te technical note techni

Simulation of the North Atlantic Air Traffic and Separation Scenarios – Communication Effects

A Study on Fuel Benefits Resulting From Reduced Separation Standards and an Improved Communication Infrastructure

Christine M. Gerhardt-Falk, ACT-520
E.A. Elsayed, Rutgers University
Dale Livingston, ACT-520
Brian Colamosca, ACT-520

August 2000

DOT/FAA/CT-TN00/17

Document is available to the public
through the National Technical Information
Service, Springfield, Virginia 22161

US Department of Transportation
Federal Aviation Administration

William J. Hughes Technical Center
Atlantic City International Airport, NJ 08405

NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents or use thereof. The United States Government does not endorse products or manufacturers. Trade or manufacturer's names appear herein solely because they are considered essential to the objective of this report. This document does not constitute FAA certification policy.

Technical Report Documentation Page

1. Report No. DOT/FAA/CT-TN00/17	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Simulation of the North Atlantic Air Traffic and Separation Scenarios - Communication Effects.		5. Report Date August 2000 6. Performing Organization Code
7. Author(s) Christine M. Gerhardt-Falk, ACT-520, E.A. Elsayed, Rutgers University and Dale Livingston, and Brian Colamosca, ACT-520		8. Performing Organization Report No. DOT/FAA/CT-TN00/17
9. Performing Organization Name and Address Federal Aviation Administration William J. Hughes Technical Center Atlantic City International Airport, NJ 08405		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Federal Aviation Administration Oceanic Procedures Branch 800 Independence Ave., S.W. Washington, DC 20591		13. Type of Report and Period Covered Technical Note 14. Sponsoring Agency Code ATP-130
15. Supplementary Notes		

16. Abstract

This report presents a comprehensive study of the air traffic over the North Atlantic (NAT) Ocean. The main purpose of the study is to assess the fuel savings benefit under reduced separation standards and improved communication systems in the NAT Minimum Navigation Performance Specification (MNPS) airspace. The report describes, in detail, the purpose of the study, various separation standard scenarios, simulation assumptions, analyses of the results, and conclusions. Using the separation standards from the 1996 NAT system as the baseline, this study presents analyses of four different separation scenarios with assigned communication environments: Reduced Vertical Separation Minima (RVSM), Reduced Vertical and Longitudinal Separation Minima (RVLSM), Reduced Vertical and Horizontal Separation Minima (RVHSM), and Free Flight. A fast-time simulation model is used to investigate the effect of the separation scenarios and communication environment on fuel consumption. The original study was completed in cooperation with the NAT Implementation Management Group (IMG) Cost Effectiveness (NICE) Task Force. The results presented in this report represent an extension of the initial findings of the NICE-USA Task Group.

17. Key Words	18. Distribution Statement
Fuel Benefits North Atlantic Oceanic Air Traffic Control Simulation Communication	This document is available to the public through the National Technical Information Service, Springfield, Virginia, 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	38	

Acknowledgements

We wish to thank all who participated in the North Atlantic (NAT) Implementation Management Group (IMG) Cost Effectiveness (NICE) Task Force. A special thanks goes to James Bass (UK National Air Traffic Services [NATS]), Manfred Classen (Lufthansa Aeronautical Services [Lido GmbH]), Alan Gilbert (International Air Transport Association [IATA]), Jon Vilberg Gudgeirsson (University of Iceland), Anna Soffia Hauksdottir (University of Iceland), Markus Huf (Lido GmbH), Asgeir Palsson (Icelandic Civil Aviation Authority [ICAA]), Sam Prince (UK NATS), Peter Simonsson (UK NATS), and Yngvi Pall Thorfinnsson (University of Iceland).

We also wish to thank Bob Lunnon and James McNair from the UK Meteorological (MET) Office for supplying the MET data used in the simulation studies. Mike Ellis' (NAT Traffic Forecasting Group [TFG]) effort in providing traffic forecast information is greatly appreciated.

Table of Contents

Page

Executive Summary vii

1. Introduction 1
   1.1 Background 1
   1.2 Purpose 1
   1.3 Scope 2
2. Method 3
3. Assumptions 3
   3.1 Step-Climbs and Communication Efficiency 3
   3.2 Traffic Data 3
   3.3 Aircraft Types and Fleet Changes 4
   3.4 Organized Track System 5
   3.5 Meteorological Data 5
   3.6 Simulated Flight Path 5
   3.7 Fuel Burn Calculations 5
   3.8 Take-off Weights 6
   3.9 OTS and Random Flight Classification 6
   3.10 Reclearance Logic 6
4. Results 6
   4.1 Fuel Savings 7
      4.1.1 Separation Scenario Fuel Savings Over Baseline 7
      4.1.2 Percentage Comparison of Separation Scenario 10
   4.2 Communication Volume 11
   4.3 Step-climbs Requested and Granted 12
5. Discussion 14
6. Conclusion 15
References 16
Acronyms 17

Appendices

A - Daily Fuel Results
B - Scenario 4% Vs. Scenario 100% Percentage Fuel Savings

List of Illustrations

Figures Page

1. NAT MNPS Area 2
2. RVSM Fuel Savings 8
3. RVLSM Fuel Savings. 9
4. RVHSM Fuel Savings. 9
5. Free Flight Fuel Savings 10
6. Fuel Savings by Communication System and Separation Scenario. 11

Tables Page

1. Separation Scenarios 2
2. 1996 Distribution of Aircraft Types 4
3. NICE Aircraft Type Distribution/Replacement Forecast 4
4. Total Number of Civilian Flights 6
5. Initial Study Results [1] 7
6. Results of Scenario 100% Vs. Baseline 4% 7
7. Results of Scenario 100% Vs. Baseline 100% 8
8. Communication Volume Results 12
9. Step-Climbs Requested 13
10. Step-Climbs Granted 13

EXECUTIVE SUMMARY

This report presents the results of a study of the air traffic over the North Atlantic (NAT) Ocean. It is an extension of the work introduced in the original NAT Implementation Management Group (IMG) Cost Effectiveness (NICE) Task Force study. The main purpose of this study was to assess the fuel savings of proposed changes to the separation standards in the NAT Minimum Navigation Performance Specification (MNPS) airspace with an improved communication infrastructure. The improved communication system allowed all flights to request a flight level change if a more fuel optimal level was desired. This report describes, in detail, the purpose of the study, various separation standard scenarios, simulation assumptions, analyses of the results, and conclusions.

This study investigates several scenarios, each with different reduced separation standards and an assigned communication environment. Simulation experiments were used to study the fuel burn savings for each scenario. In addition to the scenarios presented in the original NICE Task Force study, where all simulations were performed assuming an unchanged communication environment, the following separation standard scenarios were investigated:

a. Baseline System (2,000 ft Vertical, 60 nm Lateral, 10 minute Longitudinal, 15 minute Crossing) at 100% communication efficiency

b. Reduced Vertical Separation Minima (RVSM) (1,000 ft Vertical, 60 nm Lateral, 10 minute Longitudinal, 15 minute Crossing) at 100% communication efficiency

c. Reduced Vertical and Longitudinal Separation Minima (RVLSM) (1,000 ft Vertical, 60 nm Lateral, 7 minute Longitudinal, 10 minute Crossing) at 100% communication efficiency

d. Reduced Vertical and Horizontal Separation Minima (RVHSM) (1,000 ft Vertical, 30 nm Lateral, 5 minute Longitudinal, 10 minute Crossing) at 100% communication efficiency

e. Free Flight (FF) with no separation requirements, this is the "theoretical best case" scenario, it is not realistic and cannot be implemented in the real world

Some key results of the this study are as follows:

a. A mean fuel burn savings for RVSM with 100% communication efficiency of 1.66% of total fuel over the Baseline system with 4% communication efficiency. At the US fuel price of $0.51/gallon (Averaged from May 1998 to April 1999) this equates to a savings of over $47 Million for the 1996 to a savings of over $63 Million for the year 2010.

b. A further mean fuel burn savings of 0.072% for RVLSM at 100% communication efficiency over RVSM at 100% communication efficiency. At the US fuel price of $0.51/gallon (Averaged from May 1998 to April 1999) this equates to an additional savings for RVLSM over RVSM of more than $2 Million for the year 1996 to a savings of over $2.6 Million for the year 2010.

c. A further mean fuel burn savings of 0.12% for RVHSM over RVLSM when communication efficiency is assumed to be at 100%. At the US fuel price of $0.51/gallon (Averaged from May 1998 to April 1999) this equates to an additional savings for RVHSM over RVLSM of more than $3 Million for the year 1996 to a savings of over $5 Million for the year 2010.

d. The RVSM, RVLSM, RVHSM and FF scenarios with 100% communication efficiency, achieved an average fuel savings ranging from 0.46% in 1996 to 0.58% in 2010 for RVSM, 0.57% in 1996 to 0.65% in 2010 for RVLSM, 0.70% in 1996 to 0.76% in 2010 for RVHSM, and 1.49% in 1996 to 1.63% in 2010 for Free Flight when compared to the Baseline system with the improved communication system (100% efficiency). At the US fuel price of $0.51/gallon (Averaged from May 1998 to April 1999) this equates to a savings of over $14 million for the year 1996 and over $21 million for the year 2010 for RVSM, over $16 million for the year 1996 and over $24 million for the year 2010 for RVLSM, over $20 million for the year 1996 and over $28 million for the year 2010 for RVHSM, and over $60 million for the year 2010 for Free Flight.

e. Comparisons between the more efficient communication system (100%) and the less efficient communication system (4%) for a given scenario reveal a fuel savings for the RVSM scenario ranging from 1.14% in 1996 to 1.01% in 2010. At the US fuel price of $0.51/gallon (Averaged from May 1998 to April 1999) this equates to a savings of over $31 million in 1996 and over $32 million in 2010 for the RVSM scenario with 100% communication efficiency over the RVSM scenario with 4% communication efficiency.

f. The comparison between the RVLSM scenario at 100% communication efficiency and the RVLSM scenario at 4% communications efficiency showed a fuel savings ranging from 1.16% in 1996 to 1.03% in 2010 for RVLSM. At the US fuel price of $0.51/gallon (Averaged from May 1998 to April 1999) this equates to a savings of over $32 million in 1996 and over $38 million for year 2010.

g. The comparison between the RVHSM scenario at 100% communication efficiency and the RVHSM scenario at 4% communications efficiency showed a fuel savings ranging from 1.17% in 1996 to 1.07% in 2010. At the US fuel price of $0.51/gallon (Averaged from May 1998 to April 1999) this equates to a savings of over $32 million in 1996 and over $39 million for year 2010.

h. In all cases, improvement in the current communication systems might results in fuel savings equivalent to those achieved from the reduction in separation standards.

1. Introduction

This study investigates the effect of improvements to the oceanic Air Traffic Control (ATC) system in the North Atlantic (NAT) Minimum Navigational Performance Specification (MNPS) airspace on potential benefits. Specifically, this study provides an investigation into fuel savings resulting from improvements in the separation standards and communication infrastructure in the NAT MNPS.

This study is an extension of the work presented in the original NAT Implementation Management Group (IMG) Cost Effectiveness (NICE) Task Force study [1,2].

1.1 Background

The original study [2] was performed as part of an international effort to investigate the benefits associated with the separation elements of the Air Traffic Management (ATM) Implementation Plan (ATMIP). Three task groups participated in the NICE Task Force; NICE-UK from the United Kingdom (UK National Air Traffic Services Limited (NATS)), NICE-ICE from Iceland (Icelandic Civil Aviation Authority (ICAA) and the University of Iceland) and NICE-USA from the United States (Federal Aviation Administration (FAA) and Rutgers University). A summary of the NICE Task Force study was presented in [2].

In the original study [1], NICE-USA estimated the fuel savings for several separation standard scenarios assuming the communication infrastructure remained unchanged in future years. As part of the extension to the original study, the simulation experiments are repeated with the assumptions of an improved, more efficient communication infrastructure in the NAT airspace. Figure 1 shows the NAT MNPS and the five Oceanic CTA. More details on the NAT airspace were provided in [1].

1.2 Purpose

The purpose of this study is to estimate the potential fuel benefits realized under reduced separation standards with a more efficient communication infrastructure in the NAT airspace. The percentage of requests for flight level changes allowed in each simulation scenario is specified in this report. The exact specifications or type of the more efficient communication infrastructure (e.g. Automatic Dependent Surveillance (ADS) or Data Link.) and its requirements are not specified in this report.

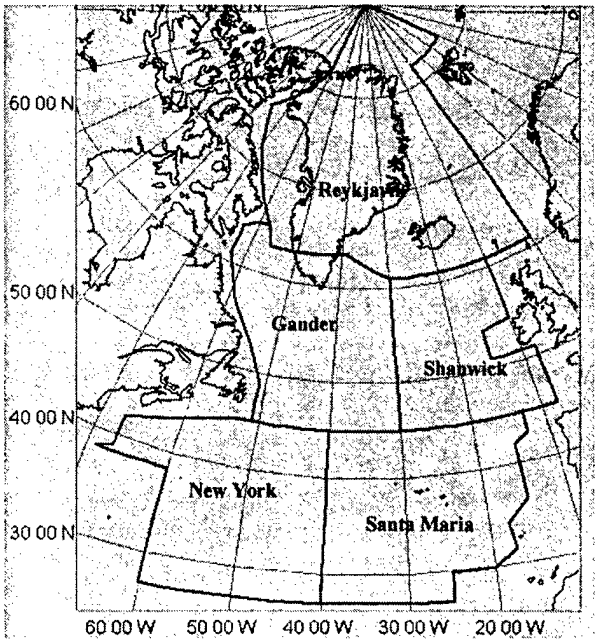

Figure 1. NAT MNPS area.

1.3 Separation Scenarios

This study investigates the effect of the separation standards within the NAT MNPS airspace on the system performance. Using the separation standards from the 1996 NAT airspace system as the baseline, this study presents analyses of four different separation scenarios as shown in Table 1. The strategy for implementing proposed separation reduction initiatives in the NAT follows a phased progression. The first separation reduction implemented is Reduced Vertical Separation Minima (RVSM). The remaining separation reductions to be implemented include Reduced Vertical and Longitudinal Separation Minima (RVLSM), Reduced Vertical and Horizontal Separation Minima (RVHSM) and oceanic Free Flight (FF).

The FF scenario, as it is presented in this report, cannot be implemented. It represents an unrealistic system in which each flight obtains its optimal path regardless of other aircraft in the system. It also assumes the actual weather information was known and available during flight planning. The separation scenarios are shown in Table 1.

Table 1. Separation Scenarios

Scenario	Separation Standards			
	Vertical	Lateral	Crossing	Longitudinal
Baseline	2,000 ft	60 nm	15 minutes	10 minutes
RVSM	1,000 ft	60 nm	15 minutes	10 minutes
RVLSM	1,000 ft	60 nm	10 minutes	7 minutes
RVHSM	1,000 ft	30 nm	10 minutes	5 minutes
FF	0	0	0	0

2. Method

The Integrated NAT Air Traffic Simulation Model (INATSIM) presented in [1] was used in this study. The simulation experiments from the original study [1] are repeated with different assumptions regarding the communications environment.

The INATSIM consists of several sub-modules. The Flight Event Module generates the stochastic input data that drive the system. The data include the origin and destination airports, direction, aircraft type, take-off weight, speed, the departure times from the origin airport, payload of the aircraft, and other information such as the coordinates of the airport locations. The two main modules are the Flight Planning Module (FPM) and the Flight Tracking Module (FTM). The FPM uses the flight events and generates the optimal flight path that minimizes the total fuel consumption for each aircraft in the flight events input file. The FTM actually tracks the NAT crossings and performs the ATC tasks. Details of the INATSIM structure are provided in [1].

3. Assumptions

3.1 Step-Climbs and Communication Efficiency

The FPM generated flight plans that contain step-climbs. During the traffic simulation (FTM), the probability of a step-climb request in each scenario was controlled in the model. Each time an aircraft approached a waypoint in the NAT airspace, the model checked its desired flight level listed in the flight plan and compared it to the current operating level. If the aircraft was operating at a lower flight level than the level listed in the flight plan, a step-climb request might be possible. The probability of a step-climb request was kept at 100% for all scenarios. Details on the step-climb procedures applied in this study were given in [1].

The difference between the original study [1] and this study are the assumptions regarding the communication efficiency. The initial study performed a simulation of the NAT air traffic for the years 1996, 2000, 2005, and 2010 under different separation scenarios, with the assumption that the communication systems in the NAT airspace remained the same as in year 1996, heavily relying on a High Frequency (HF) infrastructure. Based on historical data, the probability of a step-climb request was 4% for all scenarios (except FF). In this study, the simulation experiments were repeated with a more efficient communication system in place (probability of a step-climb request was 100%). A more efficient communication system allowed for a higher percentage of step-climb requests to be made. Aircraft request step-climbs when a higher flight level becomes more fuel-efficient than the current level.

3.2 Traffic Data

This study used the 24-day traffic sample generated statistically by the Flight Event Module in [1]. Traffic data for the 4^{th} and 15^{th} of each month from years 1996, 2000, 2005 and 2010 were simulated.

3.3 Aircraft Types and Fleet Changes

All aircraft in the reduced separation simulations were assumed to be suitably equipped and approved to operate in the reduced separation environment.

The 1996 distribution of the top 10 aircraft types generated from the real traffic data represented over 86% of the aircraft types used in the NAT in the year 1996. This list is presented in Table 2. Aircraft performance and fuel characteristics for these aircraft types were obtained and used in the simulation model.

Table 2. 1996 Distribution of Aircraft Types

Aircraft	**Percentage**	**Cumulative Percentage**
B767	28.4%	28.4%
B747-200	18.9%	47.3%
DC10	9.4%	56.7%
L1011	5.2%	62.0%
EA31	3.0%	65.0%
B747-400	5.5%	70.4%
MD11	5.8%	76.3%
B757	4.3%	80.5%
EA34	4.1%	84.6%
B777	1.6%	86.1%

The NAT fleet change forecasts were incorporated in the future years' traffic samples. This fleet forecast included the effect of replacing 'older' aircraft types like the DC10 and B747-200 with 'newer' types like the B777 and the Airbus 340. This was described in [1]; the forecast details are given in Table 3. The traffic distributions for military aircraft and miscellaneous business jets remained constant for all years.

Table 3. NICE Aircraft Type Distribution/Replacement Forecast

Aircraft	**Year 2000**	**Year 2005**	**Year 2010**
B767	No change	+100 % EA31 +100 % B757	+100 % EA31 +100 % B757
B747	No change	-30 % B777 -20 % B757	-60 % B777 -40 % EA34
DC10	-30 % B777 -20% EA34	-60 % B777 -40 % EA34	-60 % B777 -40% EA34
L1011	-30 % B777 -20 % EA34	-60 % B777 -40 % EA34	-60 % B777 -40 % EA34
EA31	No change	-100 % B767	-100 % B767
B74F	No change	No change	No change
MD11	No change	No change	No change
B757	No change	-100 % B767	-100 % B767
EA34	+20 % L1011	+20 % B747	+40 % B747

Aircraft	Year 2000	Year 2005	Year 2010
	+20 % DC10	+40 % DC10 +40 % L1011	+40 % DC10 +40 % L1011
B777	+30 % L1011 +30 % DC10	+60 % L1011 +60 % DC10 +30 % B747	+60 % L1011 +60 % DC10 +60 % B747

3.4 Organized Track System

The actual Organized Track System (OTS) from the 24 study days in 1996 was used in the simulation of the Baseline system. NICE-ICE provided two additional sets of OTS tracks for use with the RVSM and RVHSM scenarios. The OTS for the different scenarios was:

a. Baseline System (the same as the actual 1996 OTS),

b. RVSM (revised by eliminating outer tracks),

c. RVLSM (same as RVSM),

d. RVHSM (revised by compacting the tracks),

e. FF (no OTS).

The OTS was used in the simulation of all scenarios for the 24 study days and in all 4 years except in the FF scenario where no OTS was applied.

3.5 Meteorological Data

The wind conditions from each of the 24 study days in 1996 were used in both the FPM and FTM. All scenario simulations, except FF, used the forecast wind data in the FPM and the actual wind data in the FTM. In the FF scenario, the actual wind data was used in both the FPM and FTM to simulate the availability of perfect meteorological (MET) data. The FPM, FTM and MET Modules were discussed in [1].

3.6 Simulated Flight Path

This study examined the oceanic portion of flight only; domestic routings were not simulated in the model. Each aircraft operated on an optimal fuel path from the origin airport to its NAT entry point and from the NAT exit point to the destination airport. The ATC clearance procedures were applied during the NAT portion of flight only.

3.7 Fuel Burn Calculations

The fuel burn for each civilian flight was calculated over the entire flight path in the NAT. Military flights were included in the study to simulate the congestion effects; the fuel for military flights was not reported. Fuel burn comparisons were made using the total fuel burn (NAT and domestic fuel burn) calculated for each flight. The NAT fuel burn was not used for comparisons due to the fluctuations in the distances flown within the NAT Flight Information Regions (FIRs) from scenario to scenario.

3.8 Take-off Weights

Take-off weights were randomly generated based on the origin – destination pairing and the aircraft type. A description of the statistical take-off weight generation was given in [1]. The simulation experiments assumed the same flight had the same take-off weight in all scenarios (in a given year).

3.9 OTS and Random Flight Classification

The FPM generated an optimal fuel path for each flight. Before the traffic simulation (FTM), geographical comparisons between the optimal fuel path and the OTS were made for each flight. The flights meeting the OTS criteria, whose optimal fuel path was within one lateral degree of a specific track on the OTS, were assigned to the OTS. The remaining flights were kept as random flights. Details on the OTS / random flight classification were given in [1].

3.10 Reclearance Logic

The FPM generated an optimal fuel path from the origin airport, through the NAT airspace, to the destination airport for each flight. During the traffic simulation, each flight operated on the optimal fuel path from the origin airport to NAT entry. Before entry into the NAT airspace, the FTM applied the reclearance logic to provide a conflict-free path for each flight. Once the NAT portion of flight was complete, each flight operated on the optimal fuel path from the NAT exit to the destination airport. The reclearance logic applied was dependent on the separation scenario and the direction of the flight. Specific details on the NICE-USA reclearance procedure were given in [1].

4. Results

All scenarios were compared with the Baseline System (1996 system) where the separation distances of 2,000 ft vertical, 60 nm lateral and 10 minute longitudinal are maintained. The results presented include

a. fuel savings,

b. communication volume, and

c. number of step-climbs requested and granted.

Table 4 shows the total number of civilian flights simulated for each year.

Table 4. Total number of civilian flights

Year	Total Number of Civilian Flights
1996	20,173
2000	24,179
2005	28,044
2010	31,316

4.1 Fuel Savings

4.1.1 Separation Scenarios Fuel Savings Over Baseline

The percentage of fuel savings for the scenarios were calculated as 100% * (Baseline fuel - Scenario fuel) / Baseline fuel. The model calculated the fuel expended (lbs) for a scenario of a given day by adding all the fuel consumed by all flights (excluding military flights). It is important to note that the fuel calculated for each aircraft was the actual fuel consumed after the aircraft was cleared according to ATC rules.

The fuel results from all the scenarios with 100% communications efficiency were compared to the Baseline scenarios with 4% and 100% communication efficiency. Tables 5 through 7 provide the results for each of the comparisons. Table 5 shows the initial study [1], where all scenarios were simulated with 4% communication efficiency. Table 6 shows the results of the comparisons between the reduced separation scenarios at 100% communication efficiency and the Baseline scenario at 4% communication efficiency. Table 7 shows the fuel benefit results of the comparisons between the reduced separation scenarios at 100% communication efficiency and the Baseline scenario at 100 % communication efficiency. The percentage designated next to the scenario name indicates the level of communication efficiency corresponding to the results, for example RVSM 4% represents the RVSM results from the initial study (4% probability for a step-climb request) for the given year, and RVSM 100% represents the RVSM results generated for this study (100% probability for a step-climb request) for the given year. The fuel savings percentage represents the computed average benefit for the given scenario and year. The fuel savings results for each simulation day are presented in Appendix A.

Table 5. Initial study results [1]

Year	RVSM 4% vs. Base 4%	RVLSM 4% vs. Base 4%	RVHSM 4% vs. Base 4%
1996	0.5249%	0.5692%	0.6855%
2000	0.5607%	0.6292%	0.7370%
2005	0.6124%	0.6529%	0.7337%
2010	0.6887%	0.7404%	0.8022%

Table 6. Results of Scenario 100% Vs. Baseline 4%

Year	RVSM 100% vs. Base 4%	RVLSM 100% vs. Base 4%	RVHSM 100% vs. Base 4%	FREE 100% vs. Base 4%
1996	1.6675%	1.7384%	1.8647%	2.6595%
2000	1.6540%	1.7401%	1.8703%	2.6612%
2005	1.6358%	1.6949%	1.8134%	2.6612%
2010	1.6866%	1.7546%	1.8652%	2.7229%

Table 7. Results of Scenario 100% Vs. Baseline 100%

Year	RVSM 100% vs. Base 100%	RVLSM 100% vs. Base 100%	RVHSM 100% vs. Base 100%	FREE 100% vs. Base 100%
1996	0.4649%	0.5688%	0.6979%	1.4932%
2000	0.5096%	0.5972%	0.7282%	1.5405%
2005	0.5432%	0.6037%	0.7218%	1.5742%
2010	0.5836%	0.6535%	0.7608%	1.6271%

Using the results from the initial study for comparison, the results for the RVSM, RVLSM, RVHSM and FF scenarios are shown in Figures 2 through 5.

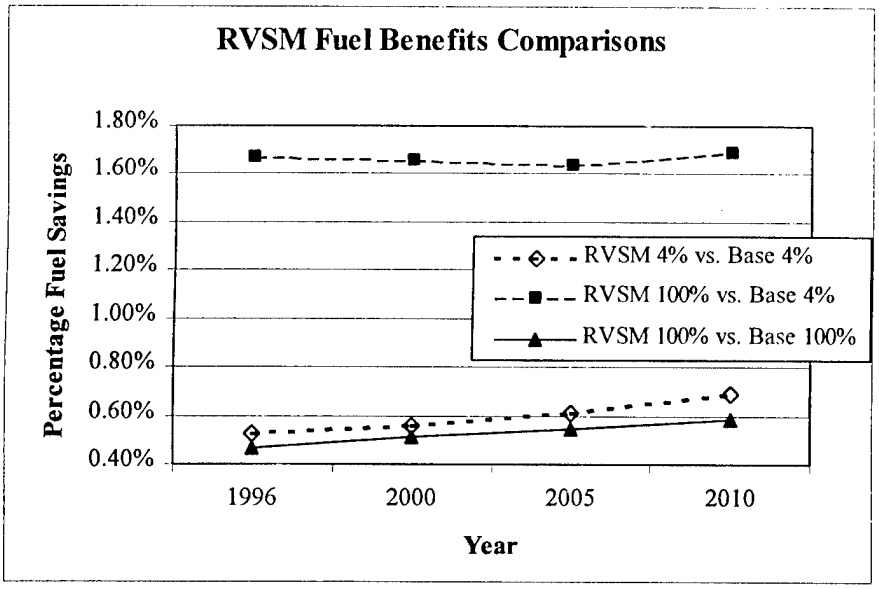

Figure 2. RVSM fuel savings.

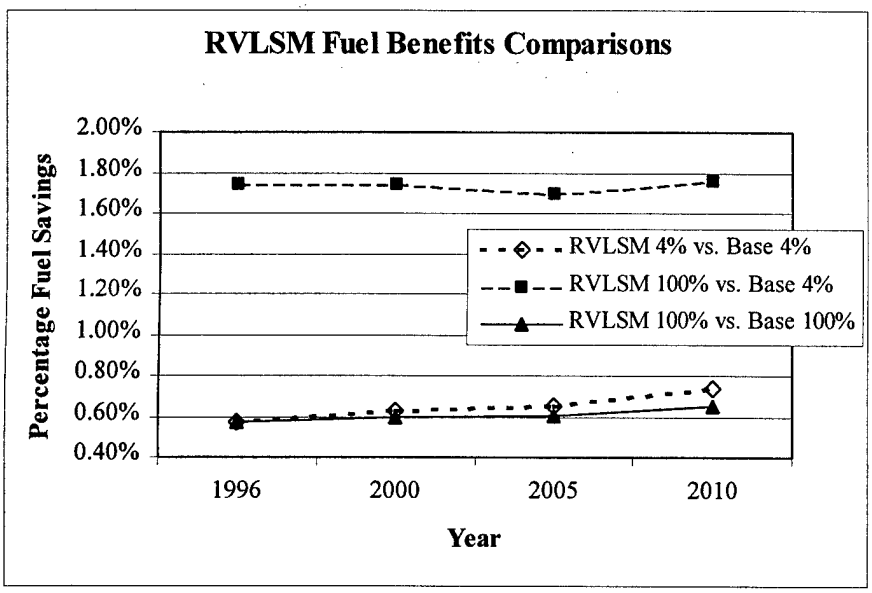

Figure 3. RVLSM fuel savings.

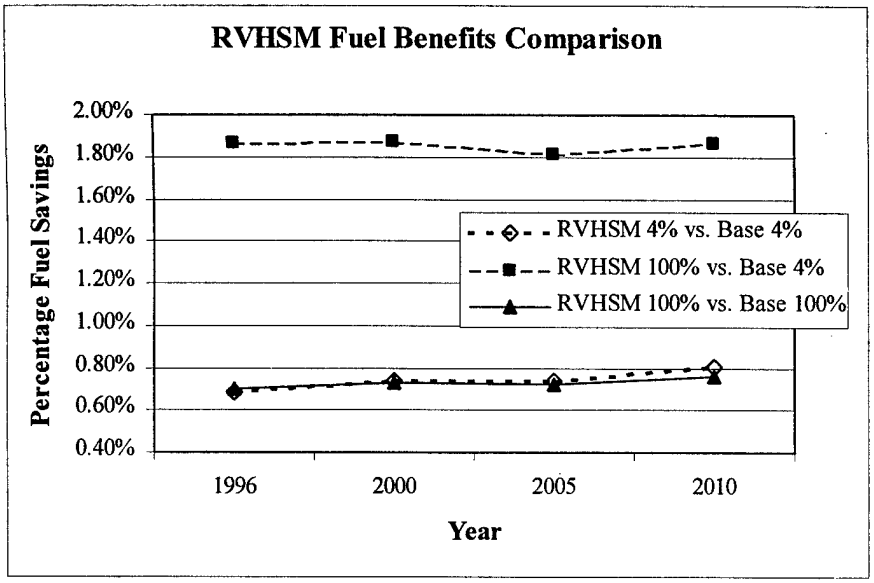

Figure 4. RVHSM fuel savings.

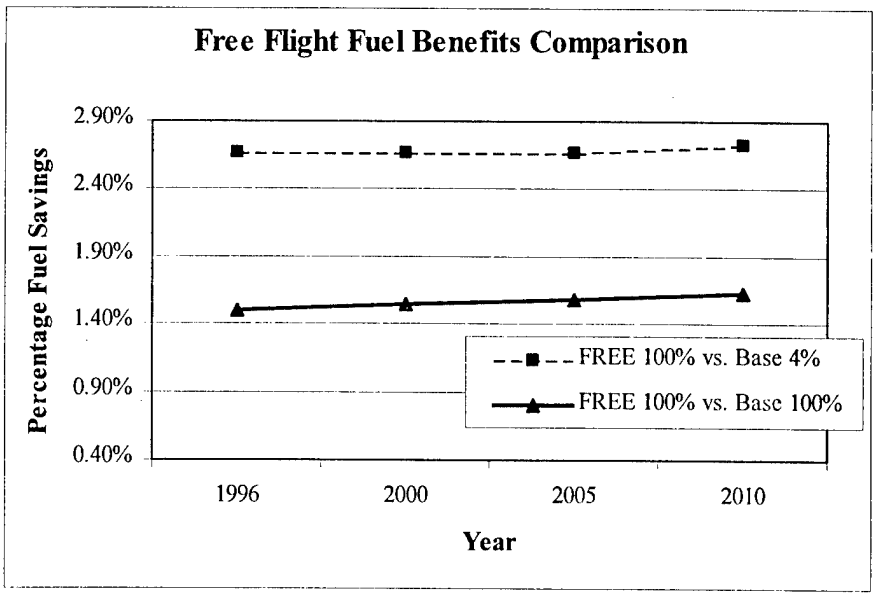

Figure 5. Free Flight fuel savings.

The separation scenarios with 100% communication efficiency showed a large fuel savings when compared to the Baseline scenario with 4% communication efficiency. The average fuel savings for the RVSM, RVLSM, RVHSM and FF scenarios at 100% communication efficiency were 1.66%, 1.73%, 1.85%, and 2.01% respectively, when compared to the Baseline scenario at 4% communication efficiency. The fuel savings results from the comparison of both the Baseline and the separation scenarios at 100% communication efficiency were slightly lower or approximately equal to the fuel results from the comparison of both the baseline and separation scenarios at 4% communication efficiency.

4.1.2 Fuel Savings Percentage Comparison of Separation Scenario at 100% and 4% Communications

The next set of results show the fuel consumption comparisons with the communication system as the only controlled influencing factor. The comparisons include RVSM at 4% communication efficiency compared to RVSM at 100% communication efficiency. Similar comparisons were performed for RVLSM and RVHSM.

Figure 6 shows the additional fuel savings achieved when a given separation scenario (RVSM, RVLSM, and RVHSM) with 4% communication efficiency (current HF infrastructure) changes to 100% communication efficiency. The fuel savings for the separation scenarios with 4% communication efficiency were given in the initial study [1]. The fuel savings were computed for each simulated day in the following manner: 100% * (Scenario at 4% communications – Scenario at 100% communications) / Scenario at 4% communications. The results were averaged for each year and scenario. The fuel savings for each simulation day and scenario are provided in Appendix B.

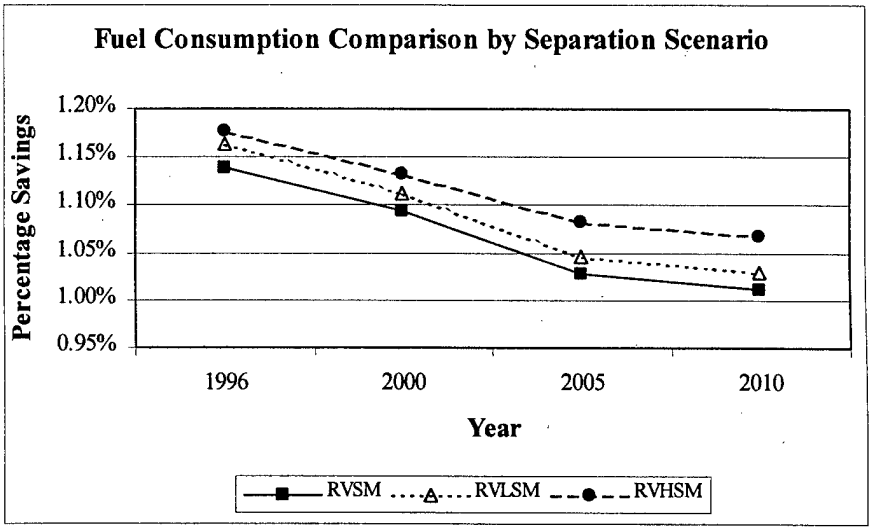

Figure 6. Fuel savings by communication system and separation scenario.

The RVSM scenario with 100% communication efficiency showed a 1.14%, 1.09%, 1.03%, and 1.01% increase in fuel savings over the RVSM scenario with 4% communication efficiency for the years of 1996, 2000, 2005, and 2010 respectively.

The RVLSM scenario with 100% communication efficiency showed a 1.16%, 1.11%, 1.05%, and 1.03% increase in fuel savings over the RVLSM scenario with 4% communication efficiency for the years of 1996, 2000, 2005, and 2010 respectively.

The RVHSM scenario with 100% communication efficiency showed a 1.18%, 1.13%, 1.08%, and 1.07% increase in fuel savings over the RVHSM scenario with 4% communication efficiency for the years of 1996, 2000, 2005, and 2010 respectively.

A downward trend in average percentage fuel savings was noticed in all scenarios with the increase in traffic (years). Due to the increased traffic volume and congestion in future years, the probability for granting a step-climb decreased. As a result, some flights were penalized in fuel consumption.

4.2 Communication Volume

Communication volume for the scenarios was calculated in the FTM. It was measured by counting the number of communication transmissions between the aircraft and ATC. These transmissions represent the waypoint crossings (mandatory position reporting points) and step-climb requests and replies. The communication counts were totaled for each simulation day, and the results are shown in Table 8. The communication volume increased from the initial study because of the increase in the number of step-climb requests (see Section 4.3).

Table 8. Communication Volume Results

Year	Scenario	4% No. Of Communications	100 % No. Of Communications
1996	Baseline	127,672	225,621
1996	RVSM	129,096	246,647
1996	RVLSM	129,083	242,328
1996	RVHSM	129,460	236,156
2000	Baseline	151,282	265,493
2000	RVSM	152,907	289,141
2000	RVLSM	152,856	283,897
2000	RVHSM	153,082	276,200
2005	Baseline	174,129	305,073
2005	RVSM	176,070	331,492
2005	RVLSM	176,113	325,863
2005	RVHSM	176,406	315,611
2010	Baseline	194,703	338,767
2010	RVSM	196,752	367,376
2010	RVLSM	196,867	359,158
2010	RVHSM	197,023	350,375

4.3 Step-Climbs Requested and Granted

Step-climbs requests were initiated at least 15 minutes before an aircraft reached a waypoint crossing during the oceanic portion of flight. An aircraft could initiate a step-climb request when the current flight level was lower than that specified in the original flight plan. A step climb was not permitted at the oceanic exit point. The total number of step climbs requested and granted are shown in Tables 9 and 10 respectively. Tables 9 and 10 include the results from the initial study for comparison and use Table 4 to compute the average number of step-climbs per flight.

The number of step-climb requests was controlled within the model. For this study, all flights operating at a lower flight level than indicated in the original flight plan requested a step-climb (assuming 100% communication efficiency). The flight level change was granted if no conflicts were present. The INATSIM was developed to model the HF communication infrastructure, with the assumption that step-climbs were requested when position reports were submitted.

Table 9. Step-Climbs Requested

Year	Scenario	4% Step-climbs Requested	100% Step-climbs Requested	4% Average No. Step-climbs Requested Per Flight	100% Average No. Step-climbs Requested Per Flight
1996	Baseline	2,717	51,692	0.1347	2.5624
1996	RVSM	3,189	61,964	0.1581	3.0716
1996	RVLSM	3,182	59,804	0.1577	2.9646
1996	RVHSM	3,354	56,702	0.1663	2.8108
2000	Baseline	3,163	60,269	0.1308	2.4926
2000	RVSM	3,740	71,857	0.1547	2.9719
2000	RVLSM	3,715	69,235	0.1536	2.8634
2000	RVHSM	3,834	65,393	0.1586	2.7045
2005	Baseline	3,707	69,167	0.1322	2.4664
2005	RVSM	4,217	81,930	0.1504	2.9215
2005	RVLSM	4,241	79,116	0.1512	2.8211
2005	RVHSM	4,446	74,048	0.1585	2.6404
2010	Baseline	4,086	76,114	0.1305	2.4305
2010	RVSM	4,728	90,038	0.1510	2.8751
2010	RVLSM	4,784	86,327	0.1528	2.7566
2010	RVHSM	4,886	81,562	0.1560	2.6045

Table 10. Step-Climbs Granted

Year	Scenario	4% Step-climbs Granted	100% Step-climbs Granted	4% Average No. Of Step-climbs Granted Per Flight	100% Average No. Of Step-climbs Granted Per Flight
1996	Baseline	1,294	21,393	0.0641	1.0605
1996	RVSM	1,753	31,823	0.0869	1.5775
1996	RVLSM	1,848	32,722	0.0916	1.6221
1996	RVHSM	2,067	32,433	0.1025	1.6077
2000	Baseline	1,451	23,777	0.0600	0.9834
2000	RVSM	2,042	35,439	0.0845	1.4657
2000	RVLSM	2,106	36,279	0.0871	1.5004
2000	RVHSM	2,391	36,434	0.0989	1.5068
2005	Baseline	1,655	25,834	0.0590	0.9212
2005	RVSM	2,192	38,461	0.0782	1.3715
2005	RVLSM	2,367	39,679	0.0844	1.4149
2005	RVHSM	2,662	39,661	0.0949	1.4142
2010	Baseline	1,779	27,227	0.0568	0.8694
2010	RVSM	2,456	40,823	0.0784	1.3036
2010	RVLSM	2,638	41,699	0.0842	1.3316
2010	RVHSM	2,874	41,931	0.0918	1.3390

The flight plans generated by the FPM contained step-climbs. There were fewer step-climbs in the flight plans of the Baseline scenario than in the separation scenario flight plans. Therefore, there were more step-climbs requested in the separation scenarios than in the Baseline scenario. For example, the number of step-climbs in the May 4, 2010 flight plans for the Baseline and RVSM scenarios were 1,790 and 3,649 respectively. The reason for the difference was that each step-climb was required to be at least 2,000 ft in the baseline scenario, whereas, in the separation scenarios (e.g., RVSM), each step-climb was required to be at least 1,000 ft. A step-climb was placed in the flight plan if the fuel savings achieved by operating at the higher flight level was at least as much as the additional amount of fuel required to make the step-climb. The fuel required to make the step-climb depended on the aircraft type, Mach speed, and the current weight of the aircraft. The heavier the aircraft, the harder it was to justify a step-climb. Therefore, it was easier to justify a step-climb of 1,000 ft compared to a step-climb of 2,000 ft because less fuel was required to climb 1,000 ft compared to 2,000 ft.

More step-climbs were granted in the 100% communication efficiency simulations because more were requested. The number of step-climbs granted increased with decreasing separation standards in both sets of simulations (4% and 100% communication efficiency).

5. Discussion

It is clear from the results shown in Table 3 to 5 and Figures 2 to 5 that the separation scenarios at 100% communication efficiency show large fuel savings compared to the Baseline scenario at 4% communication efficiency. The large fuel savings is due to the increased number of step-climbs permitted in the 100% communication efficiency simulations. In this comparison, both the communication infrastructure and separation standards influence the fuel savings results.

The fuel saving results from the comparison of both the Baseline and separation scenarios at 100% communication efficiency are slightly lower or approximately equal to those from the comparison of both the Baseline and separation scenarios at 4% communication efficiency. In these comparisons, there is no difference in the communication infrastructure; only the separation standards influence the fuel savings results.

The results also show a fuel savings due to the communication system alone. Fuel consumption results from the same separation scenario under 4% and 100% communication efficiency are compared, and the results of these comparisons reveal potential fuel savings ranging from 1% to 1.14% for RVSM, 1% to 1.16% for RVLSM, and 1.1% to 1.18% for RVHSM. The increased fuel savings in the comparisons are direct outcomes of the change in communication systems. A more efficient communication system allows for more step-climbs to be requested, thus more aircraft are achieving a more fuel-efficient route.

As expected, the number of step-climbs requested and granted increased in the 100% communication efficiency simulations. There are more requests for step-climbs in the separation scenarios with 1,000 ft vertical separation than in the Baseline scenario. This occurs because step-climbs are made when the fuel savings achieved from operating at a higher flight level is more than the fuel required to climb to the higher flight level. The results also show the number of step-climbs granted increases with the decrease in separation standards.

The actual number of communications, step-climb requests, and step-climbs granted are not important to this study. These numbers are subject to the limitations of the simulation model. The INATSIM was developed to simulate the different separation scenarios with the current HF communication infrastructure in place. The current communication system requires pilots to report their position to ATC at the mandatory reporting points (waypoints) in the NAT airspace. In this HF communication environment, requests for step-climbs usually accompany the position reports to reduce the number of transmissions made (ATC is expected to respond to a step-climb request). At this time, it is unknown what changes would be made to the reporting requirements with an improved communication system in place. The purpose of this study was to determine if the efficiency of the communication system affects the fuel savings of the system, and the results show there is an affect on fuel savings due to the efficiency of the communication infrastructure.

6. Conclusion

This study is an extension of the initial work completed by NICE-USA. Fuel savings resulting from an improved communication system for three reduced separation scenarios (RVSM, RVLSM, and RVHSM) and the FF scenario have been compared to results obtained for the Baseline scenario.

The key results from this study can be summarized as follows:

- The reduced separation systems, RVSM, RVLSM, RVHSM, and FF, under an improved communication system, achieved fuel savings when compared to the Baseline system.
- The RVSM scenario with 100% communication efficiency, achieved an average fuel savings of 1.66% from the Baseline scenario with the current communication system in place (4% communication efficiency).
- Further fuel savings over RVSM were shown to be approximately 0.072% for the RVLSM scenario and 0.193% for the RVHSM scenario with 100% communication efficiency assumed.
- The RVSM, RVLSM, RVHSM, and FF scenarios, with 100% communication efficiency, achieved an average fuel savings over the Baseline scenario with the improved communication system (100% efficiency) ranging from 0.46% in 1996 to 0.58% in 2010 for RVSM, 0.57% in 1996 to 0.65% in 2010 for RVLSM, 0.70% in 1996 to 0.76% in 2010 for RVHSM, and 1.49% in 1996 to 1.63% in 2010 for FF.

A potential fuel savings was realized from the communication system as the only influencing factor. Comparisons between the more efficient communication system (100%) and the less efficient communication system (4%) for a given scenario reveal a fuel savings ranging from 1.14% in 1996 to 1.01% in 2010 for RVSM, 1.16% in 1996 to 1.03% in 2010 for RVLSM, and 1.17% in 1996 to 1.07% in 2010 for RVHSM. This average percentage of fuel savings was shown to decrease with increasing traffic.

REFERENCES

1. Gerhardt-Falk, C., Elsayed, E.A., Livingston, D., & Colamosca, B., "Simulation of the North Atlantic Air Traffic and Separation Scenarios", Federal Aviation Administration, Report No. DOT/FAA/CT-TN00/04, February 2000.

2. North Atlantic Implementation Management Group Cost Effectiveness Task Force (NAT IMG Cost Effectiveness or NICE Task Force), "Report of the NICE Task Force", October 1999.

ACRONYMS

ADS	Automatic Dependent Surveillance
ATC	Air Traffic Control
ATMIP	Air Traffic Management Implementation Plan
CTA	Control Area
FAA	Federal Aviation Administration
FF	Free Flight
FIR	Flight Information Region
FPM	Flight Planning Module
FTM	Flight Tracking Module
HF	High Frequency
IATA	International Air Transport Association
ICE	Iceland
IMG	Implementation Management Group
INATSIM	Integrated North Atlantic Air Traffic Simulation Model
Lido	Lido GmbH Lufthansa Aeronautical Services
MET	Meteorological
MNPS	Minimum Navigation Performance Specification
NAT	North Atlantic
NICE Task Force	NAT IMG Cost/Effectiveness Program
NICE-ICE	NICE Task Force from Iceland (Icelandic CAA, University of Iceland)
NICE-UK	NICE Task Force from the United Kingdom (UK NATS)
NICE-USA	NICE Task Force from the United States (FAA, Rutgers University)
OTS	Organized Track System
RVHSM	Reduced Vertical and Horizontal Separation Minima
RVLSM	Reduced Vertical and Longitudinal Separation Minima
RVSM	Reduced Vertical Separation Minima
TFG	Traffic Forecasting Group
UK	United Kingdom
UK NATS	UK National Air Traffic Services LTD

Appendix A

DAILY FUEL RESULTS

A1. PERCENTAGE FUEL SAVINGS FOR YEAR 1996

Date	RVSM 4% Vs. Baseline 4%	RVSM 100% Vs. Base 4%	RVSM 100% Vs. Base 100%	RVLSM 4% Vs. Base 4%	RVLSM 100% Vs. Base 4%	RVLSM 100% Vs. Base 100%
1/4/96	0.8057%	1.9163%	0.7621%	0.8476%	1.9732%	0.8196%
1/15/96	0.8286%	1.9331%	0.9497%	0.9348%	2.0386%	1.0562%
2/4/96	0.3578%	1.3501%	0.3879%	0.3883%	1.4294%	0.4680%
2/15/96	0.3843%	1.6213%	0.3707%	0.4108%	1.6553%	0.4051%
3/4/96	0.3311%	1.5272%	0.3154%	0.3770%	1.6098%	0.3991%
3/15/96	0.3943%	1.6873%	0.3468%	0.4341%	1.7524%	0.4128%
4/4/96	0.3029%	1.6066%	0.2925%	0.3242%	1.6462%	0.3327%
4/15/96	0.4178%	1.7011%	0.4245%	0.4400%	1.7480%	0.4720%
5/4/96	0.4622%	1.5888%	0.4467%	0.4933%	1.6329%	0.4914%
5/15/96	0.3585%	1.4283%	0.3574%	0.4403%	1.5020%	0.4319%
6/4/96	0.4254%	1.4387%	0.3765%	0.5050%	1.5638%	0.5029%
6/15/96	0.5976%	1.8646%	0.4957%	0.5871%	1.9433%	0.5755%
7/4/96	0.4769%	1.3843%	0.4335%	0.5423%	1.4729%	0.5230%
7/15/96	0.4295%	1.6445%	0.3901%	0.4647%	1.7142%	0.4607%
8/4/96	1.0302%	2.1429%	0.9923%	1.1823%	2.2972%	1.1483%
8/15/96	0.6549%	1.8095%	0.6421%	0.6875%	1.9073%	0.7411%
9/4/96	1.2380%	2.2542%	1.0487%	1.2739%	2.3232%	1.1186%
9/15/96	0.3624%	1.4586%	0.3829%	0.4133%	1.5015%	0.4263%
10/4/96	0.4165%	1.3665%	0.3725%	0.4215%	1.4415%	0.4483%
10/15/96	0.4165%	1.8294%	0.3725%	0.4215%	1.8876%	0.4483%
11/4/96	0.1604%	1.3844%	0.1759%	0.2087%	1.4320%	0.2241%
11/15/96	0.7575%	1.9112%	0.6350%	0.8103%	1.9675%	0.6921%
12/4/96	0.3567%	1.3610%	0.4152%	0.3748%	1.4252%	0.4800%
12/15/96	0.6313%	1.8106%	0.5243%	0.6782%	1.8578%	0.5721%
Averages	0.5249%	1.6675%	0.4963%	0.5692%	1.7384%	0.5688%

Date	RVHSM 4% Vs. Base 4%	RVHSM 100% Vs. Base 4%	RVHSM 100% Vs. Base 100%	FF 100% Vs. Base 4%	FF 100% Vs. Base 100%
1/4/96	0.9245%	2.0290%	0.8760%	3.1064%	1.9661%
1/15/96	0.8356%	2.0743%	1.0923%	3.1966%	2.2258%
2/4/96	0.6490%	1.6550%	0.6958%	2.2261%	1.2724%
2/15/96	0.4885%	1.7882%	0.5396%	2.2830%	1.0408%
3/4/96	0.5401%	1.7225%	0.5131%	2.3997%	1.1987%
3/15/96	0.5466%	1.8435%	0.5052%	2.5054%	1.1761%
4/4/96	0.5111%	1.7460%	0.4339%	2.6834%	1.3838%
4/15/96	0.5353%	1.8802%	0.6060%	2.5097%	1.2437%
5/4/96	0.6635%	1.8358%	0.6966%	2.3828%	1.2499%
5/15/96	0.6539%	1.6798%	0.6116%	2.4997%	1.4404%
6/4/96	0.6773%	1.7432%	0.6843%	2.3270%	1.2744%
6/15/96	0.7466%	2.0637%	0.6976%	2.7376%	1.3809%
7/4/96	0.7503%	1.6909%	0.7430%	2.4132%	1.4723%
7/15/96	0.4202%	1.7166%	0.4632%	2.5763%	1.3337%
8/4/96	0.8793%	2.1535%	1.0030%	3.2732%	2.1359%

Date	RVHSM 4% Vs. Base 4%	RVHSM 100% Vs. Base 4%	RVHSM 100% Vs. Base 100%	FF 100% Vs. Base 4%	FF 100% Vs. Base 100%
8/15/96	0.9643%	2.1597%	0.9965%	2.7152%	1.5586%
9/4/96	1.3554%	2.4460%	1.2429%	3.9738%	2.7895%
9/15/96	0.5715%	1.6577%	0.5842%	2.4945%	1.4302%
10/4/96	0.5311%	1.5332%	0.5409%	2.1838%	1.1981%
10/15/96	0.5311%	1.9440%	0.5409%	2.8039%	1.1981%
11/4/96	0.5185%	1.8076%	0.6043%	2.7413%	1.5495%
11/15/96	1.0106%	2.0959%	0.8221%	2.7536%	1.4884%
12/4/96	0.3945%	1.5106%	0.5662%	2.3786%	1.4425%
12/15/96	0.7521%	1.9749%	0.6908%	2.6626%	1.3875%
Averages	0.6855%	1.8647%	0.6979%	2.6595%	1.4932%

A2. PERCENTAGE FUEL SAVINGS FOR YEAR 2000

Date	RVSM 4% Vs. Baseline 4%	RVSM 100% Vs. Base 4%	RVSM 100% Vs. Base 100%	RVLSM 4% Vs. Base 4%	RVLSM 100% Vs. Base 4%	RVLSM 100% Vs. Base 100%
01/04/00	0.7763%	1.8346%	0.7612%	0.8239%	1.9087%	0.8360%
01/15/00	0.7558%	1.8143%	0.8397%	0.8428%	1.9164%	0.9427%
02/04/00	0.4213%	1.3668%	0.4087%	0.5365%	1.5019%	0.5451%
02/15/00	0.3576%	1.5369%	0.3174%	0.3579%	1.6026%	0.3839%
03/04/00	0.2529%	1.5620%	0.2678%	0.3634%	1.6812%	0.3887%
03/15/00	0.3403%	1.5368%	0.2748%	0.4131%	1.6321%	0.3714%
04/04/00	0.4549%	1.5786%	0.3527%	0.4220%	1.5949%	0.3693%
04/15/00	0.3776%	1.7202%	0.4118%	0.4556%	1.8030%	0.4956%
05/04/00	0.6343%	1.7185%	0.6019%	0.6846%	1.7647%	0.6486%
05/15/00	0.5692%	1.4954%	0.5367%	0.6503%	1.5751%	0.6171%
06/04/00	0.4296%	1.4212%	0.3648%	0.4744%	1.4910%	0.4353%
06/15/00	0.6876%	1.9735%	0.5697%	0.7847%	2.0689%	0.6665%
07/04/00	0.4707%	1.3464%	0.5056%	0.5884%	1.4343%	0.5942%
07/15/00	0.5585%	1.7235%	0.4847%	0.6277%	1.8046%	0.5668%
08/04/00	0.9135%	1.9519%	0.8011%	1.1007%	2.1755%	1.0273%
08/15/00	0.5590%	1.6905%	0.4564%	0.6169%	1.7907%	0.5579%
09/04/00	0.8253%	1.8702%	0.7029%	0.9351%	2.0350%	0.8697%
09/15/00	0.3199%	1.3100%	0.3430%	0.3282%	1.3410%	0.3742%
10/04/00	0.6048%	1.5426%	0.4858%	0.6464%	1.6029%	0.5468%
10/15/00	0.6048%	1.8319%	0.4858%	0.6464%	1.8822%	0.5468%
11/04/00	0.3712%	1.4697%	0.3476%	0.4701%	1.5915%	0.4709%
11/15/00	0.9592%	2.0439%	0.8642%	1.0193%	2.0950%	0.9159%
12/04/00	0.5121%	1.5429%	0.5341%	0.5407%	1.6128%	0.6048%
12/15/00	0.6998%	1.8131%	0.5114%	0.7708%	1.8577%	0.5566%
Averages	0.5607%	1.6540%	0.5096%	0.6292%	1.7401%	0.5972%

Date	RVHSM 4% Vs. Base 4%	RVHSM 100% Vs. Base 4%	RVHSM 100% Vs. Base 100%	FF 100% Vs. Base 4%	FF 100% Vs. Base 100%
01/04/00	1.0298%	2.0441%	0.9729%	2.9726%	1.9116%
01/15/00	0.9750%	2.0659%	1.0937%	3.0042%	2.0413%
02/04/00	0.7535%	1.7067%	0.7519%	2.3030%	1.3541%
02/15/00	0.5117%	1.7445%	0.5276%	2.3666%	1.1574%
03/04/00	0.6370%	1.7998%	0.5087%	2.3952%	1.1120%
03/15/00	0.4642%	1.6901%	0.4301%	2.4746%	1.2246%
04/04/00	0.4780%	1.6958%	0.4716%	2.7065%	1.4949%
04/15/00	0.6048%	1.9429%	0.6374%	2.5342%	1.2366%
05/04/00	0.7357%	1.8589%	0.7439%	2.5654%	1.4585%
05/15/00	0.8460%	1.7582%	0.8020%	2.6661%	1.7187%
06/04/00	0.6089%	1.6907%	0.6372%	2.2974%	1.2504%
06/15/00	0.7119%	2.0757%	0.6734%	2.8527%	1.4615%
07/04/00	0.7355%	1.6328%	0.7943%	2.4259%	1.5943%
07/15/00	0.7299%	1.9657%	0.7299%	2.6536%	1.4265%
08/04/00	0.9295%	2.1237%	0.9748%	3.0764%	1.9388%
08/15/00	0.8807%	2.0049%	0.7748%	2.5829%	1.3600%
09/04/00	0.8899%	1.9898%	0.8239%	3.5660%	2.4189%
09/15/00	0.4594%	1.4826%	0.5172%	2.3561%	1.3992%
10/04/00	0.6943%	1.7302%	0.6754%	2.5369%	1.4908%
10/15/00	0.6943%	2.0235%	0.6754%	2.5369%	1.4908%
11/04/00	0.8351%	1.9809%	0.8647%	2.8376%	1.7312%
11/15/00	1.1499%	2.2618%	1.0847%	2.9431%	1.7742%
12/04/00	0.6009%	1.7066%	0.6995%	2.5734%	1.5752%
12/15/00	0.7315%	1.9117%	0.6113%	2.6425%	1.3518%
Averages	0.7370%	1.8703%	0.7282%	2.6612%	1.5405%

A3. PERCENTAGE FUEL SAVINGS FOR YEAR 2005

Date	RVSM 4% Vs. Baseline 4%	RVSM 100% Vs. Base 4%	RVSM 100% Vs. Base 100%	RVLSM 4% Vs. Base 4%	RVLSM 100% Vs. Base 4%	RVLSM 100% Vs. Base 100%
01/04/05	0.7820%	1.7575%	0.6948%	0.7769%	1.7745%	0.7120%
01/15/05	0.6017%	1.6937%	0.6607%	0.6474%	1.7975%	0.7657%
02/04/05	0.4565%	1.4227%	0.4703%	0.5097%	1.4922%	0.5404%
02/15/05	0.4586%	1.6421%	0.4329%	0.5142%	1.6944%	0.4859%
03/04/05	0.2889%	1.4652%	0.3212%	0.2926%	1.4938%	0.3501%
03/15/05	0.5124%	1.7142%	0.4008%	0.5559%	1.7798%	0.4672%
04/04/05	0.5317%	1.6849%	0.4228%	0.5795%	1.7495%	0.4882%
04/15/05	0.4080%	1.6119%	0.4412%	0.4390%	1.6347%	0.4643%
05/04/05	0.7106%	1.6968%	0.6763%	0.7380%	1.7299%	0.7097%
05/15/05	0.5502%	1.4343%	0.4226%	0.5161%	1.4424%	0.4308%
06/04/05	0.9658%	1.8883%	0.5863%	0.9569%	1.9128%	0.6111%
06/15/05	0.5833%	1.7224%	0.4767%	0.6514%	1.8172%	0.5727%
07/04/05	0.4892%	1.2623%	0.4417%	0.5226%	1.3360%	0.5160%

Date	RVSM 4% Vs. Baseline 4%	RVSM 100% Vs. Base 4%	RVSM 100% Vs. Base 100%	RVLSM 4% Vs. Base 4%	RVLSM 100% Vs. Base 4%	RVLSM 100% Vs. Base 100%
07/15/05	0.7002%	1.7982%	0.6338%	0.8243%	1.8722%	0.7087%
08/04/05	1.0171%	2.0248%	0.9885%	1.1232%	2.1430%	1.1079%
08/15/05	0.7102%	1.7155%	0.6784%	0.7807%	1.8065%	0.7704%
09/04/05	1.1240%	2.0566%	0.9782%	1.1901%	2.1645%	1.0873%
09/15/05	0.3971%	1.2972%	0.3513%	0.4284%	1.3357%	0.3901%
10/04/05	0.5878%	1.4218%	0.4844%	0.5873%	1.4596%	0.5225%
10/15/05	0.5878%	1.6161%	0.4844%	0.5873%	1.6367%	0.5225%
11/04/05	0.2598%	1.3368%	0.2716%	0.3420%	1.4241%	0.3599%
11/15/05	0.8034%	1.8466%	0.7624%	0.8261%	1.8772%	0.7933%
12/04/05	0.5782%	1.4909%	0.5366%	0.6061%	1.5716%	0.6181%
12/15/05	0.5939%	1.6591%	0.4197%	0.6737%	1.7316%	0.4931%
Averages	0.6124%	1.6358%	0.5432%	0.6529%	1.6949%	0.6037%

Date	RVHSM 4% Vs. Base 4%	RVHSM 100% Vs. Base 4%	RVHSM 100% Vs. Base 100%	FF 100% Vs. Base 4%	FF 100% Vs. Base 100%
01/04/05	0.9097%	1.8597%	0.7981%	2.9276%	1.8776%
01/15/05	0.7176%	1.9085%	0.8778%	2.9151%	1.8950%
02/04/05	0.7702%	1.6995%	0.7498%	2.3272%	1.3835%
02/15/05	0.5222%	1.7549%	0.5471%	2.4527%	1.2535%
03/04/05	0.4516%	1.5892%	0.4467%	2.3337%	1.1998%
03/15/05	0.6686%	1.8696%	0.5583%	2.6351%	1.3340%
04/04/05	0.6152%	1.8533%	0.5933%	2.7063%	1.4573%
04/15/05	0.5493%	1.7935%	0.6249%	2.4368%	1.2759%
05/04/05	0.8819%	1.9102%	0.8919%	2.6070%	1.5959%
05/15/05	0.6581%	1.6527%	0.6433%	2.4813%	1.4804%
06/04/05	1.2087%	2.2028%	0.9049%	2.8194%	1.5297%
06/15/05	0.6017%	1.8222%	0.5778%	2.6863%	1.4529%
07/04/05	0.7249%	1.5581%	0.7399%	2.3540%	1.5425%
07/15/05	0.8413%	1.9971%	0.8351%	2.8287%	1.6765%
08/04/05	0.8393%	1.9928%	0.9562%	3.0550%	2.0296%
08/15/05	1.0016%	2.0230%	0.9892%	2.6913%	1.6645%
09/04/05	0.9481%	2.0702%	0.9920%	3.7376%	2.6777%
09/15/05	0.5851%	1.4998%	0.5559%	2.4357%	1.5007%
10/04/05	0.6398%	1.5348%	0.5985%	2.2355%	1.3059%
10/15/05	0.6398%	1.7519%	0.5985%	2.5639%	1.3059%
11/04/05	0.6642%	1.7907%	0.7304%	2.7612%	1.7114%
11/15/05	0.9812%	2.0259%	0.9436%	2.7458%	1.6715%
12/04/05	0.6036%	1.5911%	0.6377%	2.6491%	1.7059%
12/15/05	0.5844%	1.7707%	0.5327%	2.4829%	1.2538%
Averages	0.7337%	1.8134%	0.7218%	2.6612%	1.5742%

A4. PERCENTAGE FUEL SAVINGS FOR YEAR 2010

Date	RVSM 4% Vs. Baseline 4%	RVSM 100% Vs. Base 4%	RVSM 100% Vs. Base 100%	RVLSM 4% Vs. Base 4%	RVLSM 100% Vs. Base 4%	RVLSM 100% Vs. Base 100%
01/04/10	0.7086%	1.7602%	0.6956%	0.7381%	1.7847%	0.7203%
01/15/10	0.7622%	1.8096%	0.7798%	0.8211%	1.8916%	0.8627%
02/04/10	0.5354%	1.4740%	0.6203%	0.6079%	1.5410%	0.6879%
02/15/10	0.2972%	1.4361%	0.3019%	0.3371%	1.5003%	0.3668%
03/04/10	0.4916%	1.5802%	0.4286%	0.4864%	1.6241%	0.4731%
03/15/10	0.5087%	1.7052%	0.4520%	0.5255%	1.7270%	0.4740%
04/04/10	0.5255%	1.6116%	0.3910%	0.5440%	1.6341%	0.4138%
04/15/10	0.5766%	1.7737%	0.5777%	0.6126%	1.8196%	0.6242%
05/04/10	0.8098%	1.7716%	0.6692%	0.8692%	1.8519%	0.7504%
05/15/10	0.6706%	1.5315%	0.5105%	0.7321%	1.6122%	0.5920%
06/04/10	1.2473%	2.1305%	0.7056%	1.3321%	2.2397%	0.8164%
06/15/10	0.7423%	1.8897%	0.6095%	0.7866%	1.9840%	0.7049%
07/04/10	0.6301%	1.3616%	0.5547%	0.6871%	1.4272%	0.6208%
07/15/10	0.6811%	1.7355%	0.6317%	0.7548%	1.7932%	0.6899%
08/04/10	0.9218%	1.8616%	0.8188%	1.0767%	2.0118%	0.9707%
08/15/10	0.5637%	1.5792%	0.5386%	0.5674%	1.6323%	0.5923%
09/04/10	1.3199%	2.3047%	1.0911%	1.3829%	2.4133%	1.2011%
09/15/10	0.4147%	1.3476%	0.3865%	0.4453%	1.3768%	0.4160%
10/04/10	0.7655%	1.6100%	0.5378%	0.8243%	1.6894%	0.6181%
10/15/10	0.7655%	1.6137%	0.5378%	0.8243%	1.6668%	0.6181%
11/04/10	0.3807%	1.4882%	0.4214%	0.4607%	1.5612%	0.4952%
11/15/10	0.7580%	1.7028%	0.5975%	0.8329%	1.8029%	0.6987%
12/04/10	0.6531%	1.5175%	0.5926%	0.6992%	1.5911%	0.6668%
12/15/10	0.7991%	1.8829%	0.5561%	0.8209%	1.9349%	0.6088%
Averages	0.6887%	1.6866%	0.5836%	0.7404%	1.7546%	0.6535%

Date	RVHSM 4% Vs. Base 4%	RVHSM 100% Vs. Base 4%	RVHSM 100% Vs. Base 100%	FF 100% Vs. Base 4%	FF 100% Vs. Base 100%
01/04/10	0.9483%	1.8965%	0.8334%	2.9764%	1.9250%
01/15/10	0.6526%	1.8305%	0.8009%	3.0114%	1.9942%
02/04/10	0.7917%	1.7040%	0.8524%	2.3566%	1.5105%
02/15/10	0.4530%	1.6384%	0.5065%	2.2762%	1.1517%
03/04/10	0.5455%	1.6922%	0.5419%	2.4033%	1.2614%
03/15/10	0.6459%	1.8626%	0.6114%	2.6580%	1.4169%
04/04/10	0.6455%	1.7353%	0.5162%	2.6353%	1.4274%
04/15/10	0.7980%	1.9730%	0.7794%	2.6540%	1.4687%
05/04/10	0.9297%	1.9655%	0.8653%	2.6738%	1.5815%
05/15/10	0.8638%	1.7319%	0.7130%	2.6023%	1.5925%
06/04/10	1.4846%	2.4465%	1.0262%	3.1062%	1.6955%
06/15/10	0.7825%	2.0488%	0.7706%	2.9310%	1.6643%
07/04/10	0.8369%	1.6486%	0.8440%	2.4413%	1.6432%
07/15/10	0.7760%	1.9171%	0.8152%	2.8358%	1.7443%
08/04/10	0.8529%	1.9524%	0.9106%	2.8973%	1.8656%

Date	RVHSM 4% Vs. Base 4%	RVHSM 100% Vs. Base 4%	RVHSM 100% Vs. Base 100%	FF 100% Vs. Base 4%	FF 100% Vs. Base 100%
08/15/10	0.7744%	1.8389%	0.8011%	2.5318%	1.5014%
09/04/10	1.2438%	2.3955%	1.1830%	4.0108%	2.8184%
09/15/10	0.6158%	1.5308%	0.5715%	2.4017%	1.4509%
10/04/10	0.7222%	1.7282%	0.6574%	2.5385%	1.4765%
10/15/10	0.7222%	1.8133%	0.6574%	2.6443%	1.4765%
11/04/10	0.7678%	1.8977%	0.8353%	2.8121%	1.7597%
11/15/10	0.9156%	1.9020%	0.7989%	2.5732%	1.4777%
12/04/10	0.6880%	1.6494%	0.7257%	2.6342%	1.7198%
12/15/10	0.7954%	1.9664%	0.6407%	2.7429%	1.4278%
Averages	0.8022%	1.8652%	0.7608%	2.7229%	1.6271%

Appendix B

SCENARIO 4% VS. SCENARIO 100% PERCENTAGE FUEL SAVINGS

B1. RVSM 4% VS. RVSM 100% PERCENTAGE FUEL SAVINGS

Date	Total	West	East
1/4/96	1.1197%	1.4599%	0.7328%
1/15/96	1.1137%	1.4739%	0.7477%
2/4/96	0.9959%	1.4171%	0.5429%
2/15/96	1.2418%	1.6117%	0.8524%
3/4/96	1.2001%	1.4671%	0.9046%
3/15/96	1.2981%	1.8160%	0.7427%
4/4/96	1.3076%	1.6193%	0.9891%
4/15/96	1.2887%	1.6785%	0.8577%
5/4/96	1.1318%	1.5706%	0.6384%
5/15/96	1.0736%	1.4042%	0.7159%
6/4/96	1.0176%	1.4197%	0.5515%
6/15/96	1.2746%	1.8347%	0.6848%
7/4/96	0.9117%	1.3271%	0.4491%
7/15/96	1.2202%	1.8118%	0.5892%
8/4/96	1.1243%	1.5317%	0.7024%
8/15/96	1.1622%	1.5596%	0.7552%
9/4/96	1.0289%	1.3534%	0.7085%
9/15/96	1.1001%	1.5836%	0.5503%
10/4/96	0.9539%	1.3165%	0.5367%
10/15/96	1.1898%	1.6724%	0.6723%
11/4/96	1.2259%	1.7690%	0.5780%
11/15/96	1.1625%	1.4623%	0.8416%
12/4/96	1.0079%	1.3534%	0.6447%
12/15/96	1.1868%	1.7860%	0.5696%
1/4/00	1.0666%	1.3707%	0.7420%
1/15/00	1.0666%	1.5778%	0.5511%
2/4/00	0.9495%	1.3645%	0.5147%
2/15/00	1.1835%	1.5312%	0.8301%
3/4/00	1.3124%	1.6329%	0.9499%
3/15/00	1.2005%	1.7845%	0.6176%
4/4/00	1.1287%	1.4526%	0.7873%
4/15/00	1.3477%	1.8412%	0.8287%
5/4/00	1.0912%	1.4959%	0.6303%
5/15/00	0.9315%	1.1950%	0.6529%
6/4/00	0.9959%	1.4769%	0.4895%
6/15/00	1.2948%	1.8032%	0.7533%
7/4/00	0.8798%	1.3009%	0.4150%
7/15/00	1.1715%	1.6833%	0.5399%
8/4/00	1.0480%	1.4258%	0.6254%
8/15/00	1.1379%	1.4765%	0.7436%
9/4/00	1.0536%	1.4142%	0.6425%
9/15/00	0.9933%	1.4119%	0.5213%
10/4/00	0.9435%	1.3028%	0.5218%
10/15/00	1.1014%	1.5991%	0.5404%
11/4/00	1.1026%	1.5567%	0.6107%
11/15/00	1.0952%	1.3963%	0.7544%
12/4/00	1.0360%	1.4276%	0.6081%
12/15/00	1.1211%	1.6479%	0.5389%
1/4/05	0.9832%	1.3277%	0.6611%
1/15/05	1.0986%	1.5559%	0.5954%
2/4/05	0.9707%	1.3780%	0.4848%
2/15/05	1.1890%	1.5187%	0.7852%
3/4/05	1.1797%	1.5873%	0.7270%
3/15/05	1.2080%	1.8360%	0.6017%
4/4/05	1.1594%	1.5444%	0.7573%
4/15/05	1.2089%	1.5794%	0.7728%
5/4/05	0.9933%	1.4021%	0.5673%
5/15/05	0.8890%	1.2200%	0.5641%
6/4/05	0.9315%	1.3568%	0.4595%
6/15/05	1.1457%	1.6135%	0.6511%
7/4/05	0.7769%	1.1743%	0.3405%
7/15/05	1.1058%	1.7282%	0.4980%
8/4/05	1.0180%	1.4212%	0.5545%
8/15/05	1.0125%	1.4076%	0.6330%
9/4/05	0.9431%	1.2736%	0.6183%
9/15/05	0.9038%	1.2924%	0.4898%
10/4/05	0.8389%	1.1770%	0.4671%
10/15/05	0.9868%	1.4047%	0.5289%
11/4/05	1.0798%	1.4935%	0.5446%
11/15/05	1.0517%	1.3697%	0.6704%
12/4/05	0.9181%	1.2236%	0.5790%
12/15/05	1.0716%	1.6225%	0.5047%
1/4/10	1.0591%	1.4125%	0.6484%
1/15/10	1.0555%	1.4928%	0.4571%
2/4/10	0.9437%	1.3781%	0.4692%
2/15/10	1.1423%	1.4155%	0.8354%
3/4/10	1.0939%	1.5048%	0.6919%
3/15/10	1.2026%	1.7872%	0.5839%
4/4/10	1.0918%	1.3816%	0.7834%
4/15/10	1.2040%	1.5979%	0.7503%
5/4/10	0.9697%	1.3597%	0.5865%
5/15/10	0.8667%	1.1263%	0.6006%
6/4/10	0.8943%	1.3366%	0.4448%
6/15/10	1.1560%	1.6647%	0.6269%
7/4/10	0.7362%	1.0781%	0.3714%
7/15/10	1.0617%	1.6135%	0.4468%
8/4/10	0.9485%	1.3062%	0.5617%
8/15/10	1.0212%	1.3864%	0.6308%
9/4/10	0.9979%	1.4019%	0.5882%
9/15/10	0.9368%	1.3811%	0.4783%
10/4/10	0.8510%	1.2096%	0.4173%
10/15/10	1.0120%	1.4087%	0.5372%
11/4/10	1.1118%	1.6228%	0.5340%
11/15/10	0.9521%	1.2070%	0.6726%
12/4/10	0.8700%	1.1494%	0.5563%
12/15/10	1.0925%	1.6536%	0.5044%

B2. RVLSM 4% VS. RVLSM 100% PERCENTAGE FUEL SAVINGS

Date	Total	West	East
1/4/96	1.1352%	1.4473%	0.7802%
1/15/96	1.1142%	1.4712%	0.7517%
2/4/96	1.0452%	1.4644%	0.5943%
2/15/96	1.2497%	1.5816%	0.9005%
3/4/96	1.2375%	1.5026%	0.9438%
3/15/96	1.3240%	1.8451%	0.7649%
4/4/96	1.3263%	1.6327%	1.0130%
4/15/96	1.3137%	1.7140%	0.8717%
5/4/96	1.1453%	1.6071%	0.6259%
5/15/96	1.0664%	1.4118%	0.6925%
6/4/96	1.0641%	1.4508%	0.6157%
6/15/96	1.3642%	1.9390%	0.7591%
7/4/96	0.9357%	1.3690%	0.4528%
7/15/96	1.2553%	1.8546%	0.6156%
8/4/96	1.1282%	1.5442%	0.6969%
8/15/96	1.2282%	1.6890%	0.7558%
9/4/96	1.0629%	1.3872%	0.7422%
9/15/96	1.0927%	1.5721%	0.5474%
10/4/96	1.0243%	1.4331%	0.5533%
10/15/96	1.1882%	1.6425%	0.7008%
11/4/96	1.2258%	1.7687%	0.5777%
11/15/96	1.1667%	1.4457%	0.8687%
12/4/96	1.0543%	1.3871%	0.7047%
12/15/96	1.1877%	1.7647%	0.5938%
1/4/00	1.0937%	1.3612%	0.8082%
1/15/00	1.0827%	1.5771%	0.5840%
2/4/00	0.9705%	1.4011%	0.5187%
2/15/00	1.2492%	1.6117%	0.8804%
3/4/00	1.3226%	1.6455%	0.9568%
3/15/00	1.2241%	1.8171%	0.6316%
4/4/00	1.1772%	1.4804%	0.8578%
4/15/00	1.3535%	1.8667%	0.8141%
5/4/00	1.0873%	1.4564%	0.6673%
5/15/00	0.9308%	1.1734%	0.6739%
6/4/00	1.0215%	1.5032%	0.5144%
6/15/00	1.2944%	1.8398%	0.7129%
7/4/00	0.8509%	1.2519%	0.4087%
7/15/00	1.1843%	1.6674%	0.5888%
8/4/00	1.0[illegible]%	1.5026%	0.6196%
8/15/00	1.1811%	1.5371%	0.7665%
9/4/00	1.1103%	1.4663%	0.7032%
9/15/00	1.0161%	1.4258%	0.5540%
10/4/00	0.9628%	1.3486%	0.5096%
10/15/00	1.1187%	1.6181%	0.5559%
11/4/00	1.1267%	1.6301%	0.5804%
11/15/00	1.0868%	1.3715%	0.7642%
12/4/00	1.0779%	1.4595%	0.6609%
12/15/00	1.0953%	1.5612%	0.5813%
1/4/05	1.0054%	1.3395%	0.6933%

Date	Total	West	East
1/15/05	1.1576%	1.5925%	0.6800%
2/4/05	0.9875%	1.3835%	0.5149%
2/15/05	1.1863%	1.5092%	0.7907%
3/4/05	1.2047%	1.5753%	0.7930%
3/15/05	1.2307%	1.9056%	0.5785%
4/4/05	1.1768%	1.5498%	0.7872%
4/15/05	1.2010%	1.5493%	0.7915%
5/4/05	0.9993%	1.3785%	0.6042%
5/15/05	0.9311%	1.2356%	0.6322%
6/4/05	0.9651%	1.3383%	0.5511%
6/15/05	1.1734%	1.6564%	0.6630%
7/4/05	0.8176%	1.1952%	0.4030%
7/15/05	1.0566%	1.6121%	0.5144%
8/4/05	1.0313%	1.4441%	0.5559%
8/15/05	1.0339%	1.4328%	0.6505%
9/4/05	0.9861%	1.2811%	0.6960%
9/15/05	0.9111%	1.2686%	0.5311%
10/4/05	0.8774%	1.2015%	0.5210%
10/15/05	1.0036%	1.4025%	0.5665%
11/4/05	1.0858%	1.4880%	0.5656%
11/15/05	1.0599%	1.3612%	0.6982%
12/4/05	0.9714%	1.2728%	0.6368%
12/15/05	1.0651%	1.6090%	0.5054%
1/4/10	1.0544%	1.4048%	0.6468%
1/15/10	1.0794%	1.5033%	0.4993%
2/4/10	0.9588%	1.3640%	0.4744%
2/15/10	1.2671%	1.4345%	0.8663%
3/4/10	1.1433%	1.5285%	0.7664%
3/15/10	1.2078%	1.7601%	0.6237%
4/4/10	1.0961%	1.3854%	0.7878%
4/15/10	1.2145%	1.6349%	0.7298%
5/4/10	0.9913%	1.4011%	0.5885%
5/15/10	0.8866%	1.1274%	0.6397%
6/4/10	0.9199%	1.3539%	0.4790%
6/15/10	1.2068%	1.7227%	0.6699%
7/4/10	0.7452%	1.0792%	0.3891%
7/15/10	1.0463%	1.5774%	0.4548%
8/4/10	0.9453%	1.3264%	0.5324%
8/15/10	1.0710%	1.4593%	0.6555%
9/4/10	1.0449%	1.4291%	0.6554%
9/15/10	0.9356%	1.3715%	0.4860%
10/4/10	0.8722%	1.2331%	0.4355%
10/15/10	1.0253%	1.4520%	0.5142%
11/4/10	1.1057%	1.6138%	0.5307%
11/15/10	0.9782%	1.2554%	0.6739%
12/4/10	0.8981%	1.1870%	0.5737%
12/15/10	1.1233%	1.7075%	0.5106%

B3. RVHSM 4% VS. RVHSM 100% PERCENTAGE FUEL SAVINGS

Date	Total	West	East
1/4/96	1.1148%	1.4601%	0.7219%
1/15/96	1.2492%	1.7092%	0.7796%
2/4/96	1.0125%	1.4450%	0.5476%
2/15/96	1.3060%	1.6172%	0.9784%
3/4/96	1.1888%	1.3670%	0.9923%
3/15/96	1.3040%	1.7980%	0.7747%
4/4/96	1.2413%	1.4966%	0.9806%
4/15/96	1.3522%	1.7710%	0.8897%
5/4/96	1.1801%	1.6026%	0.7048%
5/15/96	1.0326%	1.3441%	0.6955%
6/4/96	1.0732%	1.4540%	0.6309%
6/15/96	1.3270%	1.8698%	0.7559%
7/4/96	0.9477%	1.3471%	0.5027%
7/15/96	1.3019%	1.8012%	0.7714%
8/4/96	1.2855%	1.6503%	0.9097%
8/15/96	1.2071%	1.5907%	0.8148%
9/4/96	1.1056%	1.4646%	0.7506%
9/15/96	1.0924%	1.5241%	0.6021%
10/4/96	1.0074%	1.3888%	0.5685%
10/15/96	1.1612%	1.6240%	0.6644%
11/4/96	1.2958%	1.8755%	0.6026%
11/15/96	1.0964%	1.3535%	0.8212%
12/4/96	1.1205%	1.4620%	0.7608%
12/15/96	1.2321%	1.7927%	0.6562%
1/4/00	1.0249%	1.3337%	0.6952%
1/15/00	1.1016%	1.6175%	0.5799%
2/4/00	0.9604%	1.3891%	0.5109%
2/15/00	1.2391%	1.5631%	0.9094%
3/4/00	1.1702%	1.4243%	0.8827%
3/15/00	1.2315%	1.7796%	0.6839%
4/4/00	1.2237%	1.5342%	0.8961%
4/15/00	1.3462%	1.8413%	0.8261%
5/4/00	1.1315%	1.4908%	0.7218%
5/15/00	0.9200%	1.1577%	0.6684%
6/4/00	1.0884%	1.5532%	0.5987%
6/15/00	1.3736%	1.9619%	0.7452%
7/4/00	0.9039%	1.2897%	0.4779%
7/15/00	1.2448%	1.6650%	0.7273%
8/4/00	1.2054%	1.5575%	0.8119%
8/15/00	1.1342%	1.4291%	0.7912%
9/4/00	1.1098%	1.4511%	0.7189%
9/15/00	1.0279%	1.4230%	0.5824%
10/4/00	1.0431%	1.4301%	0.5883%
10/15/00	1.0963%	1.5794%	0.5516%
11/4/00	1.1554%	1.6235%	0.6473%
11/15/00	1.1248%	1.4310%	0.7766%
12/4/00	1.1124%	1.4771%	0.7126%
12/15/00	1.1889%	1.6832%	0.6438%
1/4/05	0.9587%	1.2965%	0.6429%
1/15/05	1.1996%	1.6790%	0.6715%
2/4/05	0.9365%	1.2741%	0.5343%
2/15/05	1.2392%	1.5853%	0.8143%
3/4/05	1.1428%	1.4395%	0.8134%
3/15/05	1.2091%	1.8328%	0.6065%
4/4/05	1.2458%	1.6403%	0.8340%
4/15/05	1.2510%	1.6236%	0.8127%
5/4/05	1.0374%	1.4367%	0.6214%
5/15/05	1.0012%	1.3569%	0.6511%
6/4/05	1.0062%	1.4478%	0.5155%
6/15/05	1.2279%	1.7162%	0.7115%
7/4/05	0.8393%	1.2009%	0.4418%
7/15/05	1.1656%	1.6885%	0.6560%
8/4/05	1.1633%	1.4430%	0.8439%
8/15/05	1.0317%	1.3698%	0.7069%
9/4/05	1.1328%	1.5881%	0.6819%
9/15/05	0.9202%	1.2789%	0.5382%
10/4/05	0.9008%	1.1984%	0.5733%
10/15/05	1.0132%	1.4356%	0.5499%
11/4/05	1.1340%	1.5401%	0.6083%
11/15/05	1.0550%	1.3947%	0.6458%
12/4/05	0.9935%	1.2972%	0.6554%
12/15/05	1.1933%	1.7551%	0.6145%
1/4/10	0.9573%	1.2643%	0.6008%
1/15/10	1.1856%	1.6603%	0.5315%
2/4/10	0.9196%	1.2510%	0.5589%
2/15/10	1.1907%	1.4777%	0.8671%
3/4/10	1.1529%	1.5448%	0.7688%
3/15/10	1.2246%	1.7879%	0.6281%
4/4/10	1.0969%	1.4101%	0.7629%
4/15/10	1.1845%	1.5745%	0.7352%
5/4/10	1.0456%	1.4511%	0.6458%
5/15/10	0.8756%	1.0939%	0.6517%
6/4/10	0.9764%	1.4168%	0.5283%
6/15/10	1.2763%	1.8257%	0.7043%
7/4/10	0.8185%	1.1835%	0.4287%
7/15/10	1.1500%	1.6518%	0.5917%
8/4/10	1.1089%	1.4411%	0.7502%
8/15/10	1.0728%	1.4088%	0.7143%
9/4/10	1.1662%	1.6183%	0.7051%
9/15/10	0.9207%	1.3060%	0.5237%

Date	Total	West	East
10/4/10	1.0134%	1.4370%	0.4989%
10/15/10	1.0175%	1.4274%	0.5256%
11/4/10	1.1386%	1.6427%	0.5672%
11/15/10	0.9955%	1.3027%	0.6573%
12/4/10	0.9681%	1.2571%	0.6417%
12/15/10	1.1804%	1.7396%	0.5935%