

HYPOXIA TRAINING AND PILOT USE OF SUPPLEMENTAL OXYGEN ABOVE  
25,000 FEET

by

Christopher Ryan Shaver

A Graduate Capstone Project  
Submitted to the Worldwide Campus  
in Partial Fulfillment of the Requirements of the Degree of  
Master of Aeronautical Science

Embry-Riddle Aeronautical University  
Worldwide Campus  
Colorado Springs Center  
December 2009

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This Graduate Capstone Project  
was prepared under the direction of the candidate's  
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## ACKNOWLEDGMENTS

The author would like to thank his family and colleagues for their continuing and unconditional support of his research and education endeavors.

## ABSTRACT

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Title: Hypoxia Training and Pilot Use of Supplemental Oxygen Above 25,000 Feet

Institution: Embry-Riddle Aeronautical University

Degree: Master of Aeronautical Science

Year: 2009

The Federal Aviation Administration has mandated regulations regarding the use of supplemental oxygen above certain altitudes. Training in the areas of high altitude operations is mandatory and pilots also have the option to receive additional training utilizing an altitude chamber to experience the effects of hypoxia in a carefully controlled environment. Despite all of these measures, there is a general tendency for pilots to forego the use of supplemental oxygen even when it is required. This research explores the attitudes and behaviors of commercial and business aircraft pilots with regards to supplemental oxygen use, and whether or not altitude chamber training (or another type of hypoxia training) influences their decisions.

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## CHAPTER I

### INTRODUCTION

#### Background of the Problem

Since the beginnings of manned flight, the desire to fly aircraft higher and faster than previously done has been the source of continuous progress in the industry. Flying at higher altitudes has many advantages: flying above weather and its associated turbulence, better fuel economy in turbine engines, and use of the jet stream winds for better groundspeed, to name a few. Prior to the invention of the pressurized cabin, aircraft were forced to fly at lower altitudes, or pilots were forced to wear uncomfortable oxygen masks or pressure suits. The Boeing Stratoliner was the first aircraft to utilize a pressurized cabin, allowing it to fly at altitudes of 20,000 feet. Since then, technologies have allowed manufacturers to certify aircraft to fly at altitudes of 50,000 feet or more.

Yet as we ascend into higher levels of the atmosphere, the potential hazards associated with flight increase exponentially. At altitudes above about 10,000 feet, the human body cannot absorb oxygen as easily. Lack of oxygen is the greatest single danger to pilots at high altitudes. The shortage of oxygen in the human body results in a condition called hypoxia, which simply means oxygen starvation. If a pilot takes a breath at high altitudes without the aid of pressurization or supplemental oxygen, there is generally not enough oxygen pressure to force adequate amounts of this vital gas through the membranes of the lungs into the blood stream so that it can be carried to the tissues of the body. The function of various organs, including the brain, are then impaired. For the normal individual, hypoxia does not occur, or at least is rarely detectable, below pressure

altitudes of 10,000 feet. Above 10,000 feet, the effects of hypoxia increase slowly at first, but then intensify rapidly as altitude is increased above approximately 12,000 feet.

Time of useful consciousness (TUC) is defined as the amount of time an individual is able to perform flying duties efficiently in an environment of inadequate oxygen supply. It is the period of time from the interruption of the oxygen supply, or exposure to an oxygen-poor environment, to the time when useful function is lost and the individual is no longer capable of taking proper corrective and protective action. It is not the time to total unconsciousness (Sheffield & Heimbach, 1996). At higher altitudes, the TUC becomes very short. Considering this danger, the emphasis is on prevention rather than treatment (Mohler, 2000). When an aircraft undergoes rapid decompression above around 35,000 feet, the time of useful consciousness for crew members may be 30 seconds or less, depending on the altitude (Table 1).

Table 1

Time of Useful Consciousness

<b>Altitude (feet)</b>	<b>Consciousness</b>
15,000	30 minutes or more
18,000	20-30 minutes
22,000	5-10 minutes
25,000	3-5 minutes
28,000	2.5-3 minutes
30,000	1-3 minutes
35,000	30-60 seconds
40,000	15-20 seconds
45,000	9-15 seconds
50,000	6-9 seconds

*Note.* From Aarons, R. N. (2001). *NTSB: Pilots must don O2 masks now*

[Electronic Version]. Business and Commercial Aviation. Retrieved February 1, 2009 from [www.aviationweek.com](http://www.aviationweek.com).

Crew surprise and perhaps lack of familiarity with decompression can contribute to dangerous delays in appropriate response. Research by the US Air Force shows 80 percent of pilots with no experience of decompression wait as long as 15 seconds to respond correctly to a loss of cabin pressure (George, 1999).

In an effort to prevent the onset of hypoxia, Federal Aviation Regulations (FAR) require that pilots use supplemental oxygen under certain conditions when flying at altitudes above 25,000 feet, and that at least one pilot use supplemental oxygen at all times when flying at altitudes above 41,000 feet.

#### Researcher's Work Setting and Role

The author of this paper is currently a captain on a long-range business jet. He has accumulated over 5,000 hours of flight time in business and commercial aviation. As a

pilot of a turbojet aircraft, the author spends much of his time in flight at altitudes above 30,000 feet.

#### Statement of the Problem

Even though the Federal Aviation Administration (FAA) has in place specific regulations pertaining to the use of supplemental oxygen, it is assumed that pilots may ignore these regulations outside of an emergency situation. The purpose of this research is look at a small sample to provide further hard evidence that points to the prevalence of this issue and the effects of previous hypoxia training on pilots' behaviors and attitudes.

#### Significance of the Problem

Flight at high altitudes poses a distinct threat to pilots in the event of a cabin decompression. A pilot's ability to maneuver the aircraft to a safe altitude after a loss of cabin pressure is the single most important factor in surviving a decompression event. If the TUC at 41,000 feet is just under 10 seconds, and there is a real chance that it might take 15 seconds or more to even begin to react to the situation, the chances of survivability are greatly reduced.

In his roughly 15 years as a pilot, the author has also noted that very few pilots wear oxygen masks when required, which exacerbates the significance of the problem. It is part of this research to determine how widespread negligence toward supplemental oxygen may be among pilots in a broad spectrum of aviation professionals.

#### Limitations

This study is limited to pilots who typically fly at altitudes above 25,000 feet and accident and incident data that relate to "explosive or rapid" decompression. Only accident and incident statistics documented between January 1, 1991, and December 31,

2007, were used in this study. Although there will be significant reference to military research in this study, data concerning military pilots will not be used as a part of the study. This research is also limited by the low number of accidents attributed to explosive decompression events. Pilot responses to survey data may be limited by fears of reprisal, even though surveys were anonymous and confidential.

### Assumptions

It is assumed that the data gathered from the FAA, National Transportation Safety Board (NTSB), National Air and Space Administration (NASA), and military resources are accurate. It is assumed by the author that there is a general lackadaisical attitude regarding use of supplemental oxygen in commercial and private aviation. It is also assumed that respondents will offer truthful responses despite any fears held by these individuals. Offers of anonymity and confidentiality may allay these fears.

### Definition of Terms

Accident – An occurrence associated with the operation of an aircraft, which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers serious injury, or in which the aircraft receives substantial damage.

Decompression – The removal of pressure.

Explosive Decompression – A sudden marked drop in the pressure of a system that occurs in less than 0.1 seconds, associated with explosive violence. Generally it results from some sort of material fatigue or engineering failure, causing a contained system to suddenly vent into the external atmosphere.

Flight Level – An abbreviation of altitude in thousands of feet. Example: FL 350 = 35,000 feet.

Hypoxia – A deficiency in the amount of oxygen delivered to body tissues.

Incident – An occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations.

Mean Sea Level – Altitude above sea level.

Rapid Decompression – A sudden severe expansion of gases due to a reduction in ambient pressure.

Time of Useful Consciousness – The amount of time an individual is able to perform flying duties efficiently in an environment of inadequate oxygen supply.

#### Acronyms

ASRS – Aviation Safety Reporting System

CAR – Canadian Aviation Regulations

CFR – Code of Federal Regulations

EASA – European Aviation Safety Agency

FAA – Federal Aviation Administration

FAR – Federal Aviation Regulation

FL – Flight Level

FSF – Flight Safety Foundation

ICAO – International Civil Aviation Organization

JAR – Joint Aviation Regulations

MSL – Mean Sea Level

NASA – National Aeronautics and Space Administration

NBAA – National Business Aircraft Association

NTSB – National Transportation Safety Board

SOP – Standard Operating Procedure

TUC – Time of Useful Consciousness

CHAPTER II  
REVIEW OF RELEVANT LITERATURE

Federal Aviation Administration

Every time a pilot boards an aircraft for flight, he or she does so at his or her own risk. Despite this assumed risk, the FAA has provided each pilot with rules and guidelines for reducing this assumed risk.

*Code of Federal Regulations*

The Code of Federal Regulations (CFR) addresses legal requirements regarding the use of supplemental oxygen for pilots in the United States. CFR Part 91.211

Supplemental Oxygen specifically states:

No person may operate a civil aircraft of U.S. Registry with a pressurized cabin at altitudes above FL 350 unless one pilot at the controls of the airplane is wearing an oxygen mask that is secured and sealed and that either supplies oxygen at all times or automatically supplies oxygen whenever the cabin pressure altitude of the airplane exceeds 14,000 feet (msl), except that the one pilot need not wear and use an oxygen mask while at or below FL 410 if there are two pilots at the controls and each pilot has a quick-donning type of oxygen mask that can be placed on the face with one hand from the ready position within five seconds, supplying oxygen and properly secured and sealed (FAA, 2009b).

The regulation continues to state that, “If for any reason at any time it is necessary for one pilot to leave the controls of the aircraft when operating at altitudes above FL 350, the remaining pilot at the controls shall put on and use an oxygen mask until the other pilot has returned to that crewmembers station.” Above FL 410, one pilot must always be using supplemental oxygen (FAA, 2009b).

Regulations involving commercial operators are more conservative than CFR Part 91. CFR Part 121 requires that one pilot wear and use supplemental oxygen above FL

350 when the other crewmember is not at the controls and that one pilot continually use supplemental oxygen above FL 350 in aircraft with less than 30 seats, and above FL 410 in aircraft with more than 30 seats (FAA, 2009c). CFR Part 135 for on-demand charter operators requires that pilots use supplemental oxygen above FL 250 when only one pilot is at the controls of the aircraft, and one pilot to continuously use supplemental oxygen above FL 350 (FAA, 2009d).

### International Regulatory Bodies

Other countries around the world provide regulations pertaining to aviation operations within their state or country boundaries. While organizations such as the International Civil Aviation Organization (ICAO) have strived for uniformity in regulations and standards, there are still many differences between agencies. ICAO does provide guidance to its member states with regards to regulatory development, but compliance is often times slow or nonexistent.

With regards to supplemental oxygen use, the ICAO recommendation in Annex 6, Part II states:

4.9 - The pilot-in-command shall ensure that breathing oxygen is available to crewmembers and passengers in sufficient quantities for all flights at such altitudes where a lack of oxygen might result in impairment of the faculties of crewmembers or harmfully affect passengers.

4.10 - All flight crewmembers, when engaged in performing duties essential to the safe operation of an aeroplane in flight, shall use breathing oxygen continuously whenever the circumstances prevail for which its supply has been required in 4.9 (1998).

Each member state of ICAO may use the guidance in Annex 6 to craft their own version of the supplemental oxygen requirements.

The European Aviation Safety Agency (EASA), formerly the Joint Aviation Authorities (JAA), is the centerpiece of a new regulatory system which provides for a

single European market in the aviation industry. All of the European Union states are now regulated by EASA. The regulations regarding supplemental oxygen use for EASA members are currently found in the Joint Aviation Regulations for Operations (JAR-OPS). However, EASA is undertaking a complete redrafting of all the JARs. Still, the current JAR-OPS regulation titled, “1.385 – Use of Supplemental Oxygen” states:

A commander shall ensure that flight crewmembers engaged in performing duties essential to the safe operation of an aeroplane in flight use supplemental oxygen continuously whenever cabin altitude exceeds 10,000 feet for a period in excess of 30 minutes and whenever the cabin altitude exceeds 13,000 feet (2007).

The JARs have no provision for supplemental oxygen use when flying above a certain altitude, only when the cabin altitude exceeds those altitudes stated in the above regulation.

Transport Canada is the agency that oversees and enforces aviation regulations in the Canadian Territories. The Canadian Aviation Regulations (CAR) regarding supplemental oxygen use mirrors both the JAR-OPS and the FARs in the fact that they prescribe limitations on both flight altitude as well as cabin altitude. CAR Part 605.32, Use of Oxygen, states that pilots of pressurized aircraft must use supplemental oxygen any time the cabin altitude exceeds 10,000 feet and also any time that an aircraft is operated at altitudes above 41,000 feet (Transport Canada, 2009).

### Regulatory Oversight

It is important to note that the amount of regulatory oversight that is applied to each of the FAA regulations. Part 91 operators are, for the most part, provided more autonomy in their operations. While there is the possibility of undergoing a spot

inspection, Part 91 operators are almost never subject to having FAA inspectors ride with them in their aircraft. Part 135 operators are slightly more supervised than Part 91 operators in the fact that they have FAA inspectors assigned to their operation who routinely verify that the operator is in compliance with regulatory requirements. Part 135 operators also have employees that are designated by the FAA as check airmen, whose purpose is to provide regular checks of line pilots and help ensure regulatory compliance. Part 121 operators are subject to the highest amount of oversight by the FAA. This is not a surprise considering that commercial airlines transport a large number of people, and any type of accident or incident is highly scrutinized. The FAA routinely provides route checks on Part 121 flights, and also designates check airmen to facilitate regulatory compliance.

#### Pilot Training

All pilots who fly pressurized aircraft that are capable of flight above 25,000 feet must receive training on the effects of hypoxia and emergency descent procedures (FAA, 2003). Most pilots receive some type of emergency descent training each time they receive recurrent training on the aircraft they are flying, which is typically every six months to one year.

Pilots are trained that upon the first detection of a loss of pressurization, they should immediately don an oxygen mask and select 100 percent oxygen flow and, at higher altitudes, select the “emergency” flow of oxygen to ensure a positive flow of oxygen into the mask. Most of today’s oxygen masks automatically provide 100 percent oxygen above a prescribed altitude. Once the oxygen mask is donned, pilots are instructed to then descend as soon as possible to a more suitable altitude.

### *Altitude Chamber Training*

There are no specific requirements in 14 CFR Part 91 or 125 for physiological training. However, in addition to the high-altitude training required by 14 CFR section 61.31(g), which should include the physiological training outlined in this chapter, 14 CFR parts 121 and 135 require flight crewmembers that serve in operations above 25,000 feet to receive training in specified subjects of aviation physiology. None of the requirements include altitude chamber training. The U.S. military services require its flight crewmembers to complete both initial and refresher physiological training, including instruction in basic aviation physiology and altitude chamber training. Other U.S. Government agencies, such as NASA and the FAA, also require their flight personnel who operate pressurized aircraft in the high-altitude flight environment to complete similar training. Although most of the subject material normally covered in physiological training concerns problems associated with reduced atmospheric pressure at high-flight altitudes, other equally important subjects such as fitness, stress, and survival are covered as well (FAA, 2003).

While it is not required, the FAA reports that a pilot's ability to recognize hypoxia can be "greatly improved by experiencing and witnessing the effects of hypoxia during an altitude-chamber 'flight'" (FAA, 2009a). Typical altitude chamber training for civilian pilots includes experience at the 25,000-foot-altitude level, a hypoxia demonstration and a decompression from 8,000 to 18,000 feet in three to five seconds. Military training is more rapid; taking participants from 8,000 to 22,000 feet in 1.5 seconds.

Critics of altitude chamber training for civilian pilots contend that it unnecessarily puts participants at risk of decompression sickness; however, the FAA contends that

among 15,412 participants in altitude chamber training between 1965 and 1992, there were only four occasions of potential decompression sickness. Roughly 1,300 participants cited other ailments, including ear blocks, sinus blocks, tooth problems, abdominal gas, hyperventilation, claustrophobia, apprehension, and pulmonary gas expansion, although none of the reactions were classified as serious (Shaw, 1992).

There are now other options for pilots who want to experience the effects of hypoxia without the risks associated with hypobaric altitude chamber training. Most of the new technologies in hypoxia training are referred to as normobaric hypoxia training devices, meaning that they simulate changes in altitude. The Mayo Clinic has developed a new training device and curriculum designed to prepare pilots for decompression events and the onset of hypoxia. The computer-based, portable Hypoxia Awareness Training System simulates the effects of hypoxia by having pilots breathe a controlled mix of oxygen and nitrogen. During the test, pilots are prompted to respond to commands and carry out tasks while a video camera records their actions. The pilots watch the videos of their actions, training them to recognize symptoms of their fellow crewmembers (McClellan, 2006).

#### NASA's Aviation Safety Reporting System

The Aviation Safety Reporting System (ASRS) receives, processes, and analyzes voluntarily submitted incident reports from pilots, air traffic controllers, dispatchers, flight attendants, maintenance technicians, and others. Reports submitted to ASRS may describe both unsafe occurrences and hazardous situations. Of particular concern for NASA in its use of the ASRS system is the quality of human performance in the aviation system (NASA, 2009).

From 1991 to 2007, a total of 68 “rapid decompression” events involving business jets were found in the NASA ASRS database. Of those 68 reports, 31 were at altitudes between FL 350 and FL 400, 28 were between FL 300 and FL 350, and eight were above FL 400. Pilots cited various problems that were encountered as a result of the decompression event, with almost half citing that they had problems donning the oxygen mask (Veillette, 2009). An additional search of the ASRS database revealed a total of 37 rapid decompression events with Part 121 carriers during the same time frame. There were no reported incidences of explosive decompression during the selected time frame.

#### National Transportation Safety Board

Every year the NTSB investigates hundreds of general aviation and commercial accidents and incidents, both fatal and non-fatal. During the investigation, facts are gathered and a factual report is written by the Investigator-In-Charge. Once the factual report is complete, it is sent to headquarters in Washington D.C., where the five-member board makes a determination as to the probable cause and contributing factors of the accident.

The NTSB has issued many safety recommendations regarding hypoxia, high altitude training, and the use of supplemental oxygen, many of which are in response to their investigation into the October 25, 1999, crash of a Learjet Model 35 airplane near Aberdeen, South Dakota. The following is an excerpt from the NTSB’s safety recommendation list:

- (1) Revise existing guidance and information about high-altitude operations to accurately reflect the time of useful consciousness and rate of performance degradation following decompression and to highlight the effect of hypoxia on an individual’s ability to perform complex tasks in a changing environment and

(2) Incorporate this revised information into both the required general emergency training conducted under 14 Code of Federal Regulations Parts 121 and 135 and training and flight manuals provided to all pilots operating pressurized aircraft.

(3) Convene a multidisciplinary panel of aeromedical and operational specialists to study and submit a report on whether mandatory hypoxia awareness training, such as altitude chamber training, for civilian pilots would benefit safety. The report should consider alternatives to altitude chamber training, clearly identify which pilots and/or flight operations would benefit most from such training, and determine the scope and periodicity of this training. If warranted, establish training requirements based on the findings of this panel.

(4) Require that operators of all pressurized cabin aircraft provide guidance to pilots on the importance of a thorough functional preflight of the oxygen system, including, but not limited to, verification of supply pressure, regulator operation, oxygen flow, mask fit, and communications using mask microphones.

(5) Require that all pressurized aircraft certificated to operate above 25,000 feet have a clear and explicit emergency procedure associated with the onset of the cabin altitude warning that contains instructions for flight crews to don oxygen masks as a first and immediate action item, followed by instructions appropriate to diagnose, manage, and resolve the condition indicated by the warning (2000).

#### Flight Safety Foundation

The Flight Safety Foundation (FSF) is an independent, nonprofit, international organization engaged in research, auditing, education, advocacy, and publishing to improve aviation safety (FSF, n.d.). Often referred to as the “conscience of the industry,” the FSF has contributed significantly to the evolution of aviation safety and the saving of lives. The FSF occupies a unique position among the many organizations that strive to improve flight safety standards and practices throughout the world. Effectiveness in bridging cultural and political differences in the common cause of safety has earned the Foundation worldwide respect (FSF, n.d.). Flight Safety Foundation researchers have published a wealth of materials concerning hypoxia and high altitude operations.

## Summary

While there is ample research, regulation, and training available to pilots with regards to hypoxia and high-altitude cabin decompression, an alarming number of aviators tend to follow the “it will not happen to me” attitude when faced with using supplemental oxygen. Many pilots think that the chance of an explosive decompression is so rare that the risks associated with no oxygen mask at high altitudes outweigh the potential rewards.

## Statement of Hypothesis

During his time as a pilot, the researcher has noticed a general attitude in the industry that the supplemental oxygen regulations are among the least followed regulations in the FARs. This led the researcher to question how widespread the behavior of not using supplemental oxygen is among the pilot population as a whole. The researcher was of the opinion that there is an overall attitude among all pilots toward non-compliance with the regulations regarding supplemental oxygen use outside of an emergency situation. It is hypothesized that Part 91 operators, who see very little inspection or regulation, would be the least likely to follow supplemental oxygen regulations. It is assumed that Part 121 operators would be the most likely to indicate they use supplemental oxygen due to the fact that they undergo the strictest inspection and supervision. Part 135 operators would fall in the middle of the two, since they have slightly more supervision but also have stricter regulations (meaning there is a greater chance of non-compliance). It is also hypothesized that pilots who have undergone altitude chamber training are more likely to use supplemental oxygen as required by

federal regulation. The null hypothesis would indicate that there is no correlation between altitude chamber training and pilot's use of supplemental oxygen.

## CHAPTER III

### METHODOLOGY

#### Research Model

This study employed the quantitative survey method of research. In addition, the researcher conducted a comprehensive study of decompression related accidents and incidents from the NASA ASRS database as well as the NTSB accident database to determine the number and severity of decompression events since 1991.

#### Survey Population

The targeted population of this survey was all pilots who typically fly at altitudes above 25,000 feet. Since it would be difficult to separate out this demographic from the entire population prior to the survey, the researcher opened the survey to the entire pilot population. The cluster method of sampling was then used to distribute the survey to those most likely to fit the demographics of the desired population. Of the 548 total respondents to the survey, 94% were within the desired population.

#### Sources of Data

The sources of data to this study were obtained from the researcher-designed survey, the review of the NASA ASRS data, and a review of data from the NTSB accident database.

#### The Data Collection Device

The researcher designed a cross-sectional survey to gather information for this study. The survey consisted of 12 questions including, demographics, likert-style questions, rating scales, simple yes/no questions, and an open response section. Responses to the survey were first collected through an online survey provider and

separated to show respondents answers based on which regulation they stated was applicable to their operation. That data was then transferred to SPSS where inferential statistics were used to analyze the information.

#### Distribution Method

The survey was distributed via various electronic modes. The researcher obtained permission to post the survey to the National Business Aircraft Association (NBAA) Airmail system, which distributed the survey to various subgroups within the structure. The following subgroups were included in the distribution: safety, business aircraft pilots, flight department managers, and aircraft specific groups. The survey was also distributed by email to various pilots, flight departments, and aviation forums that the researcher was familiar with.

#### Instrument Pretest

The researcher provided the survey to several colleagues for review. The pretest subjects were all pilots who currently operate pressurized aircraft at altitudes which require supplemental oxygen use. After the peer review of the questions, the researcher made the appropriate changes to the survey. All of the changes pertained to phrasing of the survey questions.

#### Procedures

The initial research consisted of a review of the FARs which pertain to each segment of operations that was to be examined. A search of the NASA ASRS database was then conducted to determine the number of decompression events that have been reported since 1991. The initial data from the ASRS database was then filtered to include only events that occurred above 25,000 feet. A survey was constructed to probe pilots'

opinions on supplemental oxygen use and altitude chamber training. The survey was distributed electronically and responses were collected via a web-based survey tool. The data was then extracted to SPSS for further statistical analysis.

#### Treatment of Data

The data were analyzed using the online survey tool and SPSS to obtain basic descriptive statistics. To test the null hypothesis, data regarding altitude chamber training and oxygen use were analyzed with the one sample t-test.

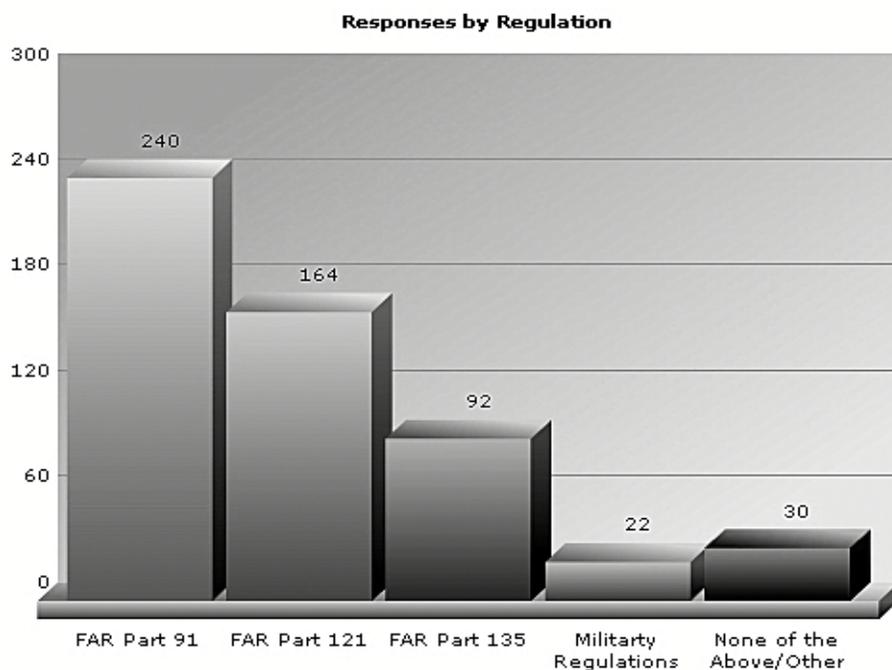
#### Pilot Study

The research conducted for this project shall be considered a pilot study, perhaps leading to a funded design. This study will allow the researcher to refine their research procedures and data collection device while providing invaluable information pertaining to the feasibility of further study on the subject.

## CHAPTER IV

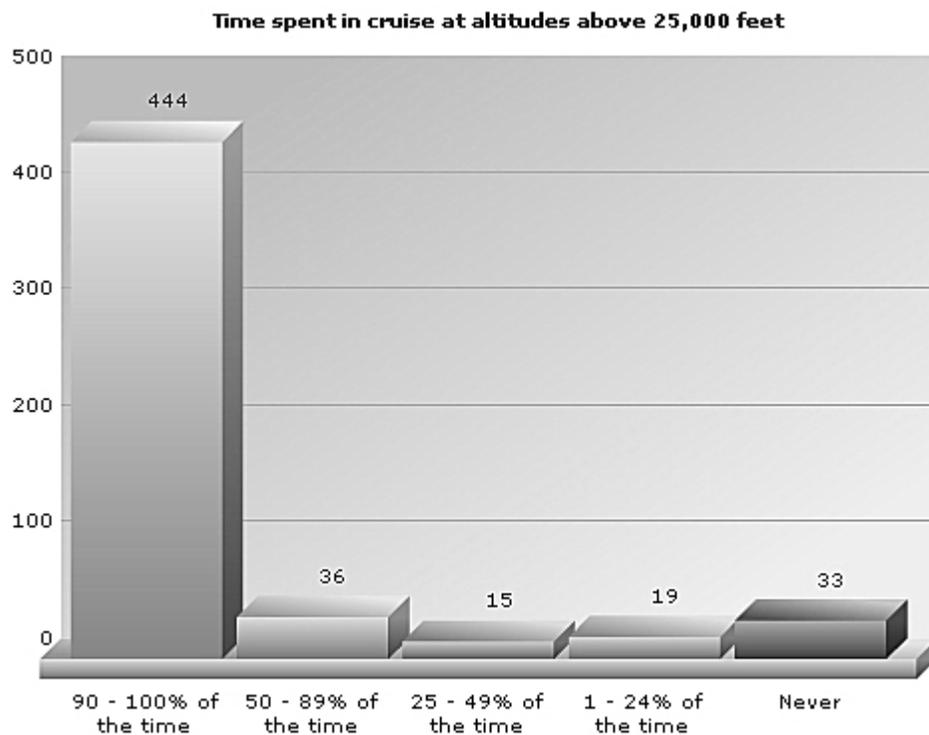
## RESULTS

This chapter includes data obtained through the administration of the survey instrument designed to conduct this study. The purpose of the study was to determine the attitudes and behaviors of pilots with regards to the use of supplemental oxygen during normal operations. A total of 548 pilots responded to the online survey questionnaire. The first question separated respondents into groups depending on which section of the FARs their flights were typically operated under. Of the 548 respondents: 240 typically operated under FAR Part 91; 164 under Part 121; 92 under Part 135; 22 operated under military regulations; and 30 identified themselves as operating under none of the above or other (Figure 1).



*Figure 1.* Total survey responses by regulation.

Question two identified how often the respondent flies above 25,000 feet in normal cruise flight. Five hundred fourteen (93%) respondents indicated that they fly above 25,000 feet at least part of the time, with 444 (81%) respondents indicating they fly at these altitudes 90 to 100% of the time (Figure 2).



*Figure 2.* Time spent in cruise at altitudes above 25,000 feet.

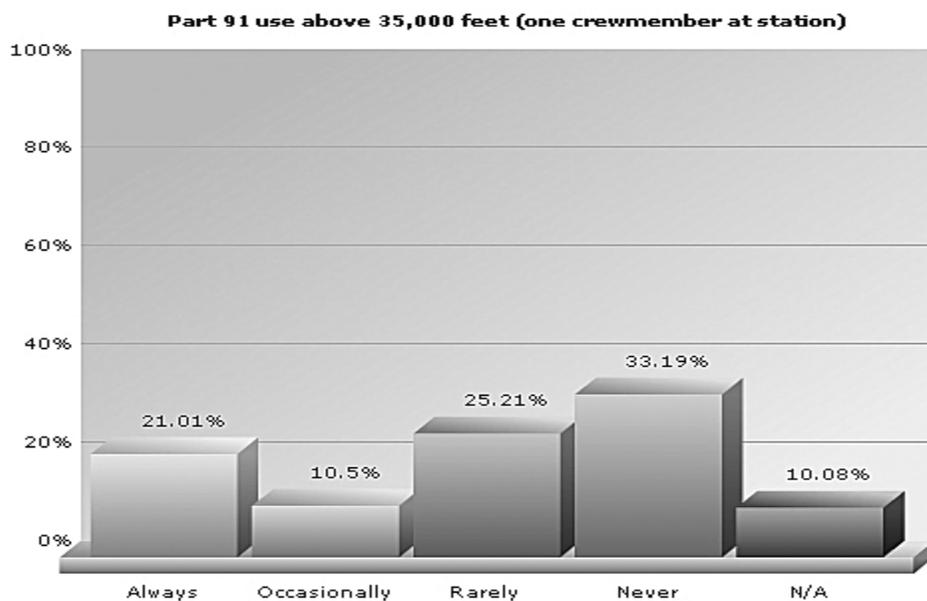
Each of the respondents was asked how often they used supplemental oxygen at the various altitudes prescribed in the regulations that pertained to them.

Figures 3 through 8 illustrate the answers separated by regulation.

#### *Part 91*

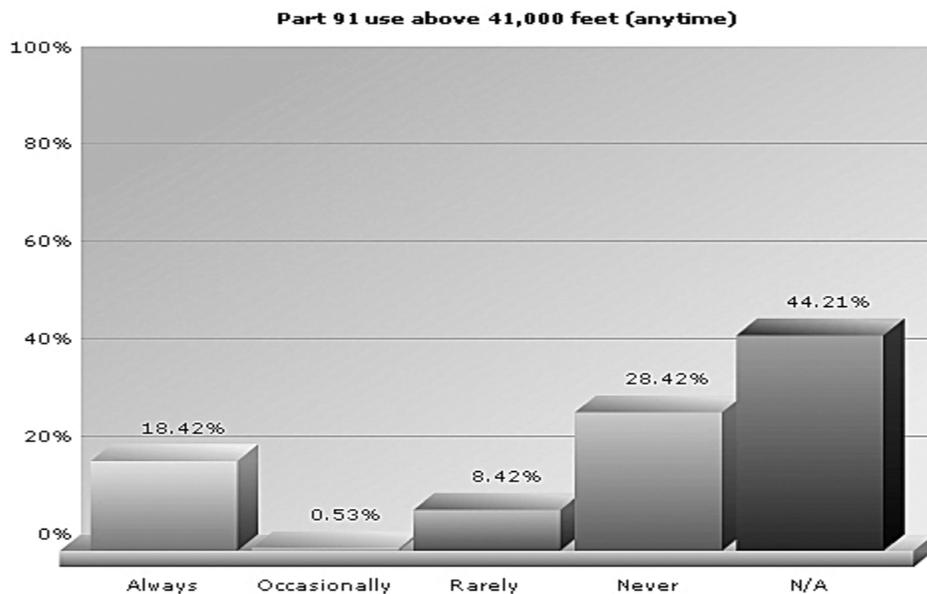
Of the responses from Part 91 pilots: 21% indicated they always use oxygen when one crewmember leaves their duty station above 35,000 feet; 10% occasionally use

oxygen; 25% rarely; and 33% never. Ten percent of respondents reported the question being not applicable to them (Figure 3).



*Figure 3.* Part 91 use of supplemental oxygen above 35,000 feet.

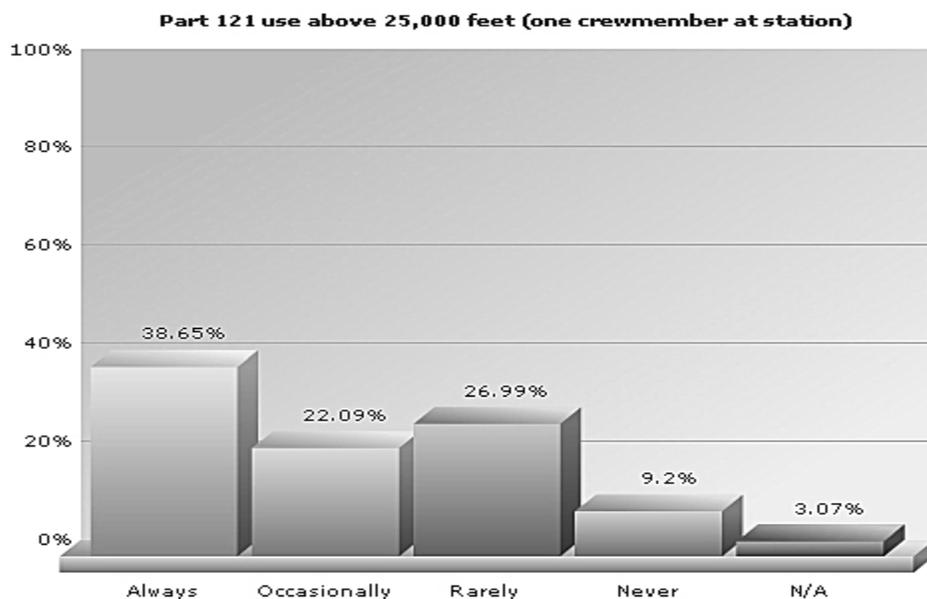
When flying under Part 91 above 41,000 feet: 18% of pilots indicated that they always continuously use supplemental oxygen; less than 1% occasionally use oxygen; 8% rarely use oxygen; 28% never use oxygen; and 44% indicated that the question was not applicable (Figure 4).



*Figure 4.* Part 91 use of supplemental oxygen above 41,000 feet.

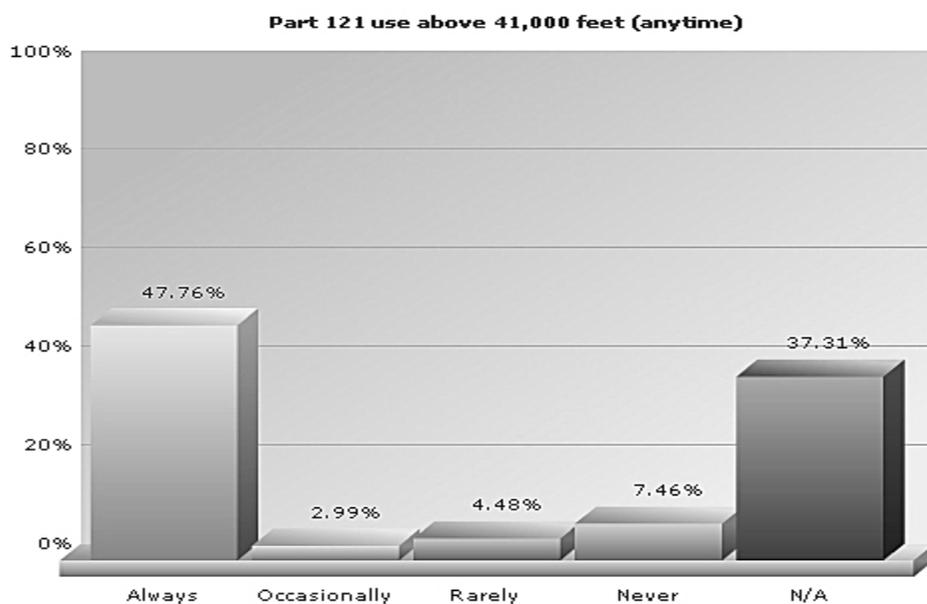
### *Part 121*

Part 121 pilots responded as follows: 39% always use supplemental oxygen when the other crewmember leaves the flight deck above 25,000 feet; 22% occasionally use oxygen; 27% rarely; and 9% never use oxygen. Three percent indicated that the question was not applicable (Figure 5).



*Figure 5.* Part 121 use of supplemental oxygen above 25,000 feet.

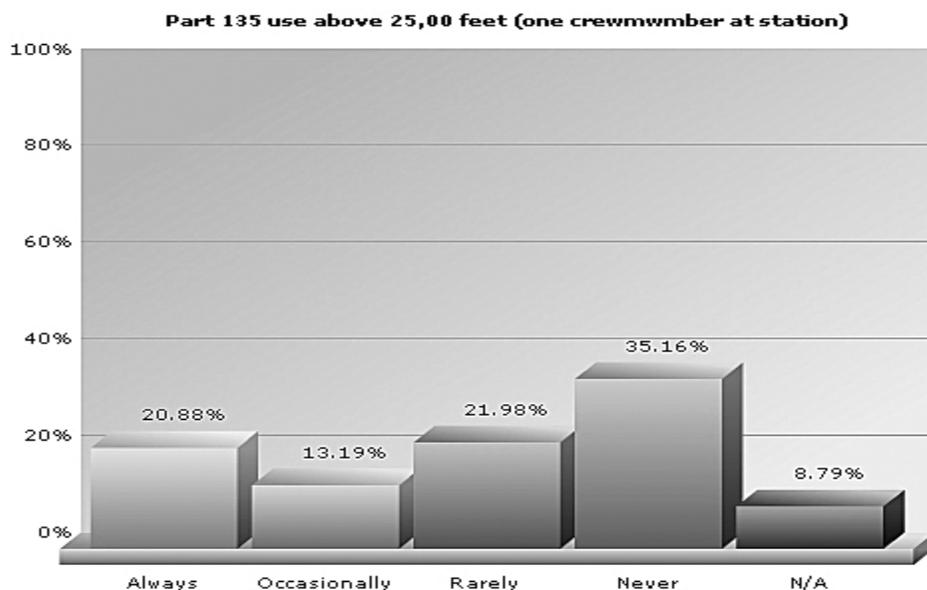
For Part 121 pilots flying above 41,000 feet: 48% of pilots indicate that they always use supplemental oxygen; 3% occasionally; 4% rarely; and 7% never. Thirty-seven percent of respondents indicated the question was not applicable (Figure 6).



*Figure 6.* Part 121 use of supplemental oxygen above 41,000 feet.

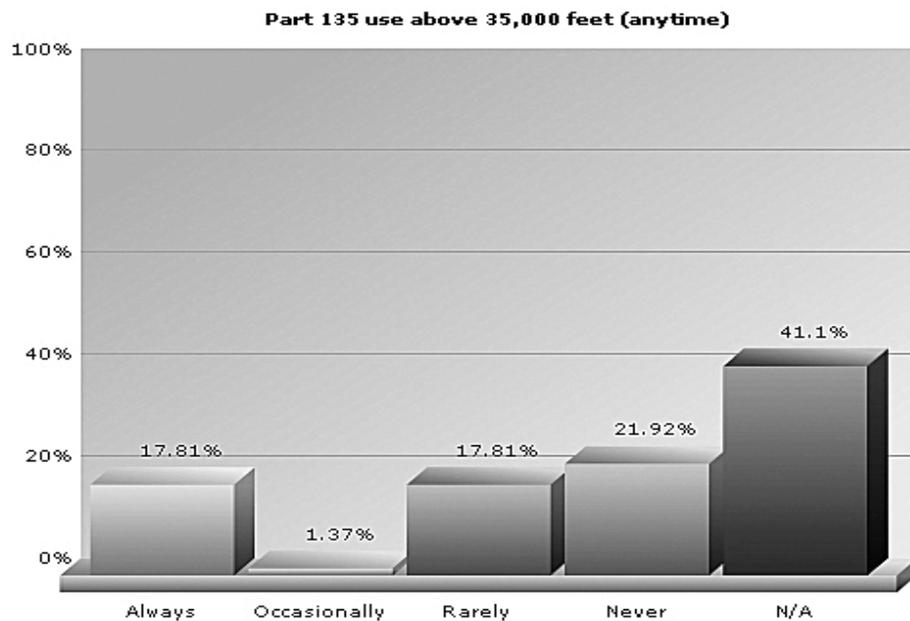
### Part 135

Pilots who typically operate under Part 135 regulations responded that above 25,000 feet: 21% always use supplemental oxygen when only one crewmember is at the controls; 13% occasionally use oxygen; 22% rarely use oxygen; and 35% never use supplemental oxygen. Nine percent of respondents answered that the question was not applicable (Figure 7).



*Figure 7.* Part 135 use of supplemental oxygen above 25,000 feet.

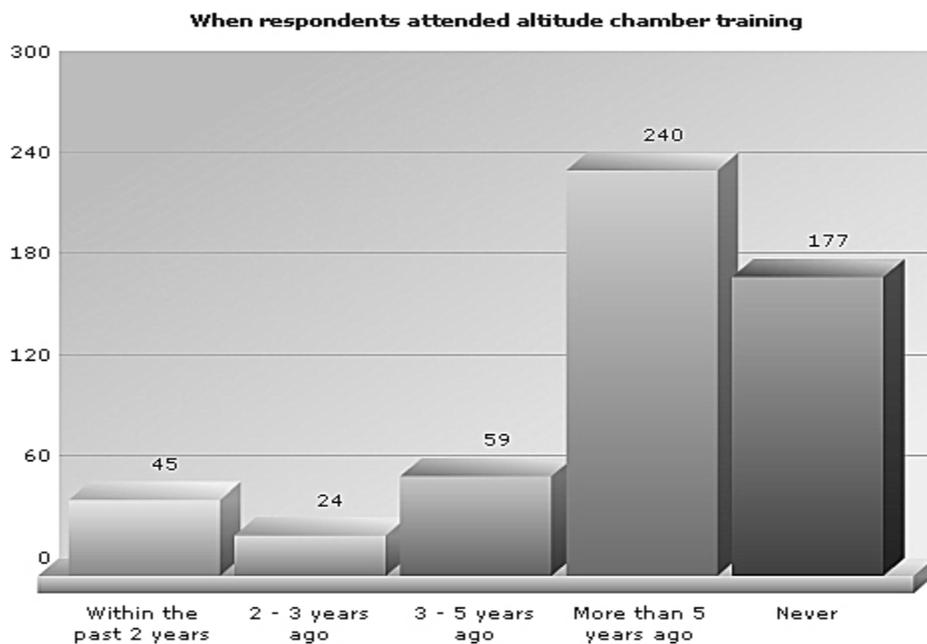
For Part 135 pilots flying above 35,000 feet: 18% responded that they always continuously use supplemental oxygen; 1% occasionally uses supplemental oxygen; 18% rarely use oxygen; and 22% never continuously use supplemental oxygen. Forty-one percent of Part 135 pilots indicated that this question was not applicable (Figure 8).



*Figure 8. Part 135 use of supplemental oxygen above 35,000 feet.*

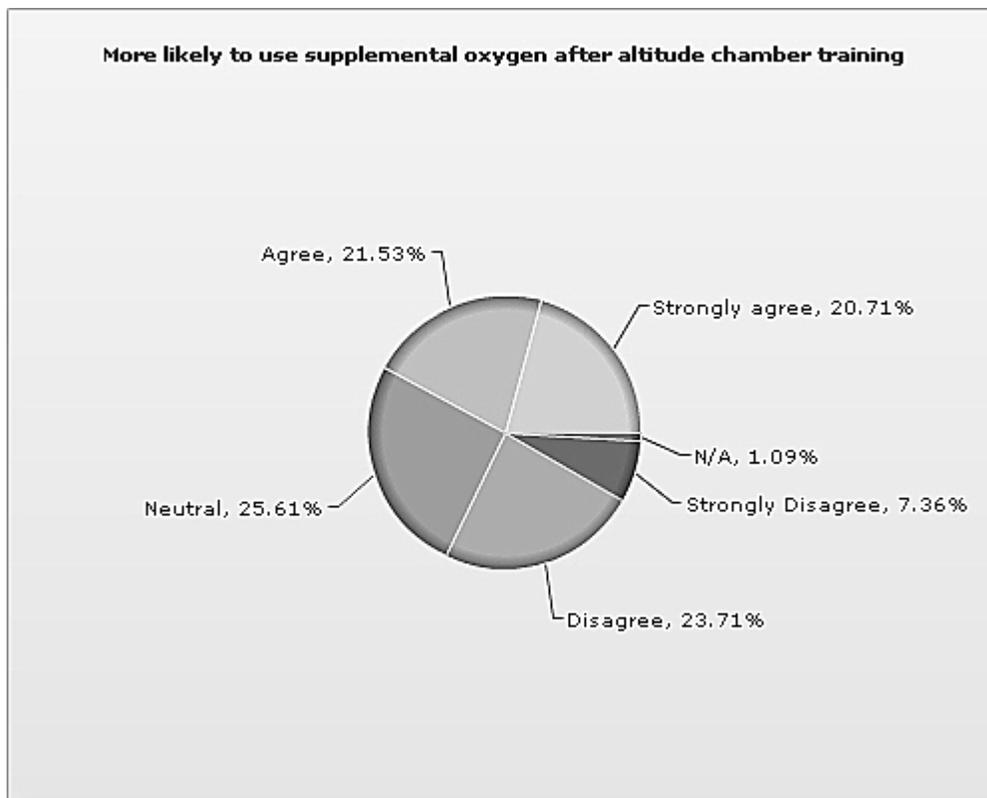
#### *Altitude Chamber Training*

Question six of the online survey asked pilots whether or not they had ever attended altitude chamber training. Of the 545 pilots who responded to the question, 368 had attended altitude chamber training before, and 177 have never attended altitude chamber training (Figure 9).



*Figure 9.* Attendance of altitude chamber training.

The respondents were then asked if they were “more likely to use supplemental oxygen after attending altitude chamber training.” Of the 368 respondents who had attended altitude chamber training: 22% strongly agree with the statement; 21% agree; 26% were neutral; 24% disagree; 7% strongly disagree; and 1% indicated the question was not applicable (Figure 10).



*Figure 10.* Likelihood of using supplemental oxygen after attending altitude chamber training.

The responses of pilots who had attended altitude chamber training were tested against their responses to the statement, “I am more likely to use supplemental oxygen after attending altitude chamber training.” A one sample t-test was used to analyze the data. Pilots who had attended altitude chamber training answered with a mean value of 2.79 to the statement of being more likely to use oxygen afterward (Table 2). This is slightly on the side of agreeing to the question. The t value was calculated as -3.187 with an observed significance value of .002, rejecting the null hypothesis that there is no significant difference in oxygen use with chamber training (Table 3).

Table 2

*One sample statistics*

	N	Mean	Std. Deviation	Std. Error Mean
Attend	368	1.00	.000 <sup>a</sup>	.000
More Likely	367	2.79	1.278	.067

a. t cannot be computed because the standard deviation is 0.

Table 3

*One Sample Test*

	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
More Likely	-3.187	366	.002	-.213	-.34	-.08

As a corollary to the one sample test, an independent samples t-test was also used to test the null hypothesis that there is no significant difference in supplemental oxygen use with attendance of altitude chamber training. The t-value was calculated at -10.622, with an observed significance level of .000. As a result, the null hypothesis was again rejected, indicating that a significant difference does exist (Table 4).

Table 4

*Independent Samples Test*

		<b>Independent Samples Test</b>					
		Levene's Test for Equality of Variances		t-test for Equality of Means			
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
More likely	Equal variances assumed	96.123	.000	-10.622	541	.000	-1.423
	Equal variances not assumed			-9.477	263.993	.000	-1.423

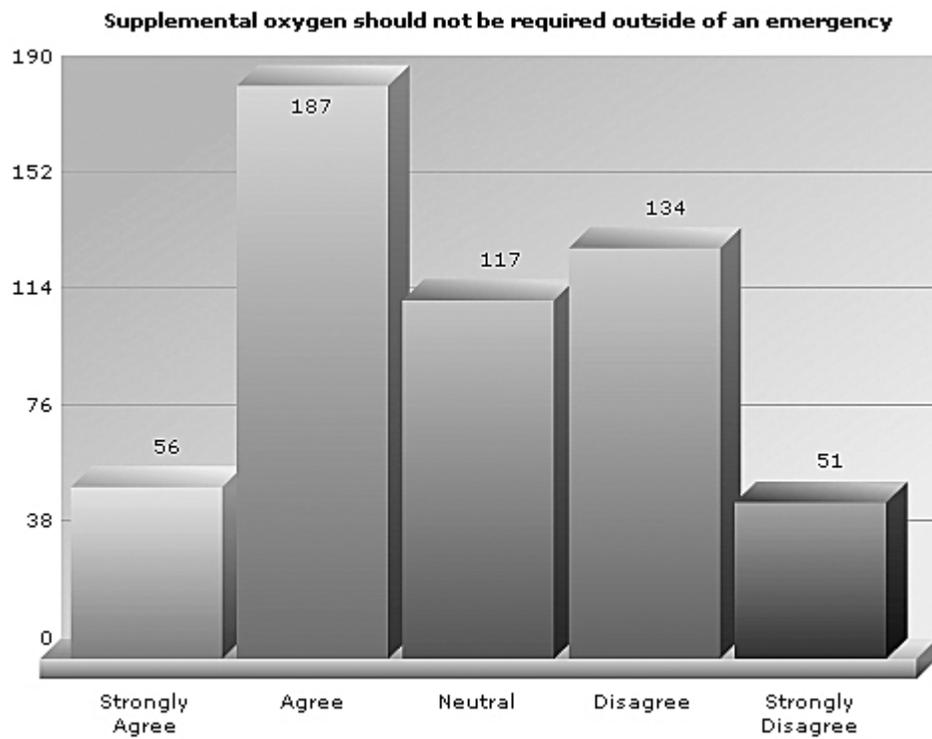
Question eight of the survey asked respondents if they thought that altitude chamber training should be mandatory for all pilots of pressurized aircraft. One hundred seventy-seven pilots (32%) strongly agreed with the statement, 208 pilots (37%) agreed, 90 pilots (16%) answered that they were neutral on the subject, 46 pilots (8%) disagreed, and 24 pilots (4%) strongly disagreed (Figure 11).



*Figure 11.* Attitudes regarding mandatory altitude chamber training.

Survey question nine queried respondents attitudes about other pilots use of supplemental oxygen. After examination of the answers, the researcher felt that this question returned no valuable data, and therefore, the question was omitted from the final analysis.

Survey question 10 asked if the respondents felt that supplemental oxygen should not be used outside of an emergency situation. Fifty six pilots (10%) responded that they strongly agree with the statement, 187 pilots (34%) agreed, 117 pilots (21%) indicated neutrality, 134 pilots (24%) disagreed, and 51 pilots (9%) strongly disagreed (Figure 11).



*Figure 11.* Supplemental oxygen should not be required outside of an emergency.

## CHAPTER V

### DISCUSSION

The purpose of this study was to determine pilots' attitudes and behaviors regarding the use of supplemental oxygen during normal operations above 25,000 feet. The study also assessed pilots' opinions on whether or not altitude chamber training influenced their decisions on supplemental oxygen use.

The participants in this study were 548 pilots selected at random through various electronic sources. The distribution of pilots by regulation in the sample was felt to be representative of the entire pilot population.

#### *Findings*

The findings of the study identified that 64% of all respondents indicated that they occasionally, rarely, or never use supplemental oxygen when the other crewmember leaves their duty station at altitudes above those prescribed by federal regulation, as opposed to 27% who always use oxygen in the same situation. At altitudes where regulations require one crewmember to continuously wear supplemental oxygen, 31% of all respondents indicated that they occasionally, rarely, or never use supplemental oxygen as opposed to 26% who say they always use oxygen. Interestingly, 185 pilots who took the survey failed to answer this question and 41% of respondents who did answer the query indicated that the question was not applicable to them. This is most likely due to the fact that many pilots do not fly aircraft at altitudes where continuous supplemental oxygen use is required. The results still support the researcher's hypothesis that there is an attitude toward non-compliance with the supplemental oxygen regulations.

The findings of the study identified that 68% of Part 91 pilots occasionally, rarely, or never use supplemental oxygen above 35,000 feet when one crewmember leaves their duty station, as compared to 21% of Part 91 pilots who indicate they always use supplemental oxygen in the same situation. Above 41,000 feet, 36% of Part 91 pilots occasionally, rarely, or never use supplemental oxygen, as opposed to 18% who indicate that they always use supplemental oxygen. The remainder of respondents either did not answer the question or indicated that it was not applicable. This data supports the hypothesis that Part 91 pilots are the most likely to forego the regulations on supplemental oxygen use.

The findings of the study found that 58% of Part 121 pilots indicated that they occasionally, rarely, or never use supplemental oxygen above 25,000 feet when one crewmember leaves their duty station, as opposed to 39% who indicate they always use supplemental oxygen in the same situation. Above 41,000 feet, 14% of Part 121 respondents indicated that they occasionally, rarely, or never use supplemental oxygen as opposed to 47% of pilots who indicate they always use supplemental oxygen. A surprisingly low number (67) of Part 121 respondents provided answers to question about supplemental oxygen use above 41,000 feet. This could be due to the fact that there are very few aircraft operating under Part 121 that fly above 41,000 feet. These results support the hypothesis that Part 121 pilots are the most likely to use supplemental oxygen.

With regards to Part 135 operations, the study found that 70% of pilots either occasional, rarely, or never use supplemental oxygen above 25,000 feet when one crewmember leaves their duty station, as opposed to 20% of pilots who indicated they

always use oxygen in the same situation. Above 35,000 feet, 41% of pilots either occasional, rarely, or never use supplemental oxygen, as opposed to 18% of pilots who indicated that they always use supplemental oxygen. Interestingly, 41% of respondents indicated that the question asking about oxygen use above 35,000 feet did not apply. Since many of today's aircraft that are used for on-demand charter service are capable of flying at altitudes well above those prescribed for supplemental oxygen use, the surprisingly high number of "not applicable" responses could be due to chance that the respondents happen to fly aircraft that are not capable of flying above 35,000 feet, or that the pilots of these aircraft choose not to fly the aircraft above these altitudes so they do not have to use supplemental oxygen. These results actually show that Part 135 pilots are slightly less likely to use supplemental oxygen than Part 91 pilots, which is contrary to the researcher's hypothesis that Part 135 pilots would fall somewhere between the other two groups.

It was hypothesized that pilots who had attended altitude chamber training would be more likely to use supplemental oxygen. Using the data from Chapter IV, and assuming a normal distribution, a mean of 2.79 (3 being neutral) with a t-value of -3.187 indicates that pilots who have attended altitude chamber training are slightly more likely to use supplemental oxygen. While this is not necessarily a strong statement, it does demonstrate that altitude chamber training may have an impact on pilot attitudes and ultimately flight safety.

Interestingly, the study found that 70% of pilots feel that altitude chamber training should be mandatory for all pilots of pressurized aircraft. This may indicate that, while

many pilots choose not to use supplemental oxygen, there is an attitude toward safety with regards to a pilot's knowledge of hypoxia and its effects on the individual.

### *Analysis*

There are multiple explanations as to why pilots do not use supplemental oxygen in normal operations. Some of the following explanations were generated from comments in the survey, while others through the author's own experiences in aviation. A first reason is comfort and convenience. The oxygen mask itself is not comfortable, and with some aircraft being capable of 12 or more hours in cruise flight, it would be very difficult to wear a mask for that duration. In addition, oxygen masks make both inter-crew and radio communications difficult.

Secondly, compliance with supplemental oxygen regulations could have a negative effect on an aircraft's efficiency. Since many of today's business aircraft are certified to altitudes above 50,000 feet, for the best efficiency they almost always need to be operated at altitudes that would require one pilot to use supplemental oxygen. This would mean that the oxygen system would need to be serviced after nearly every flight, adding time and expense to the operation. Operators are then faced with the decision of flying at the higher altitudes with supplemental oxygen and absorbing the cost of oxygen service, flying at lower altitudes and absorbing the costs of operating the aircraft less efficiently, or flying at the higher altitudes without using the supplemental oxygen and taking that risk over the costs. Some pilots are also of the opinion that if they use the supplemental oxygen for long periods of time in normal cruise, that there may not be enough oxygen remaining should an emergency situation occur where supplemental oxygen is necessary.

A third reason why pilots may neglect to wear oxygen masks may actually be due to personal health. Prolonged oxygen use has been shown to be harmful to human health.

A study by the FAA (2003) found that:

One hundred percent aviation oxygen can produce toxic symptoms if used for extended periods of time. The symptoms can consist of bronchial cough, fever, vomiting, nervousness, irregular heart beat, and lowered energy. These symptoms appeared on the second day of breathing 90 percent oxygen during controlled experiments. It is unlikely that oxygen would be used long enough to produce the most severe of these symptoms in any aviation incidence. However, prolonged flights at high altitudes using a high concentration of oxygen can produce some symptoms of oxygen poisoning such as infection or bronchial irritation. The sudden supply of pure oxygen following a decompression can often aggravate the symptoms of hypoxia.

As aircraft are manufactured that are capable of more extended flights, the possibility of oxygen toxicity could become a real issue. Additionally, pilots may have personal hygiene concerns, especially in operations where there are multiple pilots using the same aircraft in a short timeframe. Communicable diseases such as influenza are major concerns in today's society. In these types of situations, pilots are not as apt to wear a mask that has been previously used by others unless they took the time to clean and sterilize it for germs, which is not likely to happen.

## CHAPTER VI

### CONCLUSIONS

Federal aviation regulations are in place to protect pilots and passengers while onboard an aircraft. Adherence to these regulations is imperative if we are to maintain the integrity of our safety system. In 2006, the FAA eased the regulations for Part 121 operators regarding supplemental oxygen use, raising the threshold for when only one pilot is at the controls from 25,000 to 35,000 feet (FAA, 2006). This measure indicates that the FAA is cognizant of issues pertaining to supplemental oxygen use, and has taken some steps to decrease the burden of the regulation, at least for Part 121 carriers. Yet the fact still remains that there is a clear trend toward pilots not following the regulations regarding supplemental oxygen use.

It is felt that more pilots would comply with the supplemental oxygen regulations, but are discouraged because of the operational limitations that compliance would impose. Pilots are left with a choice between maximum aircraft performance and the discipline to follow a rule which is difficult to comply with and is routinely ignored by many operators. Issues with the comfort of oxygen masks as well as personal health issues also exacerbate pilots' aversions with wearing oxygen masks unless they feel it is completely necessary.

The chances of having an explosive decompression event at altitude are very low. With proper training, equipment, and exposure, anything less than an explosive decompression, up to rapid decompression, can be managed by immediate donning of an oxygen mask. Modern aircraft have a far superior design when compared to the aircraft of this regulation's era, so much so that the chances of an explosive decompression above

25,000 feet are slim to none. Still, in the rare instance that a rapid decompression should occur, the consequences would be very severe. When safety regulations are not routinely followed because they are antiquated or nearly impossible to achieve, it creates a “laissez faire” dynamic with something that should be taken much more seriously. Because many operators do not follow these regulations, it creates a safety culture that is slightly lax with regard to supplemental oxygen and decompression, regardless of how low the associated risks may be.

Overall, the results of the study point toward the need for a change in FAA regulations regarding supplemental oxygen, or if not a change in regulations, at least a different approach to high altitude training. Pilots are more than willing to take the risks associated with high altitude flight, but many are unwilling to accept the risks of training for the situations which can occur in the high altitude environment, even though there have been very few cases of illness as the result of altitude chamber training. Advances in normobaric hypoxia training have made it possible for pilots to gain all of the benefits of altitude chamber training without the ill side effects. A potential change in regulations, coupled with possibility of incorporating these new devices into the simulators that pilots currently train on, could provide significant benefits to aviation safety.

## CHAPTER VII

### RECOMMENDATIONS

It is recommended that this study be continued in order to obtain more statistically relevant data. The goal of this study was to break the surface and positively identify pilot's behaviors regarding supplemental oxygen use. The researcher feels that this was accomplished. It is the hope of the researcher that this study leads to a more in depth survey of the subject, including incidences of gradual decompression. This study gathered opinions about pilot behavior. A scientific study is recommended to accurately gauge the effects and feasibility of any type of regulatory change or change in mandated training.

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## APPENDIX A

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APPENDIX B  
DATA COLLECTION DEVICE

Fellow Colleagues,

I am currently working on a Graduate Research Project for the completion of a Master of Aeronautical Science degree from Embry-Riddle Aeronautical University. The purpose of this research is to determine whether the current federal regulations regarding the use of supplemental oxygen by flight crewmembers above 25,000 feet in pressurized aircraft are valid in today's environment and whether or not completion of altitude chamber training increases the likelihood of pilots to use supplemental oxygen.

Your assistance in completing this survey will provide invaluable, anonymous data pertinent to this research topic. It is completely voluntary and is applicable to any pilot. There are 13 questions in the survey and it should take approximately 5 minutes to complete. The survey will be open to responses for 15 days from October 20 to November 4, 2009.

Please answer honestly and to the best of your ability. The information collected therein will remain anonymous; please do not include your name anywhere on the form or in the comments area. Responses are submitted electronically to a database, wherein confidentiality is maintained. Findings will be released only as analyzed data or summaries in which no individual's answers can be identified.

For those that are interested, I will make the final results of the survey available to the participants. For any additional information, I can be contacted by email at [cshav6@gmail.com](mailto:cshav6@gmail.com)

Chris Shaver  
Captain, Level (3) Communications LLC  
Graduate Student in Master of Aeronautical Science  
Embry-Riddle Aeronautical University

DIRECTIONS

Please read the following statements below and answer each with the response that is most appropriate to you.

QUESTIONS

1. With regards to supplemental oxygen use, which of the following regulations do your flights typically fall under?

- a) FAR Part 91
- b) FAR Part 135
- c) FAR Part 121
- d) Military regulations
- e) None of the above/other

2. In normal cruise flight, I fly above 25,000 feet:

- a) 90 – 100% of the time
- b) 50 – 89% of the time
- c) 25 – 49% of the time
- d) 1 – 24% of the time
- e) Never

3. Above 25,000 feet (35,000 feet for Part 91) I use supplemental oxygen when the other crewmember leaves their duty station:

- a) Always
- b) Occasionally
- c) Rarely
- d) Never
- e) NA

4. Above 41,000 feet (35,000 feet for Part 135), one crewmember continuously uses supplemental oxygen:

- a) Always
- b) Occasionally
- c) Rarely
- d) Never
- e) NA

5. Have you ever experienced a decompression event at an altitude above 25,000 feet?

- a) Yes
- b) No

6. I have attended altitude chamber training:

- a) Within the past 2 years
- b) 2-3 years ago
- c) 3-5 years ago
- d) More than 5 years ago
- e) Never

7. I am more likely to use supplemental oxygen after attending altitude chamber training.

- a) Strongly Agree
- b) Agree
- c) Neutral
- d) Disagree
- e) Strongly Disagree
- f) NA

8. Altitude chamber training should be mandatory for all pilots of pressurized aircraft.

- a) Strongly Agree
- b) Agree
- c) Neutral
- d) Disagree
- e) Strongly Disagree

9. I recommend that other pilots use supplemental oxygen as a necessary safety practice.

- a) Strongly Agree
- b) Agree
- c) Neutral
- d) Disagree
- e) Strongly Disagree

10. I feel that supplemental oxygen should not be required to be used outside of an emergency situation.

- a) Strongly Agree
- b) Agree
- c) Neutral
- d) Disagree
- e) Strongly Disagree

11. What altitude would you set for mandatory supplemental oxygen use?

- a) I would not set a mandatory altitude for supplemental oxygen use
- b) Above 25,000 feet
- c) Above 35,000 feet
- d) Above 43,000 feet
- e) Above 45,000 feet
- f) I feel the current regulations are appropriate

Additional Comments: