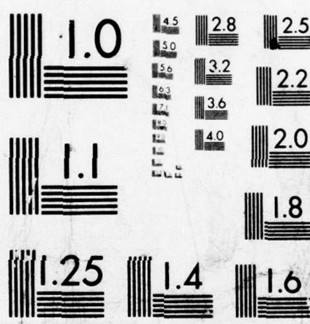
AD-A054 241   SCHOOL OF AEROSPACE MEDICINE BROOKS AFB TEX   F/G 6/16
PRELIMINARY ANALYSIS OF AVAILABLE INFLIGHT RESPIRATORY DATA.(U)
DEC 77 T R MORGAN, F W BAUMGARDNER

UNCLASSIFIED   SAM-TR-77-20   NL

| OF |

AD
A054241

END
DATE
FILMED
6-78
DDC


1.0
4.5
5.0
5.6
6.3
7.1
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

Report SAM-TR-77-20

PRELIMINARY ANALYSIS OF AVAILABLE INFLIGHT RESPIRATORY DATA

Thomas R. Morgan, Captain, USAF, BSC
F. Wesley Baumgardner, Ph.D.
Joseph C. Crigler, Major, USAF, BSC
Donald H. Reid, Commander, USN
Melvin A. Tays, Technical Sergeant, USAF

December 1977

Interim Report for Period January 1976-May 1977

USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

NOTICES

This interim report was submitted by personnel of the Crew Environments Branch, Crew Technology Division, USAF School of Aerospace Medicine, AFSC, Brooks Air Force Base, Texas, under job order 7930-10-15.

This technical report has been reviewed and is approved for publication.

THOMAS R. MORGAN, Captain, USAF, BSC
Project Scientist

WILLIAM J. SEARS, Lt Col, USAF, BSC
Supervisor

ROBERT G. MCIVER
Brigadier General, USAF, MC
Commander

Editor: MARION E. GREEN

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: SAM-TR-77-20 (14)
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): (6) PRELIMINARY ANALYSIS OF AVAILABLE INFLIGHT RESPIRATORY DATA.
5. TYPE OF REPORT & PERIOD COVERED: (9) Interim Report. Jan [redacted]76 - May [redacted]77,
6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): T. R. Morgan, Capt, USAF, BSC; F. W. Baumgardner, Ph.D.; J. C. Crigler, Maj, USAF, BSC; D. H. Reid, Commander, USN; M. A. Tays, TSgt, USAF
8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: USAF School of Aerospace Medicine (VNL), Aerospace Medical Division (AFSC), Brooks Air Force Base, Texas 78235
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62202F, 7930-10-15
11. CONTROLLING OFFICE NAME AND ADDRESS: USAF School of Aerospace Medicine (VNL), Aerospace Medical Division (AFSC), Brooks Air Force Base, Texas 78235
12. REPORT DATE: (11) Dece[redacted]77
13. NUMBER OF PAGES: 7 (12) 11p.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): (10) Thomas R. Morgan, F. Wesley Baumgardner, Joseph C. Crigler, Donald H. Reid, Melvin A. Tays
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited. (16) 7930 (17) 10
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
18. SUPPLEMENTARY NOTES
19. KEY WORDS (Continue on reverse side if necessary and identify by block number):
Respiration
Pulmonary ventilation inflight
20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

Pulmonary ventilation of aircrew members has been measured in 22 missions of C-130, T-38, A-4, F-4, and F-14 aircraft. Data were obtained by means of an in-flight physiologic monitoring device which provides continuous simultaneous recording of expiratory flow, electrocardiograph, cabin pressure, acceleration, voice, and time code signals. This effort is the first wherein it has been possible to continuously track pilot respiratory needs and identify both the extent and frequency of variation from the mean. Although minute ventilations →

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

317 000

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20. ABSTRACT (Continued)

which were measured most frequently occurred in the range of previously published averages, a significant portion of the data exhibited higher levels. These higher levels generally corresponded with the performance of specific flight tasks. It is recommended that future oxygen system design requirements take into account these routinely encountered higher levels of ventilation.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

PRELIMINARY ANALYSIS OF AVAILABLE
INFLIGHT RESPIRATORY DATA

INTRODUCTION

Although an information base has long existed of sufficient size to permit the design of safe and effective oxygen systems (1), relatively little is known of momentary pilot respiratory needs. Present knowledge dates in large part from the 1940's, when data from altitude chamber simulations were used to derive oxygen enrichment or delivery requirements appropriate to the satisfactory execution of representative performance or exercise tasks. Relatively few respiratory measurements have been attempted in actual flight, and most of these have used either low-resolution (calibrated reservoir, pressure-drop) techniques (2, 4) or, if breath-by-breath records were obtained, have required the instrumentation of dedicated test aircraft (3). The former case yields information more reflective of long-term supply requirements than momentary respiratory need, while the latter is restricted to a specific set of experimental conditions.

In an effort to obtain respiratory data from representative operational settings, this laboratory has developed a monitoring device of size and configuration compatible with the broad spectrum of military cockpits. It is presently being used for the inflight assessment of aircrew ventilation requirements, with the purpose of establishing experience-based breathing system design criteria. This report addresses the content of preliminary results, with specific emphasis on pulmonary ventilation requirements and their relationship to oxygen system sizing.

METHOD

The inflight physiological monitor employed was built under contract by SCI Systems Incorporated, Houston, Texas, and is described in previous reports (5). This device provides continuous simultaneous records of expiratory flow, electrocardiograph, cabin pressure, acceleration ($\pm G_z$), voice, and time-code signals. In the present study it was employed in the instrumentation of eight USAF pilots and six Naval aviators; the former provided data from C-130 and T-38 aircraft, while the latter provided data from A-4, F-4, and F-14 sorties. Multiple missions were flown by several, and many missions allowed repetition of critical measurements under similar conditions. In all, data from a total of 22 missions were obtained.

RESULTS

General

Figure 1 depicts the distribution of ventilation requirements obtained by extracting representative data segments from a total of 22 typical military aircraft sorties. The height of each histogram reflects the percent time the sampled population spent in a given ventilation increment. In this example, the most time (18.9%) was spent in the interval from 12-14 l/min, a figure in good agreement with Margaret Jackson's previously published mean of 13.1 l/min (2). However, significant time was spent at higher levels, and these levels frequently corresponded with specific task involvement.

Trends

Task correlation is evident in the representative mission profile of Figure 2. In this example peak needs can be seen to occur in the launch and recovery phases of flight, with only moderate requirements evident in the baseline samples. This trend is evident in the vast majority of our observation: Readings from takeoff, approach, and landing are characteristically higher than those for straight and level flight (5).

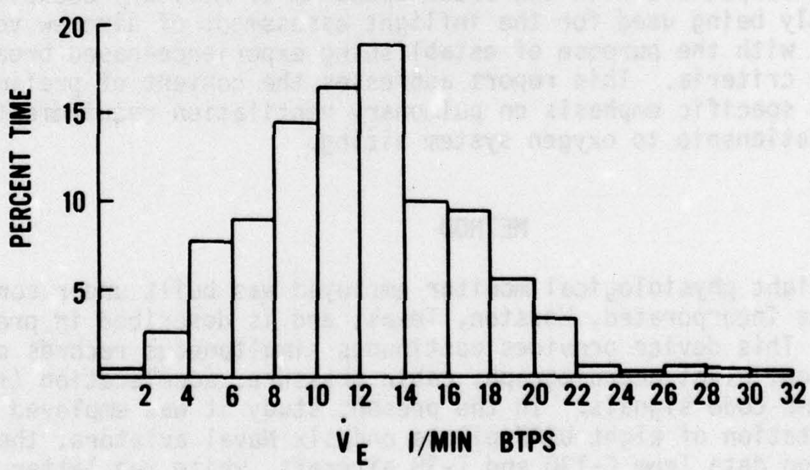


Figure 1. The distribution of pulmonary ventilation requirements derived from pooling all observations, irrespective of aircraft or mission type. The volumes are based on an extrapolation from 30-second averages and include periods of low volumes indicating speech or short periods of breath holding.

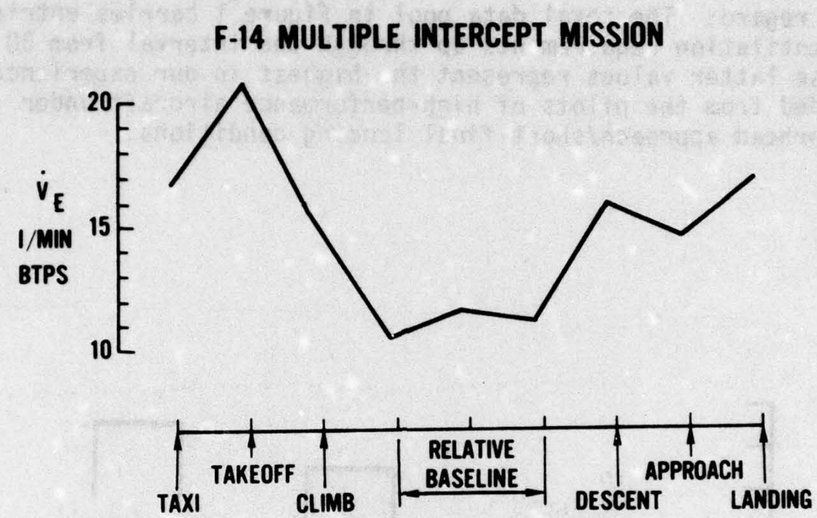


Figure 2. Characteristic mission profile, showing launch/recovery trends. Baseline draws from level flight.

Approach Comparison

Factors controlling the magnitude and duration of these elevations are presently under investigation. One such factor, in the context of approach and landing data, may well be the type of approach flown. Although additional data are necessary, there appears to be an emerging correlation between ventilation requirements and approach type (e.g., whether visual, GCA, or ILS).

Figure 3 compares the average ventilation requirements of five C-130 pilots in a total of 18 landing approaches. In this representation the brackets indicate standard deviation, and superimposed open bars are reflective of the highest rate sustained for 30 seconds or more. Although the data are so variable as to prohibit statement of significant differences between the different categories involved, two facts are evident: First, all averages are higher than previously reported means (12-13 l/min), as well as the dominant 12-14 l/min histogram of Figure 1. Secondly, all approach conditions are associated with brief but substantial demands in the interval from 21 to 23 l/min, a magnitude approaching the previously recommended 95% inclusive design standard of 25.1 l/min (2).

That such levels are encountered during relatively mundane flying activity, as opposed to the combat environment this level was derived to accommodate, should be a matter of concern to all involved with aircraft breathing system design. Further, the C-130 observations of Figure 3 are not unique in this regard: The total data pool in Figure 1 carries entries of sustained ventilation requirements up through the interval from 30 to 32 l/min. These latter values represent the highest in our experience, and were recorded from the pilots of high-performance aircraft under traditional overhead approach/short-final landing conditions.

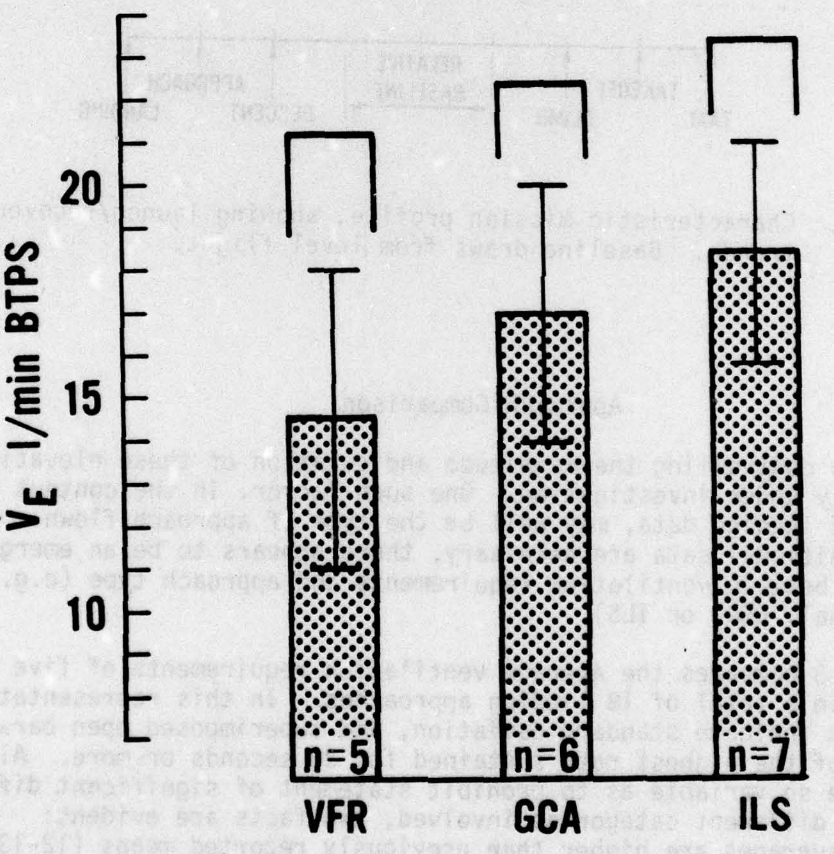


Figure 3. Ventilation requirements evident during the execution of representative landing approaches (C-130 pilots).

Combat Requirements

Actual records of air combat requirements are lacking, but can be inferred from experience with ground-based air combat simulators and recently published RAF data on pilot respiratory requirements in aerobatic flight. As representative of the former case, Figure 4 describes the ventilation needs of a volunteer pilot in a fixed-base air-combat simulator. The trace spans several two-minute engagements during which the subject is engaged in mock combat with an image flown by another pilot in a neighboring simulator. Substantial periods in excess of 25 l/min are evident, even though the individual is in a stationary environment, without the added stress of maneuvering load. Further increases in actual flight are evident from RAF experience with volunteer subjects flying an instrumented Hunter aircraft in standardized aerobatic profiles: In this latter context, ventilation rates in the interval from 50 to 60 l/min are frequently encountered (3). Such an observation is far in excess of the previously described 95% inclusive level and demands consideration in future breathing system design.

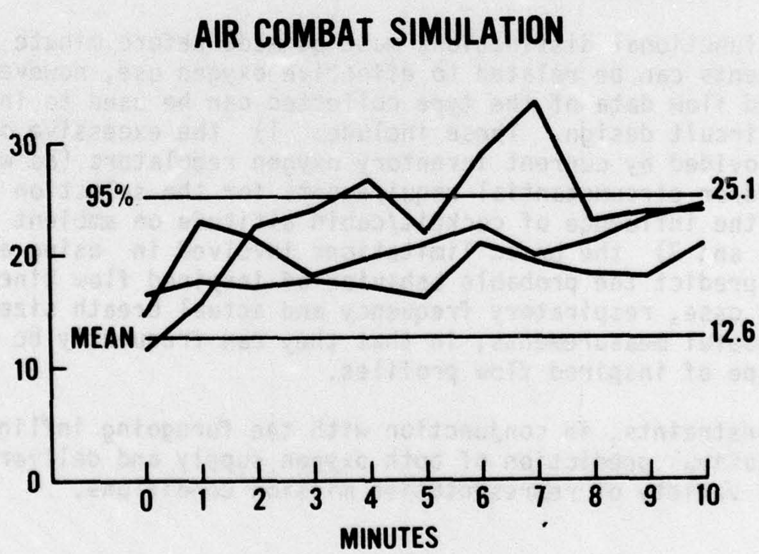


Figure 4. Pulmonary ventilation requirements recorded during a series of 2-minute engagements in a fixed-base air combat simulator. Superimposed threshold lines represent a previously published average (12.6 l/min) and 95% inclusive value (25.1 l/min) respectively.

DISCUSSION

Although ventilation requirements measured in the present study are in close agreement with previously reported averages, this effort is the first wherein it has been possible to continuously track pilot respiratory needs and identify both the extent and frequency of variation from the mean. Preliminary findings indicate that many routinely encountered (but critical) phases of flight are associated with sustained ventilation increases (e.g., takeoff, ACM, approach, and landing). Additionally, many such cases have demonstrated ventilation correlates far in excess of those predicted on the basis of sample variance alone. Predication of oxygen system sizing and regulator design criteria upon average requirements and statistical intervals based on the assumption of a normal distribution about the mean, thus offer the opportunity to underestimate real respiratory requirements, with possible compromise to aircrew effectiveness during the performance of critical tasks. For this reason we favor centering new design requirements about routinely encountered levels of respiratory need (with the ability to accommodate transient increases) to the extent that they are predictable on the basis of mission analysis or discernible by mission-specific inflight physiological monitoring.

Several functional distinctions must be made before minute ventilation measurements can be related to effective oxygen use, however, and before expired flow data of the type collected can be used to influence inspiratory circuit design. These include: 1) the excessive oxygen enrichment provided by current inventory oxygen regulators (as well as procedural and/or circumstantial requirements for the selection of 100% oxygen), 2) the influence of cockpit/cabin altitude on ambient delivery requirements, and 3) the basic limitations involved in using expired flow data to predict the probable behavior of inspired flow kinetics. In the latter case, respiratory frequency and actual breath size (tidal volume) are useful measurements, in that they can frequently be used to infer the shape of inspired flow profiles.

These constraints, in conjunction with the foregoing inflight data, can permit cautious prediction of both oxygen supply and delivery requirements under a variety of representative mission conditions.

RECOMMENDATIONS

1. Center future design requirements about routinely encountered levels of respiratory need (20 to 25 l/min), not manifest averages.

2. Provide the ability to accommodate transient periods of extreme need, up to at least 60 l/min (higher if possible), without inducing wide pressure swings in the mask, and concurrent risk of respiratory fatigue.

3. When new missions and/or aircraft types are considered, conduct inflight pulmonary monitoring to assure that the foregoing references remain valid.

4. Achieve consistent, dependable delivery characteristics, permitting the assumption of a fixed relationship between pulmonary ventilation and oxygen storage or generation requirements.

5. Dimension oxygen stores, generation rates, or accumulator size, to accommodate the measured spectrum of ventilation requirements, as modified by delivery system characteristics expressed above.

REFERENCES

1. Handbook of respiratory physiology. W. M. Boothby (ed.). Air University, USAF School of Aviation Medicine (1954), Randolph AFB, Texas.

2. Jackson, M. M. Usage rates of aircraft oxygen. WADD Technical Report 60-106 (1960), Wright-Patterson AFB, Ohio.

3. MacMillan, A. J. E., G. A. Patrick, and D. R. Root. Inspiratory flow and pulmonary flow in aerobatic flight. Proceedings of the Oxygen Systems Symposium, 16th Meeting of Working Party 61, ASCC, Farnborough, England (In Press).

4. Middleton, R. H. Oxygen utilization with the A/P 22S-2 and A/P 22S-6, high altitude flying outfit. TM ASNMC 70-1 (1970), Wright-Patterson AFB, Ohio.

5. Morgan, T. R. Development of an inflight physiological monitor. Proceedings of the Survival and Flight Equipment (SAFE) Association, 1975.

6. Morgan, T. R., D. H. Reid, and F. W. Baumgardner. Pulmonary ventilation requirements evident in the operation of representative high-performance aircraft. Proceedings of the Aerospace Medical Association, p. 158, 1976.

IED

-78