due to wet conditions or missing/degraded insulation. Therefore, this would be a "hot spot" worth investigating further. Further investigations of "hot spots" could include test excavations to determine insulation conditions or inspections from nearby manholes.

In comparison to the IR scan provided in Figure 3-1, the section of pipe north of Houston St, circled in red, and identified as 103.1F, is above a 24" steam main approximately 3.5 feet below the street based on Con Edison drawings [7]. Assuming dry conditions and 70°F ambient conditions, it can be seen in either Figure 3-3 or Figure 3-4 that the surface is likely to be in this range due to the shallow depth of this main. This surface temperature would not indicate heat loss beyond normal conditions. Additionally, this main is part of the 400 psig transmission system, so the steam temperature may have been greater than the assumed 375°F at the time this scan was performed, further contributing to the expected elevated surface temperature at this location.

Summary and Further Actions

In summary, there is shown to be a benefit of reinsulation using pumpable foam that can have a payback in approximately 5 years for locations having high heat loss due to degraded insulation and wet conditions. Using the High Priority location list and IR scans can help identify these locations. Approximate costs for the known High Priority Locations and a methodology for interpreting the IR scans are provided. Further actions should include performing IR scans, and evaluating High Priority Locations to determine housing condition and sources of water intrusion. From this information about high heat loss locations vendor quotes to re-insulate high heat loss portions of the system can then be obtained.

3.2 Investigation of Increased Superheat

Superheat is, by definition, the steam temperature above the saturation temperature (superheat = $T_{steam} - T_{sat}$). As an example, for steam at atmospheric pressure (14.7 psia) the saturation point is 212°F. If the steam were at 250°F, it would be 38°F superheated. At the elevated pressures at which the Con Edison system typically operates, typically 150 psig to 180 psig, the corresponding saturation temperatures are 366°F to 377°F. Many of the high pressure boilers in the system use a superheat temperature of 25°F, thus the send-out steam would be 391°F to 402°F. The package boilers in the system do not produce superheated steam.

From the physics of steam, it can be seen that superheat can be achieved by two methods:

1. Increase the steam temperature (T_{steam}), thus increasing the margin above saturation
2. Decrease the pressure, thus moving the saturation temperature lower (T_{sat}).

3.2.1 Benefits of Increased Superheat

Superheat can provide an advantage in operating the steam system because it reduces mass loss. When the steam is at the saturation point, any heat loss will result in the condensation of some fraction of the steam mass. The condensate mass is removed through traps and discarded. This mass loss contributes to the variance, which is defined as the difference in steam mass produced vs. steam mass consumed.

The mass of condensate is reduced because heat loss from superheated steam will first reduce the steam temperature to the saturation point before condensate accumulates. This concept is illustrated in Figure 3-5.

In Figure 3-5, Condition 1, steam enters a main in the saturated condition. Heat loss along the main produces condensate, which builds until it is removed by a trap station. Since the total mass is conserved, the outgoing steam mass is reduced by the amount of condensate removed. A simple graph below the Condition 1 figure shows a constant temperature (black line, T_{sat}) and increasing mass of condensate (blue line, M_{cond}) along the pipe length.

In Figure 3-5, Condition 2, steam enters in a superheated state. Heat loss along the pipe first reduces temperature to the saturation point. At some pipe length, saturation is achieved and then condensate starts to build. Even at the same rate of heat loss, less condensate is produced and therefore less mass is discharge at the trap. The graph below the Condition 2 figure shows the temperature reduces to T_{sat} (black line) before condensate builds (blue line, M_{cond}). For a given system, the length required to lose superheat is a function of the heat loss rate, the amount of superheat, and the steam flow rate.

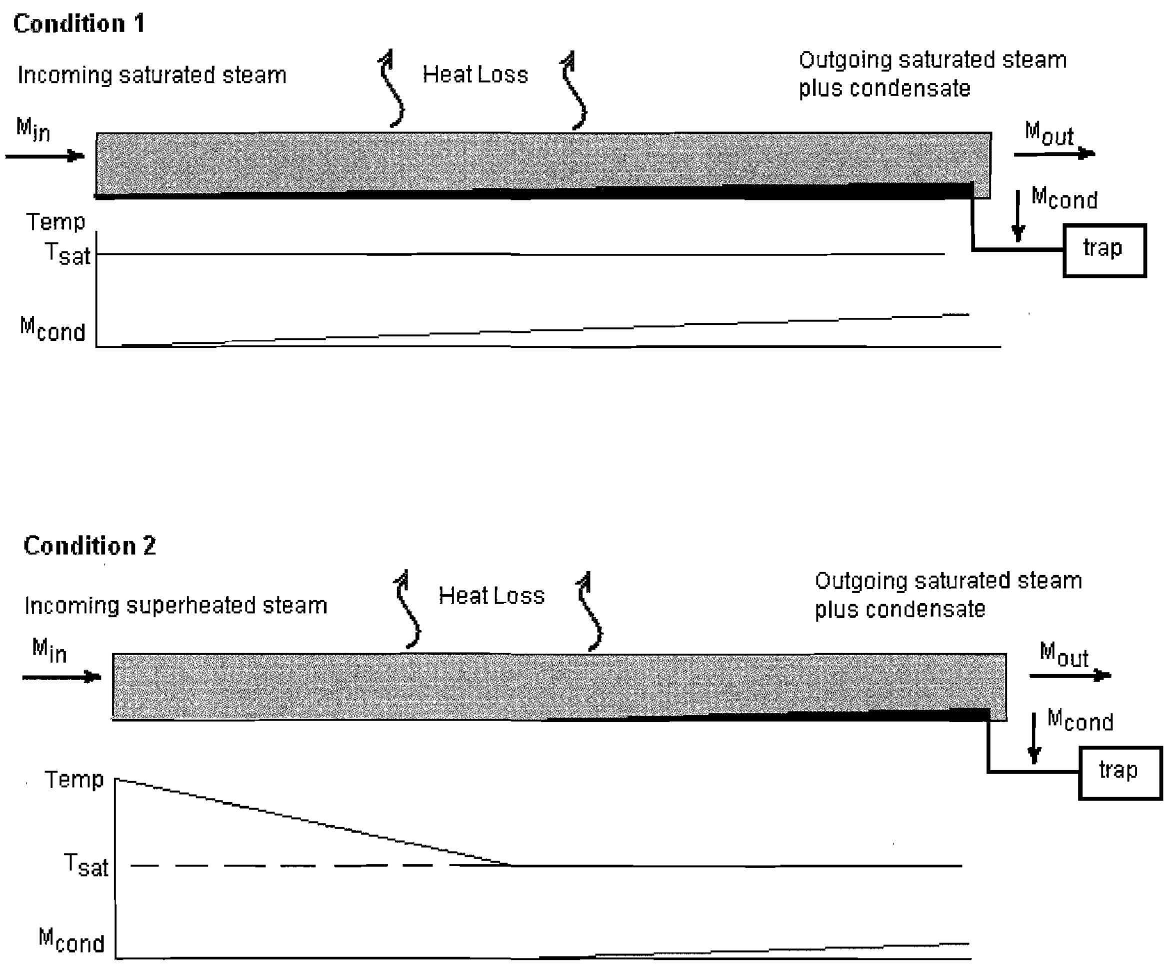


Figure 3-5: Effect of Heat Loss on Saturated and Superheated Steam

3.2.2 Effect of Increasing Temperature

Increasing steam temperature is a simple method for increasing superheat, but several technical issues must be considered. First, the piping system has specific temperature design limits based on piping material properties, thermal expansion, etc. The distribution (200 psig) portion of the system is designed for a maximum temperature of 413°F. The steam temperature at 180 psig with 25°F superheat is 405°F. Thus, there is little room to increase temperature while maintaining a reasonable margin below the design point. Increasing the design temperature is possible but is likely to involve a significant review of thermal expansion calculations and potentially the replacement of many expansion joints throughout the system. Increasing the design temperature is therefore not likely to be a cost effective approach.

Second, producing steam at a higher temperature adds cost. The cost of steam is principally based on the cost of fuel required to add heat, typically expressed as an enthalpy of the steam. To add 10°F more superheat to steam at 400°F and 165 psig (already 25°F), increases the enthalpy from 1213 BTU/lb to 1220 BTU/lb, increasing the cost to produce the steam by 0.5%.

Third, adding more superheat by increasing temperature also increases the temperature gradient to the environment, which increases heat loss. In the steam system, heat loss occurs due to the elevated temperature of the steam compared to the ambient conditions. Mathematically, the heat transfer rate (Q) is determined by the temperature gradient ($T_{steam} - T_{amb}$) divided by the sum of the thermal resistances (ΣR) as shown in the following equation.

$$Q = \frac{T_{steam} - T_{amb}}{\Sigma R}$$

To evaluate the magnitude of this effect, an example 24" steam main with a high heat loss of 2300 BTU/hr-ft (see Section 3.1.3) and carrying 165 psig, 400°F (25°F superheat) steam flowing at 100 Klb/hr (25 ft/sec) is evaluated. Numerical values for this calculation are provided in Attachment C.

In this example, superheat is lost in 750 feet from the plant or approximately 2 city blocks. Increasing the superheat to 410°F would increase the length required to lose superheat to 995 feet, but the increased heat loss reduces this length to 967 feet.

The increased length to lose superheat and start generating condensate should be compared to the overall piping lengths from the plant to the customer. If one considers an example of a short piping run, using the length of steam main from East River Station to First Ave. or approximately 3100 feet, the condensate loss would decrease by approximately 9% (3100-967)/(3100-750). Using the length from East River to Grand Central Station or approximately 16,000 ft, superheat would decrease the condensate loss by approximately 1.5%. In practice, the total system variance change would be determined by the total customer usage and the lengths to each customer from the various plants.

3.2.3 Effect of Decreasing Pressure

The second method for increasing the superheat is by decreasing the steam saturation point by operating at a lower pressure. As discussed previously, dropping the pressure from 180 psig to 150 psig would lower the saturation point from 377°F to 366°F, thus providing 11°F additional superheat. However, this method is less effective due to the lower energy content (enthalpy) of the lower pressure steam. In this case, 11°F superheat would be lost in approximately 322 feet, for the high heat loss region described above.

The operating system has limited capacity for lowering pressure while still delivering steam to customers at some margin above a minimum pressure of 125 psig. Decreasing the operating pressure decreases the steam density, thus increasing steam velocities and flow losses due to friction. Mathematically, this can be shown with the following two equations:

$$m = \rho \cdot V \cdot A \qquad \Delta P = \frac{1}{2} \cdot \rho \cdot V^2 \cdot K$$

m = mass flow of steam (lb/hr)
ρ = steam density (lb/ft^3)
V = velocity (ft/sec)
A = pipe flow area (ft^2)
ΔP = change in pressure (psi)
K = friction coefficient due to pipe roughness, geometry

For a given mass flow (m), decreasing density (ρ) will require an increase in velocity (V). This higher velocity will therefore increase pressure losses (ΔP) with the square of the velocity change.

As an example, a modestly high load (5800 kpph) summer afternoon (8/8/2007) was investigated for pressures in the downtown region (see Figure 3-6). During this period, the system pressure fluctuated from approximately 155 psig to 178 psig. The differential pressure across the downtown region during the mid-afternoon was approximately 7 psi (based on the telemetric point at 111 John St, located near the Hudson Avenue tunnel 400 psi mains exit and the New York Plaza telemetric point at the end of the system).

To increase superheat by dropping the pressure nominally 30 psi (for simplicity, from 180 psig to 150 psig, although the system was less than that all day) changes the density 17.4%. The pressure loss for this example would increase 38% to 9.6 psi (7 psi x 1.174^2). If the system fluctuates approximately 15 psi due to the variation in load, and losses are now approximately 10 psi, it can be seen that the system will be challenged to remain above 125 psi if starting from 150 psig (i.e. 150 psi – 15 psi – 10 psi = 125 psi).

During peak winter and summer loads, the differential pressure across portions of the system can be even greater. It is therefore likely that operating at reduced pressure is most likely to be effective under low load periods in the spring and fall.

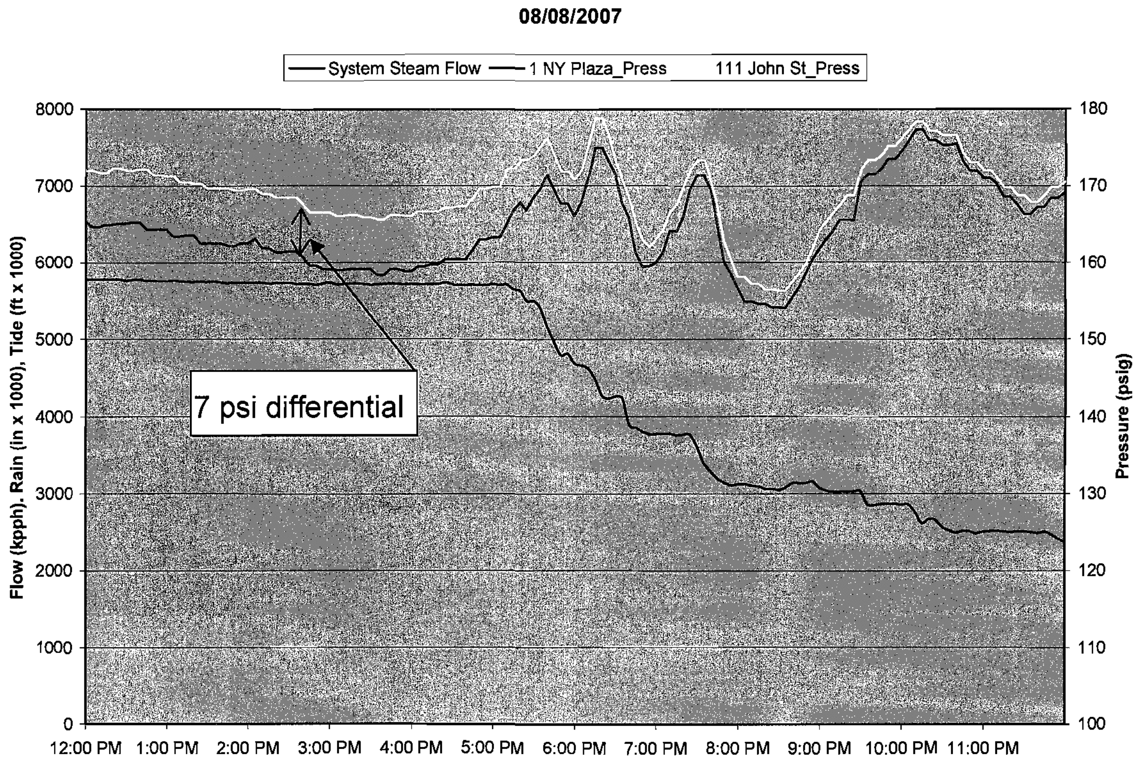


Figure 3-6: Example Steam Send-Out Plot

Summary and Further Actions

In summary, it can be seen that increased superheat may be used to decrease condensate losses and the amount of variance. Increased steam temperature may be an effective approach, but it is limited by current steam main design limits. Decreased operating pressure may be a slightly less effective method, but it is likely to be possible only in periods of low load.

Further actions should include Con Edison simulation modeling to determine a lower pressure and higher heat combination under which the system could operate. It is possible that an additional 10°F superheat could be gained from the sum of a modest temperature increase and pressure decrease. This action would also require a review of plant capability to send-out steam at higher superheat, and a review of operations controls to determine if the variability in system pressure with load can be tightened.

4.0 Conclusions

4.1 Review of Previous Reports

The variance as obtained from reviewed reports from 1998 through 2001 was primarily due to three factors. These three contributors were: metering inaccuracy (4.3%), thermal losses (10.5%), and leaks or unmetered steam (<1%) providing a total variance of approximately 15%. Meter issues were largely corrected and reduced to approximately 1.5% of the variance, bringing total variance to approximately 13%. Therefore, the primary remaining opportunity to improve variance is through the reduction of thermal losses.

4.2 Action Plans

Two technical areas were investigated as part of this effort: Re-Insulation of steam mains using pumpable insulation and Increased Superheat.

Re-Insulation of steam mains using pumpable insulation products (Ceasefire, Condufill) has the potential of lowering heat losses, particularly in wet areas with potential water intrusion. Cost benefit analysis in these high heat loss areas indicates that the payback period is approximately 5 years and the project could be beneficial. Non-degraded, dry sections, would not likely benefit from the addition of pumpable insulation.

To identify the high heat loss areas, two issues were addressed. First, the High Priority locations identified by Con Edison as having the potential for water intrusion after significant rain events were reviewed. An estimate of the complexity and cost of re-insulating each location was developed. As a further action plan, Con Edison should confirm the sources of water intrusion at each location, the condition of the steam main housing and potential leak paths for pumped insulation. Con Edison should then obtain detailed estimates for the locations from this list as deemed appropriate.

Second, a thermal Infrared (IR) scan was discussed with Con Edison Engineering personnel. The IR scan provides surface temperatures that are helpful in identifying portions of the system that may be experiencing high heat loss. A methodology to assist in interpreting these surface temperatures, in comparison to pipe depth and ambient conditions, was presented. As a further action plan Con Edison should use the IR scan in combination with the high priority list to identify further locations, investigate the conditions of these locations, and obtain detailed estimates for a re-insulation effort.

Increased superheat of the steam was investigated as a method of reducing condensate and thus the overall variance. Increasing the steam temperature provides a potential benefit, as does decreasing the operating pressure. However, there is little margin to increase temperature based on the 413°F design limit for the 200 psig system, and reducing the operating pressure risks delivering steam below the required 125 psig lower limit. Further actions should include Con Edison simulation modeling to determine a lower pressure and higher heat combination under which the system could operate. It is possible that an additional

10°F superheat could be gained from the sum of a modest temperature increase and pressure decrease. This action would also require a review of plant capability to send-out steam at higher superheat, and a review of operations controls to determine if the variability in system pressure with load can be tightened.

5.0 References

1. Ciemnicki, D.L. (Con Edison) "Reinsulation Project Summary", February 1986.

2. Bongiorno, S. (Con Edison), "Reinsulation Project Summary", Jul2 22, 1994.

3. Con Edison Report, C. Joseph, "Implementation Plan for Pumpable Insulation to Reduce Overall Thermal Losses", 10/23/07.

4. Kreith, "Principles of Heat Transfer", International Textbook, 1965.

5. Incropera and DeWitt, "Fundamentals of Heat and Mass Transfer", 2nd Edition, John Wiley, 1981.

6. Con Edison SOMIS drawings, 46-page book, Rev. 10/2003.

7. Con Edison Service Plate 16-577-3, Rev 5.

8. American Society of Mechanical Engineers, MFC-3M-1989, "Measurement of Fluid Flow in Pipes Using Orifice, Nozzle, and Venturi".

9. ASME Steam Tables, 1967 Edition.

ATTACHMENT A

Response to Plant Metering Survey

1) Are there changes to the send-out metering since 1998?
2) When were the current meters installed?
3) Is the meter location geometry the same, in particular the length of upstream piping?
4) Can we get a copy of the calibration procedure?
5) How often are the meter factors spot-checked?
6) Is the send-out flow total calculated or automated and by what instrument system?
7) Does the meter meet ASME requirements (% accuracy, calibration period, etc.) ?
8) Any other known issues with the send-out metering?

Plant	Q1	Q2	Q3	Q5	Q6	Q7	Q8
East River	Only the addition of the 11th St (ERRP) meter.	14th, 15th, Ave. D, and 1st Ave were installed in the fall of 1991.	Piping has not changed.	Twice per year (to be verified). (although delayed in 2008 due to work on the system)	Ovation System with Rosemount transmitters.	To be verified	1st Ave. Main is possibly inaccurate at low flows (<25%) since it was sized for higher flow rates. However, this operating mode is rarely used.
W59th Street				Every 6 months. Verified +/- 1%			
74th Street	No	• Express Main, 1995 • 74th St, 1991 • 75th St. 1969, moved in 1994 to add more upstream pipe	75th Street nozzle was moved in 1994 to add 18ft (9D) upstream pipe based on Lehigh recommendations	Every 6 mo. per COP 7-0-5.	The plant sendout is totalized by an M-Systems 4-20mA summer that adds 74th St Sendout, 75th St Sendout, and the Express Main Sendout. This value is displayed on an MCR recorder and indicator	Express main lab calibrated to +/- 0.5% 74th St calibrated to 0.25% 75th St. may be worn.	The 75th St SSO orifice upstream pipe length is slightly shorter than code. Per ASME [8], this is not expected to add more than 0.5% potential error.
60th St Package Boilers	No	Unknown	Piping has not changed.			The downstream piping lengths are slightly shorter than code. Per ASME [8], this is not expected to add more than 0.5% potential error.	

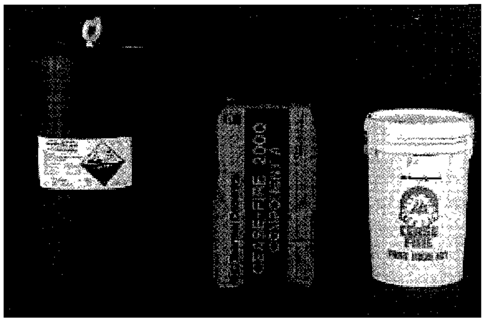
ATTACHMENT B

Pumpable Foam Insulation Product Data

Thermal Ceramics

Cease Fire® 2000

Product Information



Cease Fire 2000 is a unique, two-component refractory foam. The dry powder (component A) is mixed with water to form a semi-viscous slurry and then combined with mild phosphoric acid (component B) at the pumping nozzle. The reaction produces a foam of approximately 1½ times its original volume. The process involves the generation of moderate heat from which evolves non-toxic gaseous by-products resulting in a network of independent cellular pores. The fast setting time of Cease Fire alleviates the need for extended drying or curing times. Since the reaction is complete, steam spalling on the initial fire is not a concern.

The **Cease Fire Fast Aide Kit** consists of premeasured amounts of Components A and B to place approximately 1.3 cu. ft. of Cease Fire 2000. The components are packaged in a 6-gallon drum which serves as the mixing vessel. After removing the components, water is added to a depth 7½" from the bottom of the drum. Dry component A is mixed with the water to create a slurry. Component B, an acid catalyst contained in a one gallon cube, is then added to this mixture. Proper amounts of each component are provided with the Fast Aide Kit to meter at a 4 to 1 ratio (slurry to acid) through the Cease Fire 100 Pump.

Features

Cease Fire 2000

- Fluid nature readily fills backup insulation voids
- Highly insulating foam product (thermal conductivity equivalent to ceramic fiber)
- Easily installed while unit is on or off-line
- Unique pore structure allows for controlled crushing instead of catastrophic cracking
- Suitable for use up to 2000°F *(1093°C)*

Cease Fire Fast Aide Kits

- Convenient, pre-packaged quantity of Cease Fire Pump 2000
- Ideal for small hot spot repair

Typical Applications

- Utility boilers:
  - penthouse floors and walls
  - superheater penetration
- Iron and Steel
  - blast furnace stoves, hot blast mains, and bustle pipes
  - soaking pit sidewalls
  - coke oven backup and seals

Estimation of Material Required

1. Estimate total volume (cubic feet) to be filled.
2. Multiply volume by 41 pcf (density of Cease Fire 2000) to obtain total weight of material required.
3. Most applications of Cease Fire 2000 are difficult to estimate because exact condition of existing backup insulation is unknown. Therefore, in determining material quantity, a significant overage should be used (typically 15 - 30%).
4. After the total weight of Cease Fire 2000 is determined, quantities of Component A and B are ordered as follows:
   Component A - total weight x 0.75 = order quantity
   Component B - total weight x 0.25 =- order quantity

Packaging

Component A (dry)	50 lb/bag *(23 kg)*
Component B (acid)	200 lb/drum *(91 kg)*

Cease Fire 2000

Product Information

Physical Properties	
Design Temperature Use Limit, °F *(°C)*	2000 *(1093)*
Average lb Required to Place 1 ft^3 *(kg)*, dry	41 *(19)*
Density, dry, pcf (kg/m^3)	39 - 47 *(625 - 753)*
Compressive Strength, psi *(Mpa)* dried	
10% compression	20 - 40 *(0.14 - 0.28)*
Permanent Linear Cahnge, %	
5 hr @ 220°F *(93°C)*	0
@ 1000°F *(538°C)*	-1.3
@ 2000°F *(1093°C)*	-2.5
Slurry Consistency, wt. %, (solids content)	66
Slurry: Acid Ratio	
by weight	4.5:1
by volume	4.0:1
Foam characteristics	
rise time @ 70°F *(21°C)* sec.	30-90
initial set time (sec.)	60-120
% volume increase	50
Shelf life, months	12
Chemical Analysis, %, Weight basis after firing	
Alumina, Al_2O_3	34
Silica, SiO_2	34
Calcium oxide, CaO	12
Titanium oxide, TiO_2	1.2
Ferric oxide, Fe_2O_3	0.8
Phosphorous oxide, P_2O_3	16
Other	1.0
Thermal Conductivity, BTU•in/hr•ft²•°F *(w/m•K)*, ASTM C417	
Mean temperature	
300°F *(149°C)*	0.75 *(0.11)*
700°F *(371°C)*	0.96 *(0.14)*
1100°F *(593°C)*	1.22 *(0.18)*

The values given herein are typical average values obtained in accordance with accepted test methods and are subject to normal manufacturing variations. They are supplied as a technical service and are subject to change without notice. Therefore, the data contained herein should not be used for specification purposes. Check with your Thermal Ceramics office to obtain current information.

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ConduFill® Technical Data Sheet

ConduFill® (HT-450) is a closed-cell polyisocyanurate foam that provides exceptional insulating value for buried underground steam and hot water piping systems at continuous operating temperatures of 400° F (202° C), with intermittent service to 450°F (230° C). In contrast to open-cell foam, ConduFill® is inherently resistant to the ingress and spread of water by virtue of its molecular structure which closes the pathway between adjacent foam cells.

Once injected into an underground piping system, ConduFill® will expand 30 times its own volume and will completely fill the void between the carrier pipe and the outer casing. The presence of new insulation will significantly reduce heat losses and prevent ground water from entering the piping system. ConduFill® offers operators improved energy conservation due to increased insulating efficiency, better process controls and yields, while providing upgrades in strength, durability, stability, moisture resistance and a low installed cost.

The physical and chemical properties of ConduFill® are as follows:

PHYSICAL PROPERTIES

Property	ASTM Test Method	Result
Density, pcf (kg/m^3)	**D-1622**	2.45 (38.5)
Compressive Strength, psi (kPa) **@ 10% Deflection**	**D-1621**	
Parallel to Rise		30 (207)
Perpendicular to Rise		27 (186)
Compressive Strength after 28 day exposure to 400° F (202° C), psi (kPa)		
Parallel to Rise		17.5 (120)
Perpendicular to Rise		16.0 (110)
Closed Cell Content, %	**D-2856**	87
k-Factor, BTU-in/hr. ft^2 °F (W/mK)	C-518	
Initial		0.13 (0.018)
Aged 180 Days @ 75° F (25° C)		0.165 (0.022)
Aged 90 Days @ 140° F (60° C)		0.18 (0.026)
Water Absorption, psf (g/cm^2)	**D-2842**	0.035 (0.017)
% by Volume		< 2

DIMENSIONAL STABILITY, % Change	**D-2126**	
Dry Heat, 400° F (202° C)	**Length**	**Volume**
1 Day	+1.3	+0.1
7 Days	+2.3	-2.3
28 Days	+1.6	-4.4
Dry Heat, 450° F (230° C)		
1 Day	+10.3	+14.6
7 Days	+7.1	+1.5
28 Days	+1.9	-11.9
Dry Cold, -30° F (-34° C)		
1 Day	0	0
7 Days	0	0
Humid Age, 158° F (70° C), 95% Relative Humidity		
1 Day	+1.0	+0.84
7 Days	+1.52	+1.85
28 Days	+2.02	+1.85

Service Temperature

Continuous	-100° F(-73° C) to + 400° F (202° C)
Intermittent	To 450° F (230° C)

Surface Burning Characteristics[1]

Flame Spread, 1"	40
Smoke Developed	80

[1] The numerical flame spread and smoke developed data shown above is not intended to reflect fire hazards presented under actual fire conditions.

- The physical properties shown above were obtained by processing the chemicals through a conventional low pressure high shear mixing machine. Chemical temperatures were maintained at 90° F (32° C) for the isocyanate component and 80° F (27° C) for the polyol. Box pours measuring 24" x 24" x 24" (61cm x 61 cm x 61 cm) were made and the resulting foam was cured for 30 days at room temperature, approximately 77° F (25° C). Testing was done on core samples cut from the box pour.

CHEMICAL PROPERTIES

Property	Component A	Component B	Component C
Viscosity, cps @ 77° F (25° C)	600-800	750-1000	275-450
Specific Gravity, @77° F(25° C)	1.24	1.24	1.24
Ratio, Parts by weight	67	16.5	16.5

Reaction Profile: 200 gm Lab Hand mix with 3000 rpm mixer

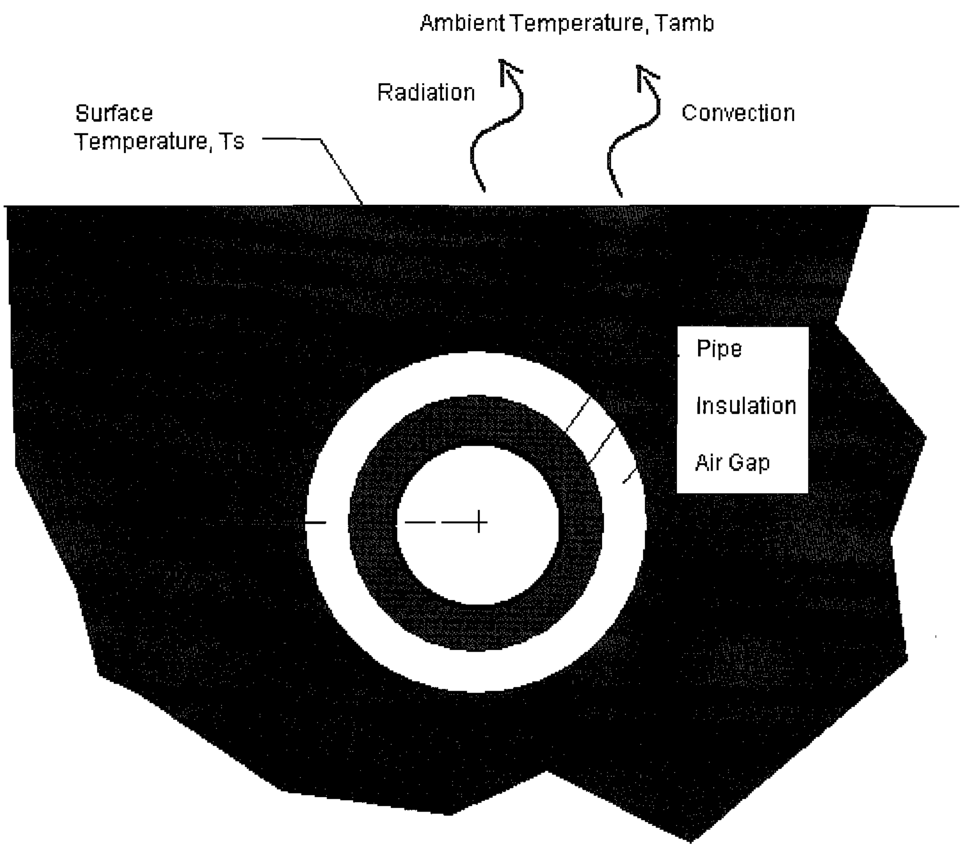
Start of Rise:	15-45 seconds
String Gel:	60-150 seconds
Rise time:	90-240 seconds
Free Rise Density:	2.1-2.3 pcf (33.7-37 kg/m^3)

ATTACHMENT C

Infra-Red Heat Loss Model
And Supporting Calculations

Development of IR - surface temperature model

Heat transfer from the pipe is limited by the resistance across insulating layers. The convection or condensation inside the pipe and the conduction through the pipe wall offer negligible resistance. The remaining resistances are based on conduction throught the soil and insulation to the surface, and from the surface to the ambient air by convection and radiation.



The heat transfer relationship provided by Report 17 (Litkouhi) is evaluated to determine the magnitude of heat tansfer across the air gap (radiation and conduction/convection) and expanded to consider heat transfer from the surface to the environment.

Per Litkouhi (17), EQ15

$$Q = \frac{2 \cdot \pi \cdot L \cdot \left(T_{stm} - T_s\right)}{\dfrac{\ln\left(\dfrac{D_{ins}}{D_{OD}}\right)}{k_{ins}} + \dfrac{\ln\left(\dfrac{4 \cdot Z}{D_{ins}}\right)}{k_{soil}}}$$

It can be seen that the denominator of this expression contains terms for conduction across the insulation and conduction through the soil. However, the radiation and conduction/convection terms across the air gap are not included. Therefore, the magnitude of these effects are evaluated.

Define Material & Thermodynamic Properties $F := R$

Concrete

concrete properties at 400K (260F) per [5]

$\rho_{conc} := 2300 \cdot \frac{kg}{m^3}$ $k_{conc} := 1.4 \cdot \frac{watt}{m \cdot K}$ $\varepsilon_{conc} := .9$

Insulation

Asbestos insulation [4]

$k_{ins} := .12 \frac{BTU}{hr \cdot ft \cdot F}$ $\varepsilon_{ins} := .6$

Soil (wet and dry (from report 15)

$k_{soil} := 2.82 \cdot \frac{BTU}{hr \cdot ft \cdot F}$ $k_{soil\_d} := 1 \cdot \frac{BTU}{hr \cdot ft \cdot F}$

Air Properties, data per [5], Table A-4. Temperature values input in deg F, using absolute Temp.

$$T_a := \begin{pmatrix} 250 \\ 300 \\ 350 \\ 400 \\ 450 \\ 500 \\ 550 \end{pmatrix} \cdot K \qquad K_a := \begin{pmatrix} 22.3 \\ 26.3 \\ 30 \\ 33.8 \\ 37.3 \\ 40.7 \\ 43.9 \end{pmatrix} \cdot \left(\frac{10^{-3} watt}{m \cdot K} \right) \qquad \nu_a := \begin{pmatrix} 11.44 \\ 15.89 \\ 20.92 \\ 26.41 \\ 32.39 \\ 38.79 \\ 45.57 \end{pmatrix} \cdot \frac{10^{-6} \cdot m^2}{sec} \qquad Pr_a := \begin{pmatrix} .72 \\ .707 \\ .7 \\ .69 \\ .686 \\ .684 \\ .683 \end{pmatrix}$$

Define general functions based on curve fit: Test

$$k_{air}(T) := \text{interp}(\text{cspline}(T_a, K_a), T_a, K_a, T) \qquad k_{air}(100 \cdot F + 460R) = 0.016 \frac{BTU}{hr \cdot ft \cdot F}$$

$$\nu_{air}(T) := \text{interp}(\text{cspline}(T_a, \nu_a), T_a, \nu_a, T) \qquad \nu_{air}(100 \cdot F + 460R) = 1.826 \times 10^{-4} \frac{ft^2}{sec}$$

$$Pr_{air}(T) := \text{interp}(\text{cspline}(T_a, Pr_a), T_a, Pr_a, T) \qquad Pr_{air}(100 \cdot F + 460R) = 0.705$$

Define steady state heat transfer functions per unit length of pipe

Functions are defined and then units are removed from functions for use in the Mathcad equation solver.
Unit system is BTU, foot, second, degree Rankine

Conduction through a radial system [5] EQ 3.26

Test functions with typical values

$$Q_{cdr}(T1,T2,R1,R2,k) := \frac{2\pi\cdot k\cdot(T1-T2)}{\ln\left(\frac{R2}{R1}\right)}$$

$$Q_{cdr}(600\cdot R,500\cdot R,2,2.1,k_{ins}) = 0.429\frac{BTU}{ft\cdot sec}$$

$$Q_{cdru}(T1,T2,R1,R2,k) := Q_{cdr}(T1\cdot R,T2\cdot R,R1\cdot ft,R2\cdot ft,k)\cdot\frac{ft\cdot sec}{BTU}$$

$$Q_{cdru}(600,500,2,2.1,k_{ins}) = 0.429$$

Free Convection on outside of pipe for air or water

Define Grashof number [5] (EQ 9.12, 9.9), for air

$$Gr_D(T1,T2,R1) := \frac{g\,|T1-T2|\cdot(2R1)^3}{.5(T1+T2)\cdot\nu_{air}[.5(T1+T2)]^2}$$

$$Gr_D(650R,600\cdot R,6in) = 52.208\times10^6$$

Per Kreith [4], free convection within an enclosure (EQ 7-35, 7-36) can be approximated by an increased conduction term:

$$\frac{U\cdot b}{k} = .04\cdot Gr^{0.37}$$

$$.04\cdot Gr_D(650R,600\cdot R,6in)^{.37} = 28.683$$

Radiation Heat Transfer [5] EQ 13.23 - between exposed bodies (pipe in housing)

Stephan-Boltzman constant

$$\sigma := 5.67\cdot10^{-8}\cdot\frac{watt}{m^2\cdot K^4} \qquad \sigma_u := \sigma\cdot\frac{ft^2\cdot sec\cdot R^4}{BTU} \qquad \sigma_u = 4.756\times10^{-13}$$

$$Q_{rad}(T1,T2,A1,\varepsilon_1,A2,\varepsilon_2) := \frac{\sigma_u\cdot\left[(T1)^4-(T2)^4\right]}{\frac{1-\varepsilon_1}{\varepsilon_1\cdot A1}+\frac{1}{A1}+\frac{1-\varepsilon_2}{\varepsilon_2\cdot A2}}$$

$$Q_{rad}(600,500,\pi\cdot1,\varepsilon_{ins},\pi\cdot1.5,\varepsilon_{conc}) = 0.058$$

Define boundary conditions

Use steam and pipe at a temperature of (Rankine) $T_{stm} := 375F$ $T_{pipe} := T_{stm} \cdot F^{-1} + 460$

Use soil temperature of (Rankine) $T_{soil} := 100 + 460$

Define radii for pipe, insulation, housing, and soil (in feet)

12" Pipe $R_{OD} := \frac{12.75in}{2} \cdot ft^{-1}$

4" Insulation $R_{ins} := R_{OD} + \frac{4}{12}$

6" Air gap $R_{air} := R_{ins} + \frac{6}{12}$

10" thick housing $R_{hous} := R_{air} + \frac{10}{12}$

Define seed values for equation solver (these variables will be solved for below)

$T_{ins} := T_{pipe} - 20$ $T_{hous} := T_{ins} - 20$ $q := 1$

Define steady state equations

Given

$q = Q_{cdru}(T_{pipe}, T_{ins}, R_{OD}, R_{ins}, k_{ins})$ The heat from the pipe thru the insulation layer

$q = .04 \cdot Gr_D\left[T_{ins} \cdot R, T_{hous} \cdot R, (R_{air} - R_{ins}) \cdot ft\right]^{.37} \cdot Q_{cdru}(T_{ins}, T_{hous}, R_{ins}, R_{air}, k_{air}(610R)) \ldots$
$+ Q_{rad}(T_{ins}, T_{hous}, 2\pi \cdot R_{ins}, \varepsilon_{ins}, 2\pi \cdot R_{air}, \varepsilon_{conc})$

The heat from the insulation conducting across enclosure and radiating to the housing

$q = Q_{cdru}(T_{hous}, T_{soil}, R_{air}, R_{hous}, k_{conc})$ Conduction through the conduit to soil

$X := Find(T_{ins}, T_{hous}, q)$ $X = \begin{pmatrix} 621.925 \\ 590.937 \\ 0.092 \end{pmatrix}$ $T_{ins} := (X_0 - 460) \cdot F$ $T_{ins} = 161.925\,F$

$T_{hous} := (X_1 - 460) \cdot F$ $T_{hous} = 130.937\,F$

$Q := X_2 \cdot \frac{BTU}{ft \cdot sec}$ $Q = 0.092 \frac{BTU}{ft \cdot sec}$

Now compare to the first term from the Litkouhi equation, modified to be consistent with the terms above. It can be seen that the air gap contributes modestly to the resistance (Q < Q1). This can be addressed by increasing the insulation thickness 25% (Q2 ~= Q).

$Q1 := \frac{2 \cdot \pi \cdot (T_{stm} - T_{hous})}{\frac{\ln\left(\frac{R_{ins}}{R_{OD}}\right)}{k_{ins}}}$ $Q1 = 0.105 \frac{BTU}{ft \cdot sec}$ $Q2 := \frac{2 \cdot \pi \cdot (T_{stm} - T_{hous})}{\frac{\ln\left(\frac{R_{ins} \cdot 1.25}{R_{OD}}\right)}{k_{ins}}}$ $Q2 = 0.072 \frac{BTU}{ft \cdot sec}$

Extend model to evaluate surface heat transfer

Using the model for conductive heat transfer from the pipe to the surface, the resulting surface temperature will be determined based on heat loss from the street surface to the ambient air. The heat transfer processes include free convection from the street surface and radiation to the sky.

Surface Free Convection

Two terms affect the heat transfer - the heat transfer coefficient and the surface area. The convection (up) from a flat plate is generally on the low end and is approxiamted (Kreith [4] Table 1-2)

$$h_{up} := 1 \cdot \frac{BTU}{hr \cdot ft^2 \cdot F}$$

The area on the surface is a function of the pipe diameter/housing. It is approximated as a function of the conduction shape factor (Kreith [4] Table 3-1) from a burried pipe as follows:

$$A_{surf}(R1, Z1) := 2R1 \cdot ft \cdot acosh\left(\frac{Z1}{R1 \cdot ft}\right)$$

Test function for:

$T_s := 100F \quad T_{amb} := 70F \quad Z := 10ft$

The free convection is thus

$$Q_{fcvup}(T1, T_{amb}, R1, Z1) := h_{up} \cdot A_{surf}(R1, Z1) \cdot (T1 - T_{amb})$$

$$Q_{fcvup}(T_s, T_{amb}, R_{ins}, Z) = 163 \frac{BTU}{hr \cdot ft}$$

Surface Radiation

The radiation to the sky is dependent on the sky temperature, which can vary between -50F for cold night to +50F for hot/cloudy day [4]. For simplicity, use Tsky based on Tamb minus 50F.

$$T_{sky}(T_{amb}) := T_{amb} - 50F$$

$$Q_{srad}(T1, T_{amb}, R1, Z1) := A_{surf}(R1, Z1) \cdot \sigma \cdot \varepsilon_{conc} \cdot \left[(T1 + 460R)^4 - (T_{sky}(T_{amb}) + 460R)^4\right]$$

$$Q_{srad}(T_s, T_{amb}, R_{ins}, Z) = 379 \frac{BTU}{hr \cdot ft}$$

Combining the two equations for heat transfer from the surface with the modified conduction equation from above produces two equations with two unknowns (heat transfer Q and surface temperature Ts). These equations can be solved for a range of ambient conditions and depths of burried pipes using the Mathcad solver:

Given

$$Q = \frac{2\cdot\pi\cdot(T_{stm} - T_s)}{\frac{\ln\left(\frac{R_{ins}\cdot 1.25}{R_{OD}}\right)}{k_{ins}} + \frac{\ln\left(\frac{4\cdot Z\cdot ft^{-1}}{2R_{ins}}\right)}{k_{soil}}}$$ conduction through insulation and to surface

$$Q = \left(Q_{fcvup}(T_s, T_{amb}, R_{ins}, Z) + Q_{srad}(T_s, T_{amb}, R_{ins}, Z)\right)$$ convection and radiation from surface

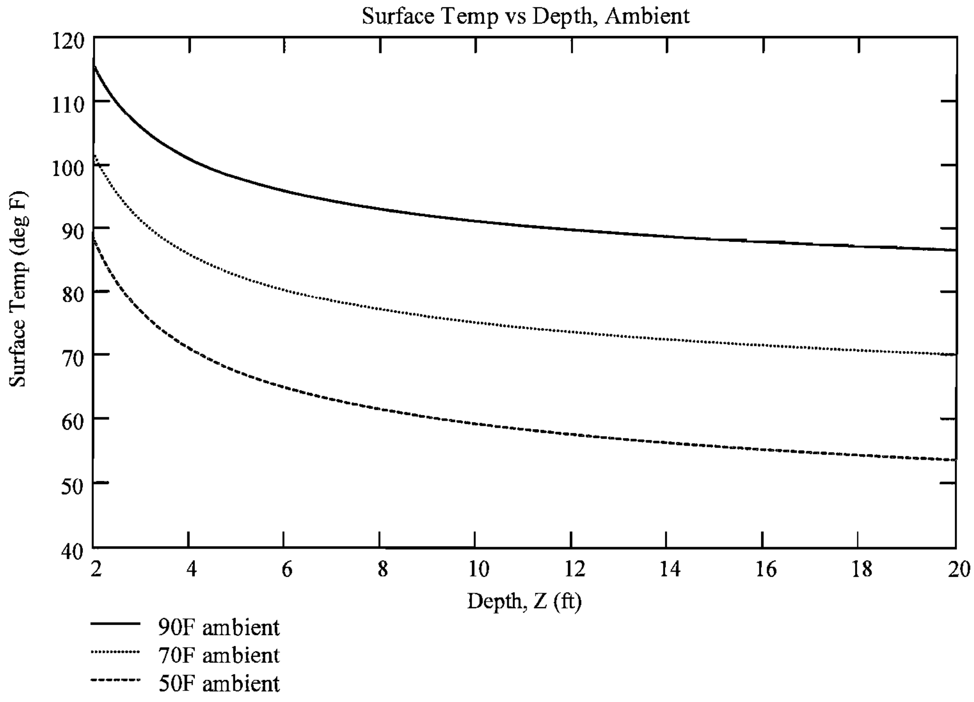
$$X(T_{amb}, Z) := \mathrm{Find}(Q, T_s)$$ Use solver (Find function) to determine Q, Ts

Show solutions for one specific ambient temperature (Tamb) and depth (Z)

$$X(T_{amb}, Z) = \begin{pmatrix} 1.864 \times 10^3 \frac{lb\,ft}{sec^3} \\ 41.65K \end{pmatrix} \qquad Q_f := X(T_{amb}, Z)_0 \qquad Q_f = 268\frac{BTU}{hr\cdot ft}$$

$$T_{surf} := X(T_{amb}, Z)_1 \qquad T_{surf} = 74.97\,F$$

Plot the results for 3 ambient temperatures over a range of buried depths, 12" pipe



Revise for 24" pipe and plot results for similar conditions to evaluate sensitivity to pipe size

$$R_{OD} := \frac{24}{2\cdot 12} \quad R_{ins} := R_{OD} + \frac{4}{12}$$

Given

$$Q = \frac{2\cdot\pi\cdot\left(T_{stm} - T_s\right)}{\dfrac{\ln\left(\dfrac{R_{ins}\cdot 1.1}{R_{OD}}\right)}{k_{ins}} + \dfrac{\ln\left(\dfrac{4\cdot Z\cdot ft^{-1}}{2R_{ins}}\right)}{k_{soil}}}$$

conduction through insulation and to surface

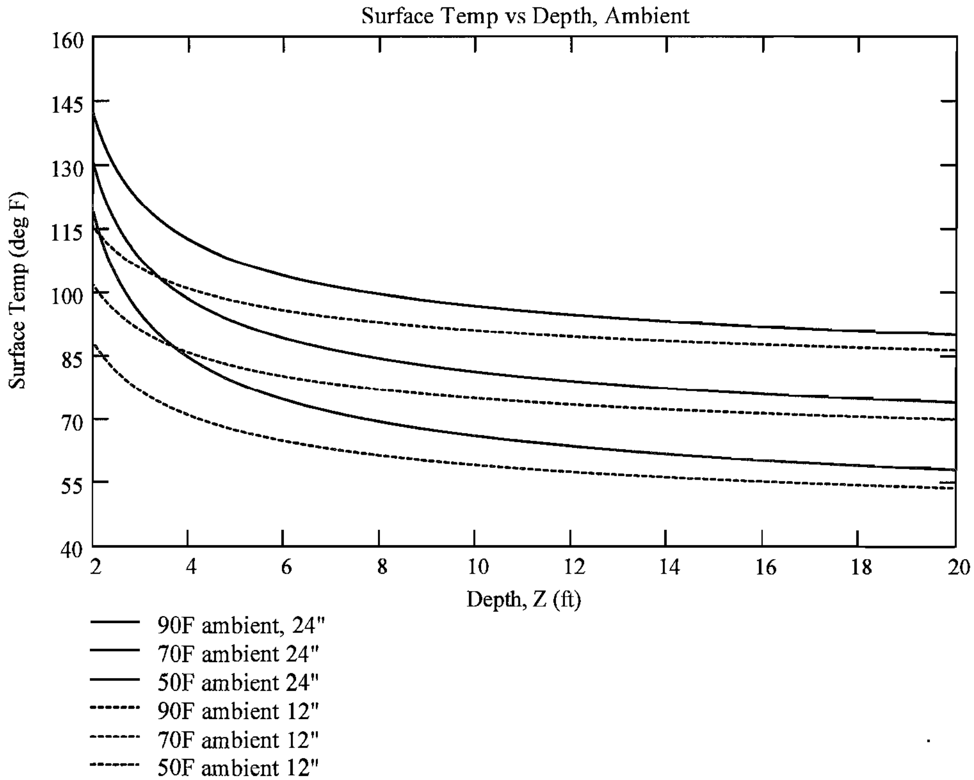
$$Q = \left(Q_{fcvup}\left(T_s, T_{amb}, R_{ins}, Z\right) + Q_{srad}\left(T_s, T_{amb}, R_{ins}, Z\right)\right)$$

convection and radiation from surface

$$X1\left(T_{amb}, Z\right) := \mathrm{Find}\left(Q, T_s\right)$$

Use solver (Find function) to determine Q, Ts

Plotting the results for both 24" pipe (solid) and 12" pipe (dashed), it can be seen that the model is sensitive to diameter at shallow depths.



Use the 24" pipe results and compare wet and dry conditions:

Given

$$Q = \frac{2\cdot\pi\cdot(T_{stm} - T_s)}{\dfrac{\ln\left(\dfrac{R_{ins}\cdot 1.1}{R_{OD}}\right)}{k_{ins}} + \dfrac{\ln\left(\dfrac{4\cdot Z\cdot ft^{-1}}{2R_{ins}}\right)}{k_{soil\_d}}}$$

conduction through insulation and to surface

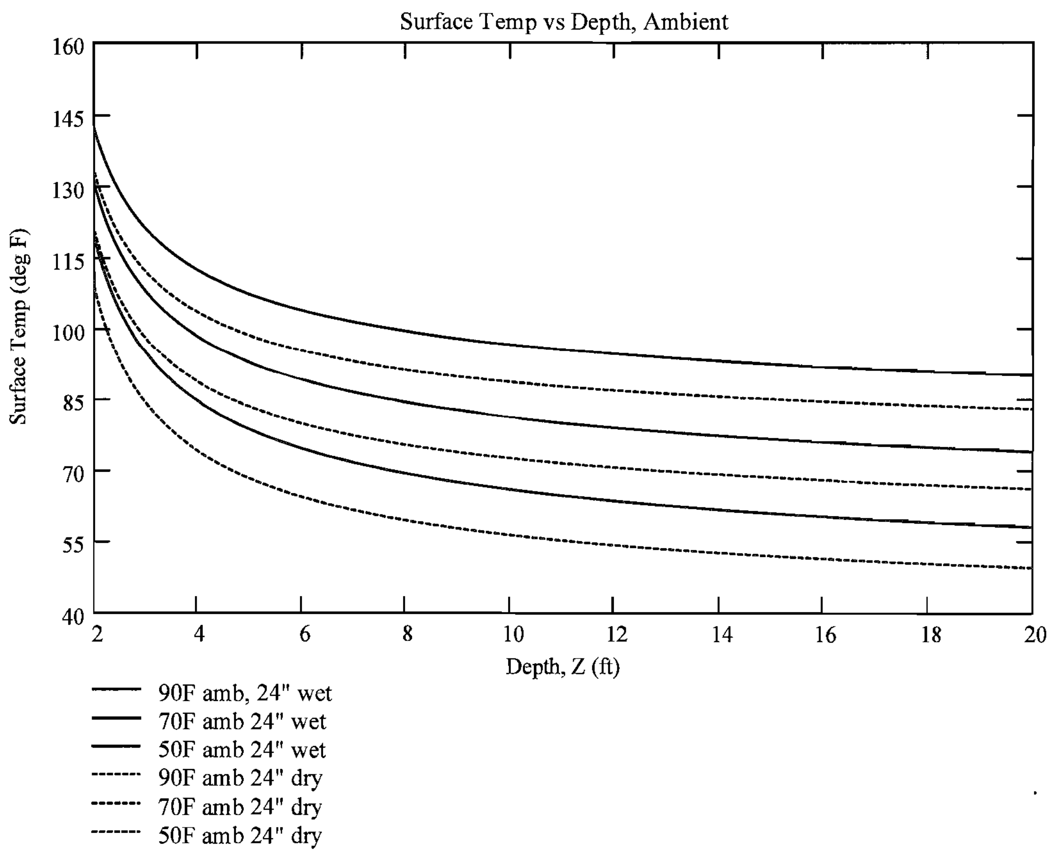
$$Q = \left(Q_{fcvup}(T_s, T_{amb}, R_{ins}, Z) + Q_{srad}(T_s, T_{amb}, R_{ins}, Z)\right)$$

convection and radiation from surface

$$X2(T_{amb}, Z) := \text{Find}(Q, T_s)$$

Use solver (Find function) to determine Q, Ts

Plotting the results for both 24" pipe in wet conditions (solid) and dry conditions (dashed)



Evaluation of the effect of Superheat on Condensate Generation

Increased Temperature Calculation

Properties of superheated Steam (400F, 165.3 psig) $\rho_{sh} := \left(2.647 \cdot \frac{ft^3}{lb}\right)^{-1}$ $h_{sh} := 1213.8 \frac{BTU}{lb}$

Properties of Saturated Steam (165.3 psig) $\rho_{sat} := \left(2.5312 \cdot \frac{ft^3}{lb}\right)^{-1}$ $h_{sat} := 1196.6 \frac{BTU}{lb}$

24" Pipe Area $A_{24} := \frac{\pi}{4} \cdot (23.25in)^2$

Assumed mass flow rate and resulting velocity $m_{sh} := 100000 \cdot \frac{lb}{hr}$ $V := \frac{m_{sh}}{\rho_{sh} \cdot A_{24}}$ $V = 24.939 \frac{ft}{sec}$

Assumed heat loss $Q := 2300 \cdot \frac{BTU}{ft \cdot hr}$

Length required to lose superheat $\frac{m_{sh} \cdot (h_{sh} - h_{sat})}{Q} = 748\,ft$

Length required to lose superheat at 410F $h_{sh2} := 1219.5 \cdot \frac{BTU}{lb}$ $\frac{m_{sh} \cdot (h_{sh2} - h_{sat})}{Q} = 995.7\,ft$

Length required to lose superheat at 410F with increased heat loss rate to 70F environment

$$\frac{410 - 70}{400 - 70} - 1 = 3.03\,\% \qquad \frac{m_{sh} \cdot (h_{sh2} - h_{sat})}{\frac{410 - 70}{400 - 70} \cdot Q} = 966.4\,ft$$

Change in condensate loss for a length of piping $L := 3100ft$ $L2 := 16000ft$

$$\frac{L - 967ft}{L - 750ft} = 0.908 \qquad \frac{L2 - 967ft}{L2 - 750ft} = 0.986$$

Decreased Pressure Calculations

Steam density at 180 psig $\rho 1 := \left(2.3472 \cdot \frac{ft^3}{lb}\right)^{-1}$

Steam Density at 150 psig $\rho 2 := \left(2.7563 \cdot \frac{ft^3}{lb}\right)^{-1}$

Density ratios $\frac{\rho 1}{\rho 2} = 1.174$ $\left(\frac{\rho 1}{\rho 2}\right)^2 = 1.379$

Properties of superheated Steam (377F, 150 psig) $h_{sh} := 1202.5 \frac{BTU}{lb}$

Properties of Saturated Steam (366F, 150 psig) $h_{sat} := 1195.6 \frac{BTU}{lb}$

Length to lose superheat $$\frac{m_{sh} \cdot (h_{sh} - h_{sat})}{\frac{377 - 70}{400 - 70} \cdot Q} = 322.5\ ft$$

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EXHIBIT_(JC-6)

Consolidated Edison Company of New York, Inc.

Review, Assessment, and Action Plan Associated with the *Thermal Efficiency and Losses: Review and Action Plan*, performed by ABS Consulting in May, 2009

Background

Pursuant to the Commission's Order in Case 07-S-1315, Consolidated Edison Company of New York, Inc. ("Con Edison" or the "Company"), in collaboration with the Active Parties, retained an independent consultant, ABS Consulting (The "Consultant"), to review and summarize the findings of the Company's previous Steam Variance studies conducted from 1991 to 2002 as well as provide a recommended action plan, which the Company could implement to reduce the Steam Variance. Steam Variance is defined as the difference between metered steam sent out from the generating stations and metered steam customer sales.

The Consultant performed a review and summary of the findings of previous Steam Variance studies and provided a recommended action plan (*Thermal Efficiency and Losses: Review and Action Plan*), in May, 2009. (A copy of the Consultant's review and summary is contained in Exhibit JC-5). The Consultant's review of previous reports concluded that there are two factors affecting the Steam Variance, namely, Metering Accuracy and Line Losses. Metering issues were addressed by the installation of Vortex meters over the last several years. Line Losses are made up leaks and thermal losses. Losses due to leaks are considered small. Therefore, the primary opportunity to reduce Steam Variance is through the reduction of thermal losses. The Consultant's action plan concluded that the Company should investigate increasing the amount of superheat in its steam and the use of pumpable insulation to determine if there are any economic benefits relative to reducing thermal losses.

Consultant's Action Plan

1. Investigate whether slightly increasing steam sendout temperature, while still maintaining a temperature below the maximum system design temperature limits for the transmission and distribution system will bring about an increase in the amount of superheat (superheated steam is dry steam with a temperature above saturation). In theory increasing the amount of superheat in the steam, increases the distance that the steam can travel before a portion of this steam becomes condensate. The expected result is a decrease in the amount of thermal losses.

2. Investigate whether reducing Steam System operating pressure, while still maintaining adequate steam pressure to customers, which would result in an increase in superheat, would reduce thermal losses and whether any such reduction is cost effective.

3. Examine the use of pumpable insulation for re-insulating the Company's High Priority Location List for water intrusion to determine the reduction in thermal losses and determine if such actions are cost effective.

<u>Con Edison's Response to the Consultant's Action Plan</u>

Action Plan Item #1 – Increase Superheat

The Company acknowledges that, in general, raising steam sendout temperature so as to increase the amount of superheat does have the potential for increasing superheat thus lowering thermal line losses. As such, the Company has performed an internal assessment of increasing superheat in its steam sendout mains. The Company's assessment concluded that there is very little margin for increasing the amount of superheat in the steam mains. All of Con Edison's Package Boilers, the Boilers at the Ravenswood Steam Plant, and Hudson Avenue Boiler 82, all of which account for more than 25% of installed steam capacity, do not have superheat capabilities.

Con Edison has a distribution piping design temperature limit of 413 °F and an operating temperature limit of 410 °F, as well as a transmission piping design limit and operating limit of 25 °F of superheat.

Actual steam distribution temperatures are within approximately 5 °F or less of the 410 °F operating limit. Steam Temperature probes, which are used to measure steam temperature, have an instrument error of 1 °F to 2 °F. The combination of the actual steam distribution temperature and instrument error leaves little margin for increasing the superheat temperature. Similarly, the actual transmission steam temperatures are close to the superheat design limit and operating limit of 25 °F. Furthermore, increasing the transmission superheat temperature will ultimately increase the downstream distribution temperatures, which are already very close to the 410 °F operating limit. It should also be noted that generally increasing the operating steam temperature has a high potential for increased heat loss to the outside environment. For more detail, please refer to the *Increased Superheat Temperature Assessment* at the end of this Exhibit.

Action Plan Item #2 – Reduced System Operating Pressure

The Company acknowledges that lowering Steam System operating pressure does have the potential for increasing superheat thus lowering thermal line losses. The Company will commence a review of the risks, benefits, and costs of taking such action and estimates that this review could be completed by the end of 2010. The Company estimates that this undertaking will cost approximately $50,000 in engineering consultant costs and will look to recover the actual incurred costs under the FAC, with Staff's approval, as was done for the ABS Consulting *Thermal Efficiency and Losses: Review and Action Plan*. The $50,000 estimate is based on 500 hours of consulting engineer labor at a rate of $100/hour. Not included in this estimate are in-house Company engineering labor, steam technical support labor, and other resources, which are already in rates.

The Steam System has limited operating flexibility to maintain a lower system operating pressure while still delivering adequate pressure to customers under certain operating conditions and contingencies. As such it is expected that a small decrease in operating pressure could be considered. The potential for the reduction of heat loss is considered limited. The impact on customer service and operations needs to be explored. The Company will use various computer models to investigate the operation of the Steam System at a reduced pressure and publish the results by the end of December, 2010. The analysis will also include any potential savings so that any economic benefits are demonstrated.

Action Plan Item #3 – Re-Insulation

The Company conducted a technical and economic review of all the High Priority Locations listed in the Consultant's review and action plan. The High Priority Location List was provided by the Consultant and reconciled with the official list maintained by Steam Distribution. As of March 18, 2010, the Company also evaluated any new High Priority Locations that were identified after the Consultant's review and action plan was issued in May, 2009. The Consultant's recommendation was to utilize recent Infrared ("IR") Scans of each of these locations to obtain a street surface temperature and then compare the street surface temperature to temperature curves developed by the Consultant. A street surface temperature that was greater than the Consultant's curve temperature would indicate an area that required further investigation and possibly be a potential "Hot Spot." Manholes and service boxes, which show up as higher temperature locations on the IR Scans, were excluded from the analysis, since there is no overlying backfill to help reduce thermal losses. A computer software model was used to evaluate the heat loss from the High Priority Locations.

The High Priority Locations covered about six miles in total. Heat losses were calculated for each location on the High Priority Location List as well as any new locations that were added to the list after the Consultant issued the review and action plan. Calculations were performed to estimate the amount of steam lost per year for each location. The steam losses were then converted into dollars. The Consultant's review and action plan estimated a re-insulation cost per foot to re-insulate with pumpable insulation. The savings from using the pumpable insulation, expressed as btu/yr and Mlb/yr, were determined and converted into dollars per the method recommended in the Consultant's review and action plan and then compared with the re-insulation cost estimate. A simple payback calculation was performed. The shortest simple payback for any one of these locations was seven years. Several of the locations had payback periods of well over 20 years. Based on the Company's payback analysis, this recommendation was considered uneconomic and unacceptable. Our assessment determined that if all of the High Priority Locations were re-insulated with pumpable insulation, the total cost would be about $31.2 million. The total reduction in Steam Variance would be about 182 MMlb, which is small relative to a typical annual Steam Variance of say 4,095 MMlb. This 182 MMlb reduction equates to an annual savings estimate of about a $2.2 million and is comparable to an annual cost of about $6 million for carrying charges and property taxes, assuming the $31.2 million is capitalized. As such, this recommendation cannot be supported based solely on thermal savings. Based on this assessment, the Company decided that it would not be cost effective to continue to review the remaining IR Scans for the remaining 99 miles of Steam Pipe. The Company's Technical and Economic Assessment of the High Priority Locations as of March 18, 2010 is as follows:

Technical and Economic Assessment of High Priority Locations

Street	Pipe Diameter (in.)	Length of Main (ft.)	IR Scan (°F)	Class	Total Heat Loss (Btu/hr-ft)	Heat Loss with Ceasefire (Btu/hr-ft)	Heat Savings (Btu/hr-ft)	Btu/Year Saved	Mlb/Year Saved	Savings/Year ($)	Reinsulation Cost ($)	Payback Rate (Years)
160 Water Street N/O Fletcher Street	16	220	62	3	653	388	265	510,361,104	600	$7,367	$209,179	28
Water Street N/O Fulton Street	24	310	88	2	1396	631	765	2,077,705,560	2,444	$29,992	$294,753	10
Water Street N/O John Street	24	380	70	3	839	503	336	1,119,442,152	1,317	$16,159	$361,310	22
Liberty Street & Williams Street	16	190	60	3	619	376	244	405,997,092	478	$5,861	$180,655	31
Church Street N/O Liberty Street	16	280	76	2	1123	496	627	1,538,126,352	1,810	$22,203	$266,228	12
Park Place W/O Broadway	12	130	86	2	920	464	456	519,440,844	611	$7,498	$123,606	16
Broad Street N/O Beaver Street	8	90	119	1	914	425	489	385,275,312	453	$5,562	$85,573	15
Broadway N/O Barclay Street	12	190	86	2	910	461	449	746,882,856	879	$10,781	$180,655	17
Platt Street W/O Pearl Street	16	180	98	1	1351	507	844	1,330,898,040	1,566	$19,212	$171,147	9
Murray Street E/O West Street	16	420	73	3	640	378	263	966,856,968	1,137	$13,957	$399,343	29
Barclay Street E/O Washington Street	12	170	51	4	394	286	109	161,846,256	190	$2,336	$161,639	69
Murray Street E/O Church Street	8	370	55	4	334	250	84	273,071,100	321	$3,942	$351,802	89
125 Barclay Street W/O Washington Street	24	450	55	4	543	380	163	643,137,300	757	$9,284	$427,867	46
Allen Street S/O Hester Street	8	150	65	3	491	331	160	210,266,280	247	$3,035	$142,622	47
4 Columbia Street S/O Delancey Street	24	550	48	4	505	363	142	684,926,880	806	$9,887	$522,949	53
Grand Street E/O Broadway	24	660	87	2	1305	611	694	4,012,950,744	4,721	$57,928	$627,538	11
527 Columbia Street S/O Grand Street	24	120	78	2	1432	651	781	821,102,832	966	$11,853	$114,098	10
20 Columbia Street N/O Stanton Street	24	470	118	1	1383	584	798	3,286,596,072	3,867	$47,443	$446,883	9
33 Madison Street W/O James Street	24	590	70	3	843	505	339	1,750,433,712	2,059	$25,268	$560,981	22
7th Ave I/S W 23rd Street	20	570	93	1	1453	588	865	4,318,319,088	5,080	$62,336	$541,965	9
7th Ave S/O 11th Street	24	270	62	3	804	494	311	734,394,600	864	$10,601	$256,720	24
41 Seventh Avenue N/O 13th Street	20	220	126	1	1099	483	615	1,185,748,344	1,395	$17,117	$209,179	12
141 Leonard Street E/O Centre Street	12	100	89	2	925	463	463	405,158,760	477	$5,849	$95,082	16
14th Street E/O Avenue C	24	640	91	1	1589	658	931	5,218,100,736	6,139	$75,325	$608,522	8
15th Street E/O Avenue C	24	660	107	1	1505	621	884	5,108,679,576	6,010	$73,745	$627,538	9
14th Street W/O Avenue C	24	600	102	1	1463	620	843	4,430,650,320	5,213	$63,958	$570,489	9
128 Avenue D N/O 9th Street	24	460	90	1	1468	637	831	3,350,088,552	3,941	$48,360	$437,375	9
Avenue A N/O 14th Street	24	200	52	4	578	399	180	315,237,360	371	$4,551	$190,163	42
545 First Avenue S/O 33rd Street	24	920	87	2	1341	620	721	5,814,632,208	6,841	$83,936	$874,750	10
319 First Avenue S/O 19 Street	30	570	83	2	1305	691	614	3,066,024,528	3,607	$44,259	$541,965	12
300 15 Street E/O Second Avenue	24	830	77	2	1471	661	811	5,893,928,604	6,934	$85,081	$789,177	9
FDR S/O 20th Street	24	930	78	2	1458	657	801	6,526,320,012	7,678	$94,209	$884,259	9
20th Street W/O FDR Drive	24	1160	81	2	1387	637	750	7,623,842,016	8,969	$110,052	$1,102,946	10
202 35th Street E/O Third Avenue	24	560	106	1	1328	589	739	3,625,091,232	4,265	$52,329	$532,457	10
Lexington Avenue N/O 36 Street	24	410	99	1	1331	598	733	2,633,971,692	3,099	$38,022	$389,834	10
346 35th Street W/O First Avenue	24	570	61	3	815	499	316	1,579,498,956	1,858	$22,801	$541,965	24
35 Street E/O Fifth Avenue	24	370	62	3	810	496	314	1,017,120,972	1,197	$14,682	$351,802	24
71 35th Street E/O Sixth Avenue	24	770	94	1	1377	613	764	5,150,297,460	6,059	$74,346	$732,128	10
150 42nd Street W/O Third Avenue	30	360	105	1	1878	789	1090	3,436,067,952	4,042	$49,601	$342,294	7
205 41st Street E/O Third Avenue	16	930	84	2	997	461	536	4,365,136,908	5,135	$63,012	$884,259	14
126 41st Street W/O Lexington Avenue	20	370	145	1	1012	446	567	1,836,561,156	2,161	$26,511	$351,802	13
252 52nd Street W/0 Second Avenue	24	370	71	3	791	483	308	996,993,120	1,173	$14,392	$351,802	24
140 52nd Street E/O Lexington Avenue	24	430	77	2	1283	617	666	2,509,253,820	2,952	$36,222	$408,851	11
Madison Avenue S/O 53rd Street	4	420	86	2	568	407	162	594,779,472	700	$8,586	$399,343	47
360 57th Street W/O First Avenue	20	420	58	4	468	329	139	511,850,304	602	$7,389	$399,343	54
58th Street W/O Lexington Avenue	20	820	76	2	1171	555	616	4,423,270,896	5,204	$63,851	$779,669	12
209 E 58th Street	20	440	94	1	1334	565	769	2,965,305,552	3,489	$42,805	$418,359	10
250 58th Street W/O Second Avenue	20	570	54	4	437	314	123	614,263,464	723	$8,867	$541,965	61
64th Street & Park Avenue	8	270	57	4	352	260	92	218,591,784	257	$3,155	$256,720	81
First Avenue N/O 59th Street	20	70	104	1	1267	541	726	445,262,916	524	$6,428	$66,557	10
1185 First Avenue N/O 64th Street	16	280	82	2	1108	487	621	1,522,183,152	1,791	$21,973	$266,228	12
256 72 Street W/O Second Avenue	16	650	88	2	980	454	526	2,996,638,320	3,525	$43,257	$618,030	14
537 71st Street W/O FDR Drive	20	630	59	4	485	337	148	815,678,640	960	$11,775	$599,014	51
444 75 Street W/O York Avenue	24	690	74	3	814	491	324	1,956,028,284	2,301	$28,236	$656,063	23
1392 Third Avenue N/O 79th Street	16	1720	65	3	641	382	260	3,910,993,104	4,601	$56,456	$1,635,403	29
Columbus Circle N/O 58th Street	20	235	80	2	1258	571	686	1,413,002,454	1,662	$20,397	$223,442	11
45th Street W/O Fifth Avenue	8	670	90	1	881	440	441	2,585,910,828	3,042	$37,328	$637,046	17
900 7th Avenue S/O 57th Street	30	960	77	2	1377	719	658	5,537,469,312	6,515	$79,935	$912,783	11
49th Street E/O 7th Avenue	12	830	100	1	996	465	530	3,856,795,860	4,537	$55,674	$789,177	14
75 49th Street E/O Sixth Avenue	12	190	112	1	1051	466	585	973,490,916	1,145	$14,053	$180,655	13
3 Columbia Street N/O Henry Street	24	320	60	3	807	496	311	871,290,624	1,025	$12,577	$304,261	24
Avenue D S/O 3rd Street	24	240	72	3	860	510	350	736,807,104	867	$10,636	$228,196	21
Broadway I/S 17th Street	20	250	99	1	1537	594	942	2,063,505,600	2,428	$29,787	$237,704	8
60th Street E/O Lexington Avenue	20	490	85	2	1049	516	533	2,285,788,848	2,689	$32,996	$465,900	14
E 79th Street E/O Park Avenue	16	490	67	3	611	369	242	1,039,318,812	1,223	$15,003	$465,900	31
Columbia Street N/O Rivington Street	24	385	110	1	1454	608	846	2,853,961,572	3,358	$41,198	$366,064	9
34th Street E/O Seventh Avenue	12	720	87	2	881	452	429	2,704,275,072	3,182	$39,037	$684,587	18
43rd Street W/O Fifth Avenue	12	875	81	2	1034	486	548	4,200,420,000	4,942	$60,634	$831,964	14
								Total:	**181,980**	**$2,232,899**	**$31,210,523**	

Conclusion:

The Company has addressed action items identified in the *Thermal Efficiency and Losses: Review and Action Plan*, performed by ABS Consulting in May, 2009. Action Plan Items #1 and #3 have been examined from a technical and economic standpoint and have been determined to not require any further action. Action Plan Item # 2 - Reduce System Operating Pressure, requires further analysis, which will be performed by the Company and reported on by the end of December, 2010.

Increased Superheat Temperature Assessment

For Consideration to Reduce Steam Variance

The average steam temperatures, pressures and degrees of superheat from the steam mains connected to its Generating Stations for 2008 were reviewed.

All of the Package Boilers can only generate saturated steam and do not have superheat capability.
The Package Boilers consist of:

74th Street - Boilers 1-6
59th Street - Boilers 116-118
60th Street - Boilers 1-6
East River SSS - Boilers 115-119

The Boilers at the Ravenswood Steam Plant, Boilers 1-4, and Hudson Avenue Boiler 82, can only generate saturated steam and do not have superheat capability.

We shall call these units Non-Superheat Units (NSH).

The Steam Units that can produce Superheat are:
74th Street – Boilers 120-122
59th Street – Boilers 114-115 (Annex Boilers)
East River – Boilers 60 and 70
East River – HRSGs 10 and 20
Hudson Avenue – Boilers 71, 72, and 81
BNYCP – Units 1 and 2

We shall call these units Superheat Units (SH).

The Steam System has thermal constraints with the purpose of delivering dry saturated steam to each customer.

The thermal constraints are:

1. Distribution piping has a Design Pressure Limit of 200 PSIG and a Design Temperature Limit of 413 °F. The Sendout Temperature Guideline (Operating Limit) is 410 °F.

2. Transmission piping has a Design Pressure Limit of 400 PSIG and a Design Temperature Limit and Sendout Temperature Guideline (Design Limit and Operating Limit respectively) of 25 °F degrees of Superheat.

59th Street Generating Station
59th Street's steam piping configuration allows the mixing of steam from Boilers 114-115 (SH) with steam from the Package Boilers – Boilers 116-118 (NSH). The Station's steam piping exits into distribution piping with the temperature of the Annex Boilers at 417 °F and the weighted average Steam temperature is 406 °F.

The Station has a Sendout Temperature Guideline of 410 °F. This leaves a 4 °F margin for safe operation and a 7 °F margin for the Design Temperature Limit. The margins of 4 °F and 7 °F do not leave any available room to increase Superheat with system temperature fluctuations while maintaining the Steam Temperature below the Design Temperature Limit.

Hudson Avenue Generating Station
Hudson Avenue steam piping configuration allows the mixing of steam from Boilers 71, 72, 81 (SH) and 82 (NSH) before exiting into the Grand Street and Water Street Mains.

The steam piping enters the mains with an average of 24 °F superheat and a Superheat Design Temperature Limit and Sendout Temperature Guideline of 25 °F. This leaves a 1 °F margin for the Superheat Design Temperature Limit and Sendout Temperature Guideline. The margin of 1 °F does not leave any available room to increase Superheat with system temperature fluctuations while maintaining the Steam Temperature below the Superheat Design Temperature Limit.

74th Street Generating Station
74th Street steam piping configuration allows the mixing of steam from Boilers 120-122 (SH) with steam from the Package Boilers – Boilers 1-6 (NSH) into all of its exiting headers.

For the 74th Street Express Main, the average degrees of Superheat available is 12.4 °F.
The 74th Street Express Main was the only steam main that had any appreciable margin for increasing the Superheat temperature. However if we consider keeping a safe margin for temperature excursions, instrument error, and variation in steam flow, the amount of reduction on Steam Variance is deemed insignificant.

74th Street Distribution Main – 406 °F average temperature with a Sendout Temperature Guideline of 410 °F. This leaves a 4 °F margin for safe operation and a 7 °F margin for the Design Temperature Limit. The margins of 4 °F and 7 °F do not leave any available room to increase Superheat with system temperature fluctuations while maintaining the Steam Temperature below the Design Temperature Limit.

75th Street Distribution Main – 405 °F average temperature with a Sendout Temperature Guideline of 410 °F. This leaves a 5 °F margin for safe operation and an 8 °F margin for the Design Temperature Limit. The margins of 5 °F and 8 °F do not leave any available room to increase Superheat with system temperature fluctuations while maintaining the Steam Temperature below the Design Temperature Limit.

East River Generating Station
East River steam piping configuration allows the mixing of steam from HRSGs 10 and 20 and Boilers 60 and 70 (SH) with steam from the South Steam Station – Boilers 115-119 (NSH) into all of its exiting headers except the one exiting into the 11th Street Main, which does not mix with the Package Boilers.

Avenue D Main – Already meets Superheat Guideline of 25 °F.

14th Street Main – 407 °F average temperature with a Sendout Temperature Guideline of 410 °F. This leaves a 3 °F margin for safe operation and a 6 °F margin for the Design Temperature Limit. The margins of 3 °F and 6 °F do not leave any available room to increase Superheat with system temperature fluctuations while maintaining the Steam Temperature below the Design Temperature Limit.

15th Street Main – 404 °F average temperature with a Sendout Temperature Guideline of 410 °F. This leaves a 6 °F margin for safe operation and a 9 °F margin for the Design Temperature Limit. The margins of 6 °F and 9 °F do not leave any available room to increase Superheat with system temperature fluctuations while maintaining the Steam Temperature below the Design Temperature Limit.

1st Avenue Main – Has a Superheat Sendout Temperature Guideline and Superheat Design Temperature Limit of 25 °F. The average temperature was not available at the time of the assessment.

11th Street Main – 24 °F average superheat with a Superheat Sendout Temperature Guideline and Superheat Design Temperature Limit of 25 °F. This leaves a 1 °F margin for the Sendout Temperature Guideline and Superheat Design Temperature Limit. The margin of 1 °F does not leave any available room to increase Superheat with system temperature fluctuations while maintaining the Steam Temperature below the Design Temperature Limit.

First Avenue Tunnel
The First Avenue Tunnel receives steam at 20th Street from East River, which leaves the Station with 25 °F Superheat, but reduces to 20 °F Superheat when it reaches the Tunnel. Superheat cannot be increased at East River Station in order to increase Superheat of the steam entering the tunnel because it will exceed the Design Temperature Limit as it leaves the Station.

BNYCP
BNYCP steam mixes with Hudson Avenue Generating Station steam before entering into the Grand Street and Water Street Mains. The mixing of steam from these two Stations results in steam with an average of 23 °F superheat for the Grand Street Main and 20 °F superheat for the Water Street Main and a Superheat Sendout Temperature Guideline and Superheat Design Temperature Limit of 25 °F. This leaves a 2 °F margin for Grand Street and a 5 °F margin for Water Street, which does not leave any available room to increase Superheat with system temperature fluctuations while maintaining the Steam Temperature below the Design Temperature Limit.

Con Edison does not control the temperature of the steam output from BNYCP and the metered steam from BNYCP is located on the Hudson Avenue premises, close to the Grand Street and Water Street Mains, so the line losses from the BNYCP Units to the steam meter is not part of the Steam Variance.

Based on the foregoing, raising superheat at BNYCP will insignificantly impact Steam Variance.

Ravenswood Steam Station
Ravenswood's steam piping configuration allows the mixing of steam from Boilers 1-4 (NSH) before entering the Ravenswood Tunnel. The steam exiting the station is saturated and superheat is not available.

60th Street Generating Station
60th Street's steam piping configuration allows the mixing of steam from Boilers 1-6 (NSH) before exiting into the distribution mains. The steam exiting the station is saturated and superheat is not available.