Analysis of Climatic Data and Cockpit Thermal Conditions at a Fighter Base in North West India

SQN LDR GURUMUKH SINGH*

Abstract

IN the first stage of the study temperature humidity index was analysed at a fighter base in North West India for one year and periods of high thermal stress were identified. In the 2nd stage, serial cockpit air temperatures before taxying out and take off were recorded and total sweat loss in actual operational sorties was found out in winters and summers. This gave mean values of 25.5°C/28.7°C cockpit air temperature with 123 gms total sweat loss in winter and 37.8°C/41.4°C cockpit air temperature with 796 gms total sweat loss in summers.

Introduction

In operational flying, pilots are expected to fly to the maximum capability of the machine. In this man-machine system, machine has undergone vast improvements in its power and aids to flying. These improvements have not made the task of the pilot any easier but on the contrary the system now demands more from the pilot in terms of optimal human performance and acceleration tolerance.

Tropical climate imposes excessive heat load which is particularly severe in ground operations and low level flying[2]. This is due to limitations in cockpit cooling capacity which is based on principles of air cooling through compression and rarefaction. In military aircraft, the necessity of airconditioning for optimal crew performance has to be balanced against its cost in weight and power[2]. These design considerations have prevented evolution of a satisfactory airconditioning system for cockpit thermal comfort during taxying and low level flying. These days military aircraft have to fly low to avoid radar detection and this operational necessity has further highlighted the problems of excessive heat stress.

The present study deals with thermal comfort in operational flying in Mig 21 aircraft. This aircraft is provided with bubble canopy which improves the outside vision at the cost of causing excessive radiant heat load (Green house effect).

This study has been carried out in two parts as follows:

Part I: Analysis of climatic data at the base.
Part II: Measurement of thermal stress in the cockpit.

PART I: ANALYSIS OF CLIMATIC DATA AT THE BASE

Material and Methods

Annual variation of temperature and humidity at the base was analysed. Thompson and O'Brien[3] have published a nomogram (Fig. 1) for calculation of temperature humidity (TH) index from the values of given temperature and corresponding relative humidity (RH). This nomogram was used for finding out annual variation of temperature humidity index.

The meteorological data of this base pertaining to the period July 77 to Jun 78 were procured. These included the temperature and RH record for every 3 hours for all these days. Daily maximum and minimum temperatures with the corresponding relative humidity were noted for the entire 365 days. These values were then converted into the TH index with the help of the nomogram discussed above. Thus we had maximum TH index, minimum TH index and also the maximum and minimum temperatures for each day throughout the year.

* Squadron Medical Officer, No. 7 Squadron, Air Force C/o 56 APO

These values were plotted in a graphical form against the respective dates. In order to present a concise graphical record, only the data of every third day were taken and plotted.

Results and Discussion

Fig 1 shows the graphical representation of the data in which the left hand side scale in 'Y' axis shows the TH index, while the right hand side scale gives the dry air temperature in degree centigrade. The scale was so selected that the value of 35°C temperature coincides with TH index value of 80. Values of TH index below 55 and the air temperature below 20°C were not plotted resulting in discontinuous graphical presentation.

Nunneley and James[1] in their report on cockpit thermal conditions and crew skin temperature state "Because of highly effective insulation of crew clothing and equipment, relatively low air temperatures were required to produce thermo neutrality. Even when light clothing is worn, a huge portion of body cannot dissipate heat because of close contact with seat or coverage by helmet, visor and mask". This implies that cockpit thermal condition is such that effective humidity in the micro-environment around the pilot is always higher than corresponding ambient humidity. In flight, steady state cockpit temperature rises with each increase in speed or decrease in altitude. Due to these factors cockpit thermal conditions can be expected to be closely related to ground level ambient conditions particularly in low level, high speed sorties.

A comparative analysis between air temperature and TH index from Jul 77 to Jun 78 for this base reveals the following (Fig 1 – Hatched area shows the drift between max TH index and max. air temp.) :

In July, August and September, there was a wide drift between maximum air temperature and TH index. The maximum air temperature was always below 35°C while the TH index was always above 80 and mostly around 85. In these three months even the minimum TH index was in the region of 75, while minimum temperature was around 25°C.

In April, maximum air temperature exceeded 35°C on two occasions and TH index exceeded the value of 80 just once, but on a different day.

In May, maximum air temperature was always above 40°C whereas maximum TH index showed little fluctuation beyond the value of 80.

In June, maximum air temperature had started falling below 40°C but TH index value was fluctuating around 85. On one day during June, the TH index attained a peak value of 94.

From the above analysis it is clear that air temperature exhibits a marked disproportionate and non-synchronous deviation from TH index which is an accepted criterion for the evaluation of thermal comfort. As such air temperature alone cannot be accepted as reliable criterion for determining zone of thermal comfort.

PART II : THERMAL STRESS AND STRAIN IN COCKPIT

Material and Methods

Cockpit air temperature and total sweat loss was recorded in actual operational sorties. The cockpit air temperatures were recorded by the pilots, using pen type alcohol thermometers with a range of 20°F to 120°F and graduations of 2°F. These thermometers have a lag period of 15–20 secs. The cockpit temperatures were recorded immediately after strapping up in the cockpit. The aircraft was taxied with the canopy closed and it took about 10 min. to reach the take off point. The second temperature reading was taken at the take off point. An accurate weighing machine was used for recording nude body weight of pilots before and after an operational sortie. The weighing machine had a sensitive arm and gave an accuracy upto 50 gms. The pilots were weighed with underwear on, just before the sortie and immediately after completion of the sortie. The average duration of all the sorties was 35-40 min.

The pilots travelled in an aircrew van from the crew room to the aircraft and back. Subjects were studied for three sorties each in winter (Jan 78) and summer (May 78). The January sorties were mostly combat sorties in the afternoon block between 1400 hrs to 1600 hrs. The May sorties were also the last sorties of the day which was between 1000 hrs to 1100 hrs due to local restriction of flying whenever ambient air temperature exceeded 38°C. These were all range sorties with medium and low level profile.

Five healthy Ops Under Training pilots in the age group of 23 to 32 yrs, picked up randomly, were

FIG. 1 ANNUAL VARIATION OF TEMP HUMIDITY INDEX AT THE BASE FROM JUL 77 TO JUN 78 WITH THE NOMOGRAM (INSET)

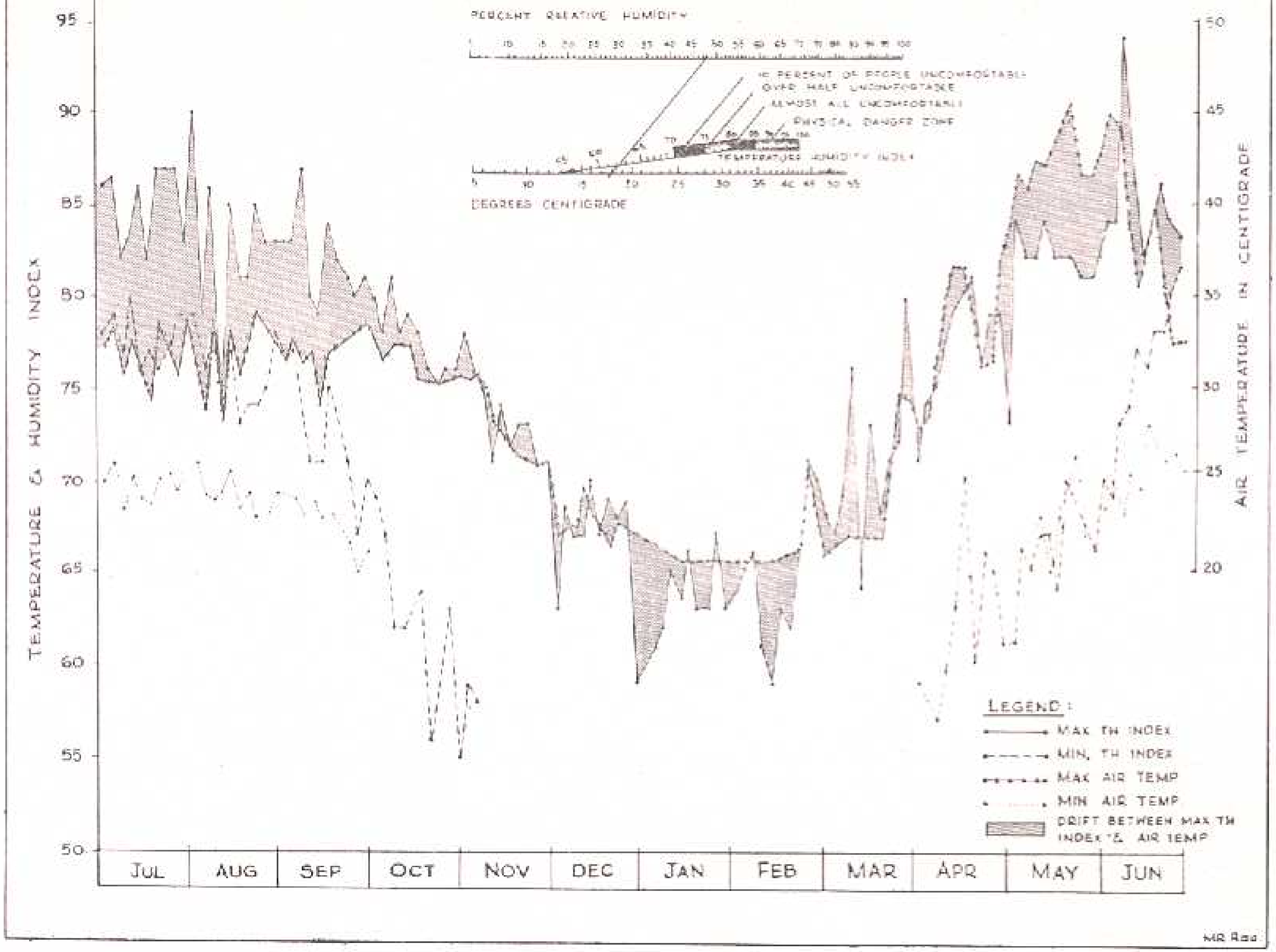

TABLE II

Cockpit air temperature at taxying out, and take off. Total sweat loss of pilots during actual operational sorties in winters and summers

	WINTER (JANUARY 1978)						SUMMER (MAY 1978)					
	Cockpit Air Temp °F				Total sweat loss (gms)		Cockpit Air Temp °F				Total sweat loss (gms)	
Subject	Taxying out	Take off	Rise	Average Rise	Individual sortie	Average	Taxying out	Take off	Rise	Average Rise	Individual sortie	Average
	81	91	10		100		98	110	12		400	
BS	82	88	6	7.3	50	83	96	108	12	11.3	900	700
	86	92	6		100		100	110	10		800	
	73	79	6		100		101	110	9		950	
YD	77	80	3	5.0	150	117	102	108	6	6.3	1050	1000
	76	82	6		100		98	102	4		1000	
	82	85	3		100		98	102	4		600	
AK	78	83	5	3.7	150	117	98	104	6	4.7	450	583
	80	83	3		100		102	106	4		700	
	80	84	4		100		100	108	8		900	
JS	76	83	7	6.7	200	133	102	106	4	6.3	800	833
	74	83	9		100		99	106	7		800	
	72	79	7		150		101	106	5		1000	
GS	64	70	6	6.0	100	166	102	106	4	4.0	750	866
	78	83	5		250		102	105	3		850	
Mean	78°F or 25.5°C	83.7°F or 28.7°C		5.7°F or 3.2°C		123	100°F or 37.8°C	106.5°F or 41.4°C		6.5°F or 3.6°C		796
Range	64°F to 86°F	70°F to 92°F	3°F to 10°F		50 to 250		96°F to 102°F	102°F to 110°F	3°F to 12°F		450 to 1050	

the subjects of this study. Their physical characteristics viz. age, height, weight and body surface area are given in table I.

TABLE I

Physical characteristics of subjects in Part II of the study

Subject	Age (Years)	Height (Cms)	Weight (Kgs)	Body Surface Area* (m^2)
BS	25.5	187.5	75	1.84
YD	23.0	168.5	56	1.50
AK	24.5	174.0	66	1.65
JS	23.0	177.0	69	1.70
GS	32.0	176.0	70	1.70
Mean	25.6	176.6	67.6	1.68
Range	23–32	168.5–187.5	56–75	1.50–1.84

* From Dubois Nomogram.

Results and Discussion

Values of cockpit air temperature and total sweat loss along with their mean and range are given separately for individual sorties and subjects in Table II.

The mean cockpit air temperature in winter was 25.5°C and it increased by 3.2°C during taxying. In summer, the mean value of cockpit air temperature was 37.8°C which increased by 3.6°C during taxying. These increases in the cockpit temperature during taxying were found to be relatively less in the present study compared to that reported by Nunneley and James[2] who observed a sharp rise in cockpit dry bulb temperature (t_{DB}), as much as 60°C, until take off, when the ambient temperature on the ground was 35° — 40°C. The taxying time in their study was 15 min.

In the present study, the mean sweat loss values were found to be 123 gms and 796 gms in winter and summer respectively. In our earlier study[1] in the "Simulated Hot Cockpit" the mean sweat loss value for subjects, exposed to 59°C t_{DB} with 55% relative humidity for a duration of 30 min, was found to be 380 gms.

The comparative analysis of the sweat loss values reported in the above study[1] vis a vis the present study reflects the severity of thermal strain that accrues in our pilots during hot weather flying in our climate. The contrast between the mean sweat loss values in the winter and the summer shows the differences caused by the seasonal variation.

Recommendations

TH index could be taken as a criterion of cockpit thermal comfort for strenuous sorties like combat, low level and range. TH index above 75 should be taken as relatively uncomfortable and above 80 as absolutely uncomfortable.

It is recommended that an extensive study be conducted with the help of electronic instrumentation to record t_{DB}, t_{WB}, t_{GT}, and air movement in various phases of flight.

It should be ensured that crew arrive cool and well hydrated to the cockpit by providing effective air conditioning of crew rooms, briefing room and also giving adequate replacement fluids in the form of fresh fruit juice for making up fluid and salt loss due to excessive sweating in operational sorties.

Measures for micro-environmental thermal comfort could be adopted to improve functional efficiency of pilots.

Acknowledgement

I am indebted to Wg Cdr VK Verma, Officer Commanding and the aircrew of the Squadron who actively participated in this project. My thanks are due to Flt Lt Rameni who gave most willing cooperation in working out analysis of weather data at the base.

References

1. Gurmukh Singh, RR Kapur and CA Verghese. Liquid cooling for thermal protection applied studies. Course project report IAM 16/17.

2. Nunneley SA and GR James. Cockpit thermal condition and crew skin temperature measured in flight. Avia. Space Environ Med 48 : 44-47, 1977.

3. Thompson PD and R O'Brien. Life science library "Weather". Time Life International. Netherland, p 84, 1968.