Original Article

Optical correction in ametropic aircrew

Wg Cdr GKG Prasad, VSM*, Air Mshl Kuldip Rai, AVSM, PHS**, Gp Capt Ranjit Kumar ***
Gp Capt KS Soodan****, Wg Cdr HK Nath+, Wg Cdr TK Mookherjee++, Wg Cdr P Shingal *
** Classified Specialist (Ophthal) AFCME,*
*** DGMS (Air) Air HQ, New Delhi*
****Senior Adviser (Av Med), INM, Bombay*
***** DPMO HQ SWAC, Jodhpur*
+ Classified Specialist (Ophthal) 7 AFH
++ Classified Specialist (Ophthal) IAM, IAF

Optical correction in ametropic aircrew presents some unique problems. The problems are related to the compatibility of spectacles with different mask /helmet combinations used in fighter aircraft, aviation stresses encountered in aviation environment and the visual requirements and working distances in the cockpit. Studies were conducted in regard to problems associated with use of spectacles for flying high speed aircraft, use of modulated power lenses by presbyopic aircrew during flying and use of trifocal lenses by presbyopic aircrew of transport aircraft so as to include viewing of overhead panels in the visual correction. In the first study, tear drop shaped Ray-ban type frame with thin metallic side arms with CR-39 plastic lens was found compatible with most of the mask/helmet combinations used in Indian Air Force. In the second study modulated power lenses were found to give problems like restricted field of vision and increase in head movements due to peripheral distortions. In the third study trifocal lenses were found to be useful in correcting presbyopic aircrew of transport aircraft with overhead panels.

Keywords : Aircrew spectacles, Corrective flying spectacles, Refractive errors, Multifocal lenses.

Flying is a visually intense occupation with visual cues providing approximately 80% of the information needed to fly an aircraft. In the fighter aircraft excellent vision is still regarded as a pilot's greatest asset inspite of the plethora of sensory equipment available in today's modern aircraft [1]. With modern technology presently used in the cockpits with infrared imaging systems, head up displays (HUD) and equipment connected with the electronic warfare, emphasis on the visual requirement of pilots becomes much more important and in ametropic aircrew an appropriate correction with spectacles is imperative. Spectacle correction in ametropic aircrew presents some unique problems. Proper design and well fitting glasses compatible with flying environment is essential, as the pilot is required to wear different flying headgear like helmet and ew

Ranjit Kumar ***
'g Cdr P Shingal *

mels.

acles, Corrective
ractive errors,

lense occupation
es providing
80% of the
n aircraft. In the
vision is still
t asset inspite of
pment available
1]. With modern
in the cockpits
stems, head up
ment connected
emphasis on the
becomes much
etropic aircrew
ith spectacles is
correction in
s some unique
nd well fitting
ng environment
quired to wear
ke helmet and

---

mask combination and are prone to exposure to aviation stresses like hypoxia, rapid decompression, accelerative forces, vibrations, climatic extremes and pressure breathing. Over and above, he is involved in visual tasks such as target detection, reading of staggering number of panel instruments, use of optical aids etc. The presbyopic pilot is required to wear proper glasses, keeping in view his visual requirements of seeing the maps and overhead panels at close distance, the eye level instrument panel at intermediary distance and visual tasks outside the cockpit at far distances [2]. The problems with spectacles include reduced field of vision, fogging of lenses, nasal bridge discomfort, reflections at nights, excessive weight, decentration due to G Force or vibrations and hot spots underneath the helmet.

The visual standards of pilots followed in Indian defence forces are as listed below:- At initial entry glasses are not permitted for flying pilot duties.For a trained serving pilot of fighter stream relaxation upto uncorrected vision of 6/18 in each eye is permitted provided the vision is correctable to 6/6 and 6/9 with corrective glasses of maximum diopteric power not exceeding ± 3.0 D. However these pilots would be made unfit for flying aircraft where pressure clothing is mandatory. For the trained pilots of transport and helicopter stream, relaxation upto uncorrected vision of 6/36 in each eye is permitted provided the vision is correctable to 6/6 in the better eye and 6/12 in the other eye with corrective glasses of maximum diopteric power not exceeding +/- 3.50D. The pilot is advised to carry an extra pair of glasses while flying [3].

Methods and Results:

Aircrew spectacles of high performance aircraft:

In a study conducted on the fighter aircrew, out of many available frames of different shapes, it was found that tear drop shaped frame of Ray-ban design with thin metallic side arms was compatible with the different mask/ helmet combinations used in various existing fighter aircraft. CR-39 plastic lenses were found more comfortable than the mineral glass lenses by the pilots as they were light and impact resistant. The subjects were exposed to aviation stresses in ground simulators followed by inflight trials. In the human centrifuge when the subjects were exposed to a maximum of +5.5GZ acceleration, no displacement of spectacles was noticed. During positive pressure breathing and rapid decompression the spectacles were displaced upwards due to lift of the oxygen mask. The mask was lifted up for the duration during which all the excess volume of gas was eliminated from the mask. In hot cockpit studies the subjects showed fogging of the spectacle lenses. In the inflight trials, the subjects were asked to note their problems encountered during different flying profiles, on a proforma after the flight sorties. Two pilots reported fogging during taxiing and take off stages in hot and humid weather and one pilot reported limitation to the field of vision while looking through gun sight. The presbyopic pilots complained of blurring of vision at transition line/zone of the executive bifocal lenses [4].

Spectacles for presbyopic aircrew:-

Asthenopia or eye strain for near work is the earliest symptom of a presbyopic. In the aircrew it manifests itself as difficulty in seeing the flight instruments or flight charts in dim illumination or specially under the cockpit lighting at nights due to chromatic aberration. Good clinical knowledge coupled with the working knowledge of the aviator's environment is essential in order to prescribe the presbyopic lenses. Type of aircraft, crew position, size of print and working distances at which the flier is required to see are to be kept in mind in prescribing the lenses as near vision demands and working distances vary with each aircraft.

(a) Modulated power (Varilux - 2) lenses : Twenty presbyopic pilots were given spectacles fitted with modulated power lenses as per their individual power requirement. They were asked to report their remarks on a questionnaire proforma. On ground, 17 pilots reported restricted field of vision, 16 pilots experienced difficulty in judging distances and 3 aircrew reported seeing ghost images. When flying, 17 pilots c/o discomfort with glasses, 16 experienced difficulty in reading overhead panels, 3 pilots reported fogging of glasses. On the whole 16 of them found the lenses unsuitable for flying environment [5].

(b) Trifocal lenses (double `D' or double executive) : In order to benefit the presbyopic aircrew of transport aircraft, to see the overhead panel instruments, trifocal lenses with top and bottom segments catering for close distance and middle segment for far distance were evaluated on 20 pilots of transport stream. While prescribing the near vision correction, amplitude of accommodation, eye position of gaze in the cockpit, sitting height, aircraft seat position and ambient illumination of cockpit lighting system were taken into account. 50% of them found the lenses comfortable and useful and the rest had minor problems were overcome with corrections.

Discussion:

The present policy for selection of defence pilots with no acceptance of optical correction is the most desirable. Some of these emmetropes develop ametropia during their flying career and of course all will become presbyopic as a normal ageing process. The tear drop shaped frame was reasonably compatible with the oxygen mask/helmet combinations existing in Indian Air Force. Some amount of adjustment and reshaping of the frame may be required for frame integration. However the spectacle lenses are not suitable for fighter aircrew who use pressure helmets, and the new visual aids. As the presbyopic pilots reported distortion at the transition zone of bifocal lenses, modulated power lenses with no abrupt line of seperation were studied. However , the modulated power lenses did not suit the majority of the subjects as they could not get adapted to the lenses. The trifocal lenses, double 'D' or double executive lenses were found to be very useful by presbyopic pilots of transport aircraft for all their visual distances including the overhead panels in the cockpit.

References:

1. Michael R Mork, Laurance A Watson 'Prevalence of corrective lens wear in Royal Australian Air Force flight crews. Aviat Space Environ Med, 64(6); 541-5, 1993

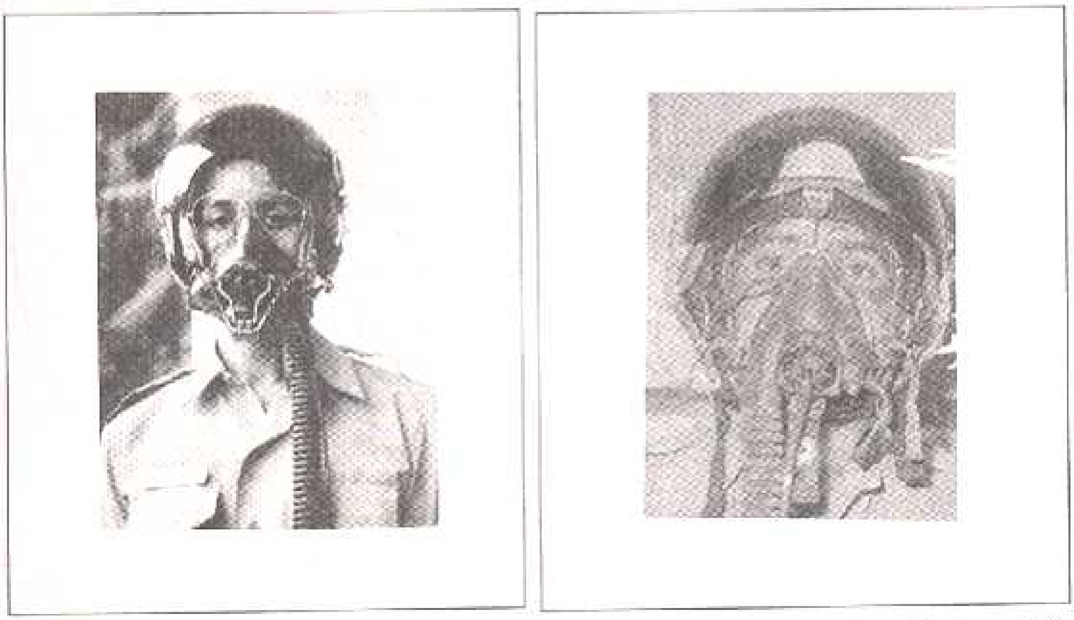
2. Miller RE II, Kent JF, Green RP Jr, 'Prescribing spectacles for aviators : USAF

re taken into
d the lenses
the rest had
rcome with

n of defence
of optical
le. Some of
ropia during
urse all will
mal ageing
frame was
the oxygen
existing in
amount of
frame may
n. However
uitable for
re helmets,
presbyopic
transition
ited power
ration were
ited power
ity of the
adapted to
uble 'D' or
und to be
f transport
distances
ne cockpit.

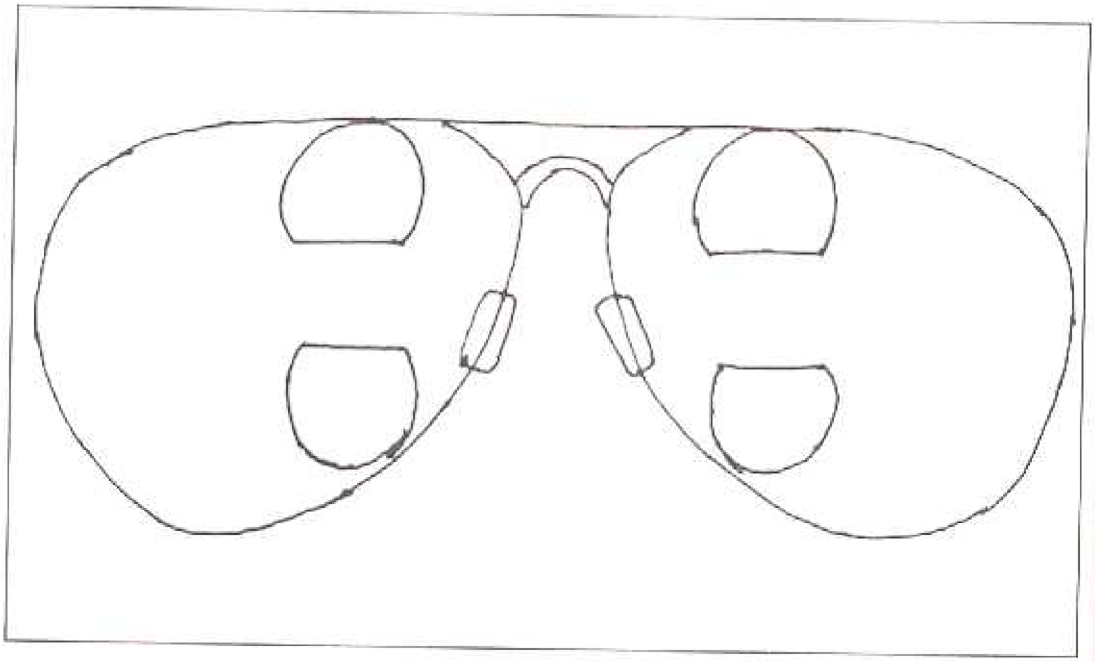
A Watson
r in Royal
ws. Aviat
5, 1993

en RP Jr,
s : USAF

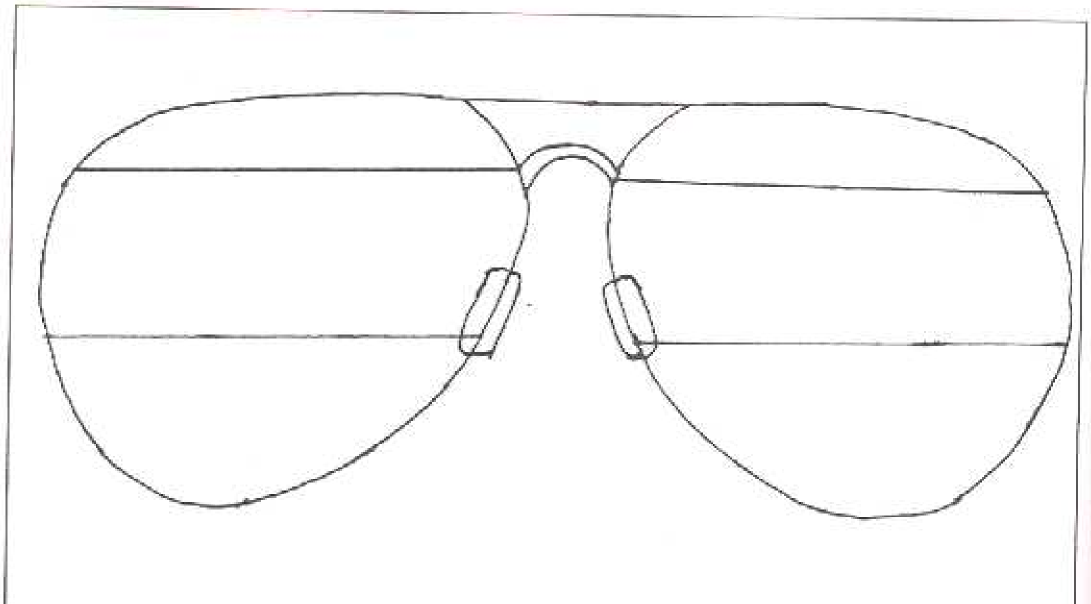


Tear drop shaped frame with P mask and helmet (Lt) and KM-32 mask and helmet (Rt)

Tear drop shaped frame before pressure breathing (Lt) and during pressure breathing (Rt) showing upward displacement.



Trifocal Lens (Double 'D')



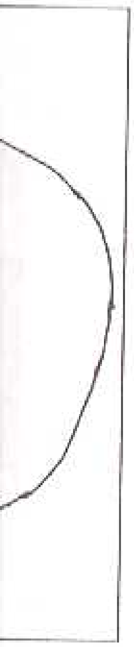
Trifocal Lens (Double executive)

Experi
63;80-5

3. M
Medica
1987.

4. Ku
Mookh
Study c
spectac
AFMR

5. Na
'Study



Experience. Aviat Space Environ Med 63;80-5, 1992.

3. Manual of Medical Examinations and Medical Boards IAP 4303, IInd Edition 1987.

4. Kumar R, Prasad GKG, Baboo NS, Mookherjee T.K, Kuldip Rai, Tyagi P; Study of problems associated with use of spectacles for flying high speed aircraft AFMRC Project No. 1586/86 IAF.

5. Nath HK, Prasad GKG, Soodan KS, 'Study of problems associated with use of modulated power lenses (varilux - 2) by presbyopic aircrew during flying', AFMRC Project No. 1856/91, IAF.

6. Prasad GKG, Shingal P, 'Study of problems associated with use of double 'D' or double executive trifocal lenses by presbyopic aircrew flying aircraft with overhead panels, 'AFMRC Project No. 1969/93, IAF .

tem
raft

h altitude always
it risk of rapid

RD)at altitude is a
can by itself cause
ung damage if the
s exceed the upper
ven if this does not
h sets in after RDC
n incidence of 2-3
ions per 100,000
corded worldwide
nercial operations
oughout the world
) per year has been
idence of RDC
ing even in peace
gher than that in
]. In one study in
pressions above
n a 6 year period
hat affects human
mpression is the
This is dependant
n / area of defect
creased increases
sion and (ii) the
nigh, extends the
eases the severity

---

due to a higher pressure change. The time and severity affect the transthoracic pressure differential which in turn is responsible for the lung damage that can occur. Faster the decompression, higher is the sudden rise in the transthoracic pressure difference and greater is the chance of lung damage. However, it is the final altitude that determines the physiological outcome by causing acute hypobaric hypoxia, and the potential problems of expansion of gases and Decompression Sickness. In a fighter aircraft (it has been estimated that) with a 50 cu ft cockpit and loss of a canopy area of 9 sq ft the time to decompression from 16000 ft to 40000 ft is 0.007 secs [3].

The major causes of inadvertent decompression of military aircraft are flameout (in those with single engines), malfunctions of the pressure control system, failure of transparency and loss of canopy [1]. In combat there is naturally a rise in the incidence of decompression due to enemy guns or missiles.

Physiological effects of RDC

The effects of RD are many and can be conveniently divided into those that occur during RD and those that occur post - RD.

The effects occurring during RD are due to pulmonary overpressure and this can be aggravated by closed airways but more importantly by the presence of a breathing apparatus, especially one which uses a mask with a compensated expiratory valve, and can lead to pulmonary barotrauma. The pulmonary overpressure that falls within the safe limit is now reduced to 50 mm Hg against the value of 80 mm Hg with airways open [3].

Hypoxia occurs due to an extremely rapid fall in PAO$_2$ due to sudden expansion and exit of air from the lungs, possible alteration in the ventilation perfusion ratio and covert lung damage that could be expected to occur. The resultant fall in PAO$_2$ will cause rapid deterioration in performannce and if oxygen is not delivered to the respiratory tract at the earliest, unconsciousness will supervene. The time of useful consciousness is reduced by half, which above 30000 ft at altitude, will only be about 10-15 secs resulting in a rapid loss of consciousness due to Hypoxia [4].RD to above 30000 ft cabin altitude always causes the PA02 to drop below 30 mm Hg. This leads to reversal of oxygen flow through the lungs and causes very severe performance decrement to the highly oxygen dependent and sensitive brain.

From Table 1 we note that whenever RDC ocurs at a cabin altitude of 16,000 ft to a final cabin altitude of 39,000 ft while breathingAIR - OX mixture which contains 40% O$_2$, PAO$_2$ drops to 30 mmHg. Above this cabin altitude, even if the pilot is breathing a linearly rising O$_2$ concentration which will maintain PAO$_2$ at 104 mmHg before RDC, the PAO$_2$ will fall to a lower value than 30 mmHg on RDC. However if 100% O$_2$ is pre breathed, then an altitude 48000 ft can be reached without the PAO$_2$ dropping to below 30 mm Hg. As can be seen from the table, a higher concentration of oxygen ranging from 50% to 78% instead of 44 to 50% normally required to maintain PAO$_2$ of 104 mm Hg is required to ensure that PAO$_2$ does not drop below 30 mm Hg. The overall pressure difference will obviously affect the final PAO$_2$ as also the final pressure. The PAO$_2$ will also be governed by the time of decompression to the extent that faster decompressions do not allow any compensatory mechanisms to develop.

Table I :

Requirements of Oxygen during steady state flying and rapid decompression

Aircraft Altitude (Ft)	Cabin Altitude (Ft)	Pressure Differential (PSI)	Oxygen Concentration in Breathing Gas (%)	Partial pressure of Oxygen (alveolar)	
				Before RDC	After RDC
Ground	0	0	21	104	NA
5000	5000	0	25	104	104
8000	8000	Start of Pressurization	29	104	104
15,000	8000	2.63	29	104	75
20,000	8000	4.17	29	104	57
23,000	8000	5.00	29	104	48
26,000	10000	5	31	104	46
36,000	15000	5	38	104	32
39,000	16000	5	40	104	30
43,000	18000	5	44	104	25
46,000	19000	5	46	104	21
49,000	20000	5	49	104	16
57,000	22000	5	54	104	4

Table : II

Requirements of Oxygen during rapid decompression

Aircraft Altitude	Cabin Altitude	O_2 Conc. to keep PAO_2 at 104mmHg	O_2 Conc to keep PAO_2 above 30mmHg if RDC occurs
39000	16000	40	40
43000	18000	44	50
46000	19000	46	62
57000	22000	54	100% + PPB

It can be seen from table II that with a regulator delivering 50% O_2 at 20,000 ft altitude (the requirement to keep PAO_2 of 104mmHg) the PAO_2 will drop to 16 mm Hg. on a decompression to 41,000 ft. This is equivalent to an RD to 40,000 ft breathing air. The time taken for the PAO_2 to fall to 16 mm Hg is 2 seconds. Luft, Clammann and Alder found that over a wide range of altitudes, the PAO_2 immediately following a 2 second RDC was close to that which was predicted on the assumption that there is no exchange of O_2 between the gas in the alveoli and the blood in the lungs. Hence the importance of giving 100% oxygen within 2 seconds of the onset of RDC [5]. The level of PAO_2 rises slowly on giving 100% oxygen following a RD. It takes 10 seconds to rise to 30 mm Hg and another 20 to 30 seconds to rise to 60 mm Hg - the acceptable PAO_2 - to prevent any serious performance decrement. The time of Useful Consciousness (TUC) is restricted to 12-14 seconds at 40,000 ft [4]. The brain has an oxygen reserve of 6 seconds. Also the blood already oxygenated in the lungs, just prior to RDC, supplies oxygen need to the brain for another 6 seconds (i.e. lung-brain circulation time). Hence performance decrement and loss of useful consciouness occurs only after 10-12 secs. Total LOC will occur after 20 secs after RDC due to oxygen lack in the Brain stem areas, specifically the reticular activating system which subserves consciousness. [2]

Though useful consciousness is maintained upto 10-12 secs, some deterioration of performance occcurs much earlier i.e. at 5-6 seconds [2]. This may be because, when PAO_2 drops below 60 mmHg, production of biogenic amines gets effected. These biogenic amines act as neurotransmitters in the central nervous system and hence essential for normal brain function. Loss of consciousness can be predicted if the area under the PAO_2/ time curve referred to earlier exceeds 140 mm Hg. sec. However a minium time to LOC of 10-15 secs is always available in decompression at 50-52000 ft and above.

At RD, gases in the lungs, mask and hose expand due to the decreased atmospheric pressure obeying Boyle's law.

Table III gives us Lung volumes and Mask and hose volumes, before and after RDC.

From the figures it is seen that : -

(a) Gas expansion in the lungs is influenced by the altitude at which RDC is taking place.

(b) The increase in lung volume is greater during RD occurring at inspiration than expiration.

(c) The increased lung volume will impose a physiological stress on the lung. The total lung capacity is about 5800 ml in an adult male . If final lung volume increases above this value, the lungs will initially over distend and then rupture.

(d) When the pressure difference across the lung exceeds 80 mmHg, lung rupture will take place.

Lung expansion due to increased volume will result in a rapid outflow of gas into the mask cavity, thereby increasing the mask cavity pressure. The gas in the mask before RD also expands on RD which further adds to the mask volume thereby increasing the pressure further.

The volume of gas/ air in the hose cavity increases, it is prevented from entering the mask cavity due to the simultaneous expansion of air/gas in the mask cavity pressures. The net result is an increase in pressure in the the hose cavity. This rise of pressure is transmitted through the compensatory tube to the rear of the expiratory valve. The mask cavity pressure also increases since venting of the air through the expiratory valve is compromised. The increase in mask cavity pressure further produces an obstruction to the outflow of air from the lungs causing over distension and rupture when the trans thoracic pressure differential exceeds 50 mm Hg. Therefore the mask pressure should not exceed 40 mm Hg to prevent lung damage [2,6].

The increase in lung volumes post RD, is dependant on the phase of respiration of the lung at the time of RD; it exceeds the TLC (total lung capacity) in decompressions above 30000 K ft even if the lungs are in expiration at the time of RD. This has been depicted in table III.

Table III

Expansion of gases in lung, mask hose and mask cavity pre and post RD.

Cabin Altitude (Feet) ml	Final Altitide (Feet) ml	Lung Volume (Before RDC)		PostRDC Lung Volume		Mask Volumes Before After RDC		Hose Volumes* Before After RDC	
		Insp ml	Exp ml	Insp ml	Exp ml	RDC ml	ml	ml	ml
10000	26000	2800	2300	5400	4500	125	242	250	484
15000	36000	2800	2300	7000	5800	125	315	250	630
16000	39000	2800	2300	7847	6446	125	350	250	700
18000	44000	2800	2300	9172	7534	125	409	250	818
20000	49000	2800	2300	11232	9226	125	477	250	954

RDC and Expansion of Gases in Lungs & Mask + Hose Assembly

* Hose volume of mask is 125 ml another 125 is for the connecting tubing to the PEC. This may however be variable.

The expected expansion of gas in the mask cavity and hose, calculated for various decompression profiles are presented in TableIII. The expansion of gases in the lung does not pose a problem if free venting of gases is permitted. With the personal breathing equipment interfaced, a trans thoracic pressure differential of more than 50 mm Hg results. As discussed earlier the problem is further aggravated by a rise in mask pressure due to venting and expansion of existing gas in the mask cavity and by the simultaneous rise in the hose cavity pressure which also prevents the compensated expiratory valve from opening. The rise in the volume of air in the mask and hose cavitywill now provide a large reservoir of dilute air which the pilot will breathe immediately - post decompression.

Therefore it can be seen that RD influences O_2 system design considerably. To cater for the expansion of gases we will need to provide a dump valve so that a rise of more than 40 mm Hg is not allowed. Similarly breathing a high O_2 concentration pre RD will prevent the PAO_2 from dropping below 30 mm Hg - a modification required in the regulator. Further the regulator should deliver 100% O_2 within 2 secs of start of RD to obviate any performance decrement and LOC beyond 12 to 14 secs. We have seen that it is within 2 secs that the PAO_2 reaches the nadir and by that time if 100% O_2 is available in the mask, the PAO_2 will rise to a minimum acceptable 30 mm Hg within 10-15 secs and in another 8 secs to 60 mm Hg. This will prevent LOC definitely and severe performance decrement will also be avoided. However, for all this to happen it is vital to deliver 100% oxygen within one breath of 500 ml, as more delay than this will not only increase the time since each breath takes upto 6-8 secs but will also provide additional diluted oxygen to the pilot prolonging the hypoxia [6].

Material and Methods

In order to test the hypothesis of larger volume masks giving higher pressures all the existing masks in use by the IAF were evaluated at IAM finding out the rise in mask pressure during RDC. The various masks in use in the Air Force which have differnet volumes of mask cavity and hoses were connected to a headform and this in turn was connected to a breathing machine. The mask cavity presures were measured from a dedicated port from the mouth cavity of the head form connected to a mercury manometer. Two decompression profiles were used viz. from 8000 ft to 20000 ft and 20000 to 50000 ft. Both RD profiles were completed in 1.6 secs.

Results:–

The results show that : -

(a) The mask cavity pressures did not exceed the upper safe limit of 40 mmHg during RDC from altitudes of 8000 ft to 20000 ft in any mask except the large KM34.

Mask	Mask+ Hose Vol (in ml)	Altitude		Rise in Mask cavity pressure (mmHg)
		before RDC	After RDC	
KM-32	224	(a) 8000	20000	40
		(b) 20000	5000	60
KM-34	237	(a) 8000	20000	45
		(b) 20000	50000	48
Ulmer	192	(a) 8000	20000	38
		(b) 20000	50000	50
ABEU	222	(a) 8000	20000	40
		(b) 16000	40000	50
		(c) 22000	50000	60

(b) Mask cavity pressures exceed 40 mm Hg during RDC from altitude of 20000 ft to 50000 ft in all masks.

(c) Whenever RDC occurs at a cabin presssure exceeding 8000 ft in a 5 PSI differential cabin, the mask pressures will exceed 40mmHg which can potentially cause lung damage due to over distension.

Discussion :

As mentioned earlier, 100% O_2 should start within 2 secs of the ONSET of RD. The intensity of a RD will be greater if

(a) There is a delay in giving 100% O_2.

(b) Final altitude is greater.

The amount of air being inspired with every breath is about 500 ml (Tidal Volume) out of which only 350 ml is actually ventilating the alveoli, the remaining volume occupying the dead space volume.

Immediately after RDC, the first breath taken by pilot comprises

(a) Dead space volume (150 ml)

(b) Volume of air in mask cavity(Table III)

(c) Volume of air in the hose(Table II)

At 49000 ft (Cabin altitude), the volumes are : Dead space volume of 150 ml and a Mask cavity volume of 477ml. (normal - 125 ml) Making a correction for leakage of air which occurs when the mask lifts off the face due to excessive rise in mask cavity pressure on RD, the volume of air would be 150-250 ml (approx). Air/gas in Hose cavity volume is 950 ml (normal - 250ml) The total volume will thus be 1200 ml (approx) (950+250). Even if 100% O_2 is delivered at the onset of RDC, the first 3-4 breaths will thereafter contain diluted air which is already present in the hose, mask cavity and the respiratory tract. The alveoli recieves 100% O_2 at the 3rd or 4th breath (i.e., after 12 to 16 secs) and the brain will get the increased O_2 concentration after another 06 seconds (Lung-Brain circulation time). Thus even if 100% O_2 is delivered immediately (i.e. <2 secs), brain receives it only after 18-22 sec. If brain receives 100% O_2 under ideal conditions after 18-22 secs, and keeping in mind that deterioration of performance occurs in 6-8 secs and loss of consciousness in 10-12 secs, RD would have a disastrous outcome for both the pilot and the aircraft. Hence it is essential that the mask-hose volume is kept to the barest minimum (ideally the volume of expanded air should be below 600 ml after RD).

It should be noted that these time values have been calculated, in the event of a RD occurring at 20000 ft cabin altitude with a 5 PSI presssure differential , to a final cabin altitude of 49000 ft - the worst scenario. RDC occurring at lower altitudes will have lesser time value and a better and more favourable outcome of the event.

Therefore it is important that the different volumes of the mask are kept at the minimum to ensure that 100% O_2 reaches the alveoli earlier. This can be done in two ways.

(a) Introduction of a compensated dump in the hose between mask and regulator. This results in reduction of pressure in the hose cavity, which is transmitted through the compensatory tube to the expiratory valve. Hence the expiratory valve can open and vent out all the gases coming from the lungs. The utility of such a valve can be seen in the KM 34 which is a large mask has a dump valve incorporated in the compensatory tube.

(b) Reduce the hose and mask volume to a minimum by -

(i) Decreasing hose length

(ii) Use of a firm and relatively rigid hose (as in Ulmer mask) rather than a corrugated hose.Such a hose prevents expansion of the gas and promotes venting out into the mask cavity.

(iii) Keeping the hose diameter to the minimum without imposing any resistance to breathing.

This aspect can be seen by the fact that the ulmer mask gives relatively lower pressure changes than the larger volume KM32 and ABEU masks.

Conclusion

RD is a potential emergency in fighter aircraft in modern day flying. It is during RD that the pilot is likely to experience severe and rapid onset of hypoxia. Appropriate modification in oxygen system design can however obviate these imminent threat and need to be carefully evaluated on the design considerations for modern oxygen equipment.

ompensatory tube
nce the expiratory
out all the gases
he utility of such
KM 34 which is
alve incorporated

and mask volume

ose length

n and relatively
isk) rather than a
hose prevents
romotes venting

hose diameter to
imposing any

n by the fact that
elatively lower
larger volume

ency in fighter
ing. It is during
to experience
of hypoxia.
oxygen system
these imminent
fully evaluated
ns for modern

References:

1. Ernsting J Aviation Medicine 2nd edition Butterworths 1988.

2. RB Rayman internal medicine in clinical aviation medicine. Ist advantage Press 1982 P. 56

3 Ernsting J Operational and Physiological requirements for aircraft oxygen systems. In 7th Advanced Operational Aviation Medicine course. Report No. 697, pp 1-1 to 1-10 Neuilly sur Seine: AGARD/NATO 1984.

4. Sheffield JP, Heimbach RD. Respiratory Physiology in Fundamentals of Aerospace Medicine. DeHart 1985, 97

5. Ernsting J, The 10th Annual Harry G Armstrong Lecture. Prevention of Hypoxia acceptable compromises. Aviat Space Environ Med. 49 (3), 495-507, 1978.

6. Ernsting J Pressure breathing in high altitude, agile aircraft. IJASM Vol 38 No. 2 special issue, pp 38-48. 1995.

7. Chatterjee PC, Ranjit Kumar et al. Dynamic Assessment of oxygen regulator under simulated flying clothing conditions and emergencies. AFMRC 885/77.