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Incidence of Low Clouds at Bombay airport (Santacruz) with reference to Jet landings with the help of the Instrument Landing System (ILS)

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ABSTRACT. Santacruz airport constitutes a high traffic density area, with a substantial number of jet aircraft movements. Aviation hazards at this airport get particularly accentuated during the monsoon season on account of the occurrence of very low clouds, strong gusty winds and poor visibility conditions in mist or haze, or showers. There are a few important hill features around the airport, not far from the landing area.

The airport is equipped with standard radio navigational aids, namely, very high frequency omnidirectional range (VOR), Instrument Landing System (ILS), the Aerodrome Surveillance Radar (ASR). A precision approach radar (PAR) will become operational at this airport shortly. On the ILS the glide path angle has recently been reduced from 4 degrees to 3.3 degrees above the horizon, necessitating the approach of the aircraft generally at a lower altitude, the altitude above the middle marker being of the order of 561 ft only. The distance of the middle marker from ARP is 2972 m (1.6 n.m.). Fig. 1 is the instrument approach chart for the Bombay airport.

The aviation hazards that may be encountered by the jet aircraft especially in the monsoon season, on the phase of the final approach, have been discussed in this note with reference to climatological statistics and the synoptic climatology of this airport. It is hoped that the result arrived at will be of some practical value to pilots operating jet aircraft and to air traffic controllers.

1. Introduction

Low clouds covering half and more of the sky can become an aviation hazard for aircraft approaching the airport for landing. At Santacruz the hazard due to presence of low clouds assumes special importance during the months of July and August in view of the frequency of its incidence and the existence of certain obstructions in the vicinity of the airport. In many cases when low clouds cover 3/4 or more of the sky, aircraft will have to make a break-through below the clouds, close to the airport before landing. At such times almost invariably the tops of the hills near the airport are covered with low clouds. If these clouds are very low (which is the case at Santacruz in the heavy rain/heavy showers during mor soon) such a situation may result in accidents or near-accidents, missed approaches etc, to aircraft especially when landing with the help of the ILS. This is particularly significant when an aircraft approaching to land with the help of the instrument landing system encounters poor visibility and/or strong gusty winds after breaking through clouds. For jet operations under such conditions a visibility of less than 1000 metres and a 25 to 30 knots gusty wind from S/SSW can be a source of difficulty for landing. It may be pointed out here that the normal SW/W surface wind of Bombay during monsoon months fairly frequently backs to SSE/SSW under the influence of local thunderstorm cells and off-shore troughs which appear over sea area during phases of strengthening of monsoon.

2. Descriptions of hill features in the vicinity of the airport

(*i*) *Hill features* — A sketch of the airfield showing the positions of the runways, hill features and locations of radio-navigational aids over and around the airport is given in Fig. 2. Santacruz airport (19.05°N, 72·52°E) is located at about 10 km north of Bombay and about 3 km east of sea coast. It has three runways, *viz.*, 14/32 runway, 09/27 runway and 05/23 runway. Aerodrome reference point (ARP) is located in the airport having a bearing of 331 degrees and at a distance of 355 metres from the inter-section of 09/27 and 14/32 runways and is at an altitude of 27 ft. Its co-ordinates are 19·0527N, 72·5200E. Between east and northeast of the airport within 5·56 km (3 nautical miles), there are a series of hills called Chanduvelli hills at an altitude ranging from 75 to 221 metres. This is one of the classified obstructions for landing and extends from 0° to 090° azimuth. Another important hill and also very potential obstruction for jet landing is the Trombay hill at a distance of 8·5 km (4·59 n.m.) with an altitude of 315 metres (307 metres above ARP) and at a bearing of 144 degrees with reference to the ARP. Jet aircraft in descent at 3·3° glide path angle approaching 32 end of the runway will normally be at an altitude of about 1600 ft over summit of the Trombay hill.

(*ii*) *Runways* — The 09/27 runway (total paved length 3330 metres/10,925 ft) is the main jet runway at the present time, for aircraft approaching

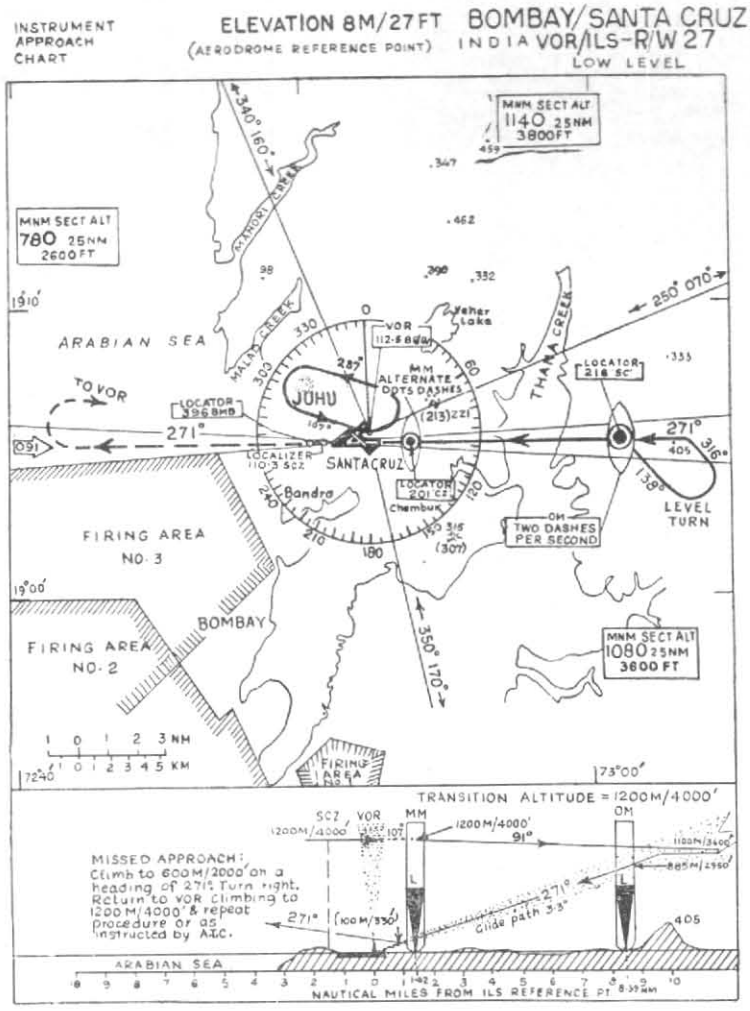

Fig. 1

Adapted from Instrument Approach Chart No. 4 dated 10 July 1964 (with kind permission of the Civil Aviation Department)

27 end of the runway, almost during the entire monsoon season and also when sea breeze blows in the non-monsoon seasons. The approach is from 09 on much fewer occasions, *i.e.*, during winter months and early mornings and also on some occasions during spells of weak monsoon activity. The glide path makes an angle of 3·3 degrees above horizon and this is used by the aircraft approaching from 27 end of the runway. The noteworthy hill features for this approach are hills at height of about 457·20 metres (1500 ft) near outer marker which is 15·9 km (8·6 n.m.) from ARP and the Chanduvelli hills which girdles the airfield from east to northeast. The peak nearest to the airfield is at a bearing of 069 degrees from ARP at a distance of 4707 metres/2·54 n.m. with an altitude of 221 metres/725 ft (213 metres higher than the level of the ARP).

The 05/23 runway (length 1828 metres/6000 ft) is used mainly during monsoon by Dakotas, Viscounts and Fokker Friendship aircraft. This runway does not have any instrumental aids.

The 14/32 runway (length 1828 metres /6000 ft) is being extended to a length of 2560 m/8400 ft and developed into another instrument runway for Santacruz airport. During certain situation in monsoon season, when the wind blows from west to northwest, aircraft will approach from 32 end of this runway. The presence of the Trombay hill (bearing 144 degrees at an altitude of 315 metres/1034 ft, and 307 m/1007 ft above ARP) is a source of hazard to approaching aircraft at such times.

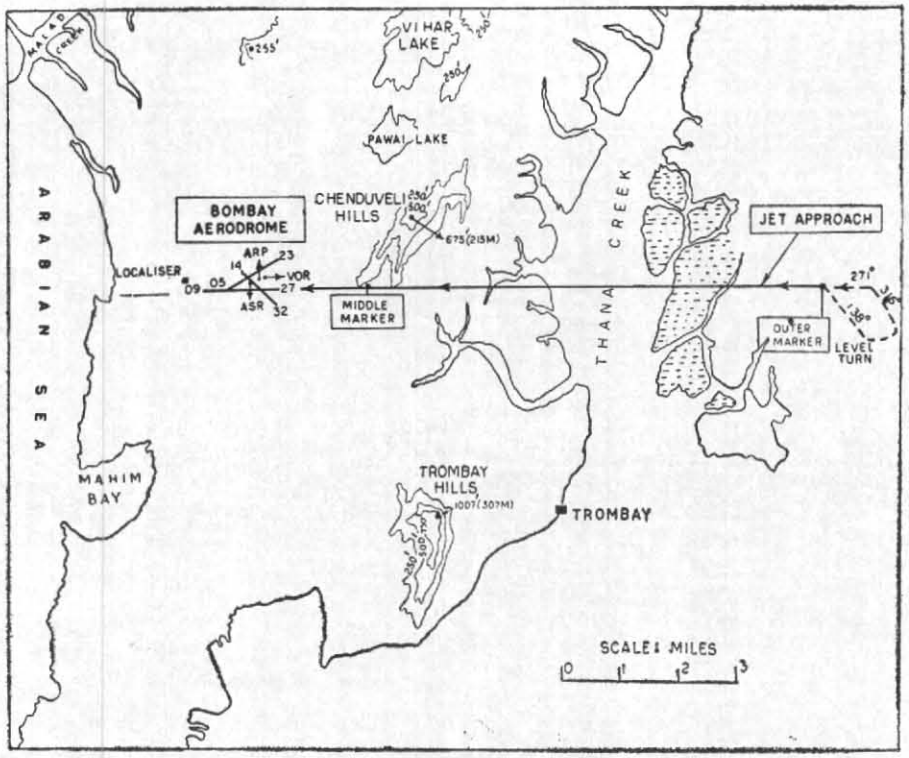

Fig. 2

3. Records used for study

Records used for investigations are current weather registers of Santacruz for five years from 1960 to 1964. Occurrences of low clouds etc for the preparation of this paper have been taken from routine half-hourly observations and also special observations like MMMMM reporting phenomenon below the chosen minima (say cloud base at a height of less than or equal to 240 metres). However, the possibility of bad weather conditions prevailing between successive observations cannot be ignored and has to be kept in view while considering the subject.

It is necessary here to make a few general comments about the system of cloud reporting. As is well-known, the cloud formations during the monsoon season are rather peculiar; below a fairly uniform layer of altostratus, there are cumuli of various sizes, starting from the ordinary cumulus to the full fledged cumulonimbus cloud. The lowest layer is constituted by stratus which is almost never of uniform texture. They occur in fragments at different layers the amount of each fragment varying between 2 to 5 oktas. The ceilometer is located at one particular point whose distance is about 2 km from the location of the middle marker. The ceilometer readings and ceiling balloon ascent data are taken into account for cloud reporting, but it can be readily appreciated that the cloud heights at different parts of a large airfield like Santacruz can be considerably different. The height actually reported by the observer is representative of the broad mean of the conditions actually prevailing, but at any given time this mean value can be considerably different from the actually prevailing height at the middle marker position where or near where the penetration of aircraft actually occurs for the final approach for landing. Reporting of cloud heights at night has inherent difficulties, for with the high intensity lighting system, the sky is often not clearly visible. To this extent, the data on which the present analysis is based, should be treated with a certain amount of reserve in the sense that the statistics derived may probably amount in certain cases to an underestimate of the hazards that develop due to low clouds.

4. Climatology of the airfield during monsoon

The climatology of Santacruz airfield during monsoon has been classified for the purpose of convenience of discussion under three heads, *viz.*, (1) low clouds, (2) visibility, (3) surface winds, and these have been discussed separately,

TABLE 1

Daily incidences of low clouds 4 oktas and more (base 240 m or less)

Date	JUNE					JULY					AUGUST				
	1960	1961	1962	1963	1964	1960	1961	1962	1963	1964	1960	1961	1962	1963	1964
1						8	28		7	2	6				
2						31	6		6		12	12			2
3						6	24		14		8	14			10
4						7	31		10		1			1	19
5	1						21	13	23	2				9	5
6	4						12	4	46					21	5
7							1	12	24					8	37
8	1							27	8	3	1				1
9			10				8				13		2		
10							18	2	1					24	10
11		11		2			6	14	1	6	1		1	20	11
12					1		2	28			1				6
13	8				2		1	12					8		
14	12				2	3							26	4	
15				3	1								3		
16	14								1				1		
17												5		2	
18									4		2	9	1	1	
19												7			1
20								9		2					
21							15			7				3	
22	12	12			8		24			10				8	
23	24	2			2		15			4				5	
24	14	1			5		22	3		4	5	3	2		2
25	23	11			8	25	21							11	
26	2	1			6	25	14					4		20	2
27	38			25	24	24		3	4				1		1
28	20			7	17	9		3	11				2	1	
29		2		2	13	27	14		9						4
30	4	7		4	9		2		22					1	
31									2					1	
Total	177	47	10	43	98	165	286	130	193	40	50	54	47	140	116

Allowing due margin for the observational error in visual estimation of elements, it is assumed that the data recorded in current weather registers are representative of the actual weather prevailing at that time over the airfield and vicinity.

(1) *Low clouds* — The monsoon sets in at Bombay approximately during the second week of June and withdraws by about third week of September. Low clouds are predominant meteorological phenomenon during monsoon period. As such it is a factor to be reckoned with from the end of May upto the middle of September, the worst affected period being June, July and August. Occurrences of this hazard increase gradually and are frequent generally between 15 June and 15 August. Low clouds are common during monsoon months but in order to assess the exact frequency of this hazard, statistics have been prepared by examining situations when clouds of 4 oktas and more with height of base being 240 metres or less, and also when it is 180 metres or less. When two or more layers of clouds below the minima of 240 m (or 180 m) have been recorded the total of such clouds were taken into consideration. For example, if there are 2 oktas at 90 m and 3 oktas at 210 m it is computed as 5 oktas at 240 m or less and will be found in Table 1. But if there are 3 oktas at 240 m and 4 oktas at 150 m, it is taken as 4 oktas at 180 m or less and 7 oktas at 240 m or less and will find its place in Tables 1 and 2. The incidences of low clouds during the months of June, July and August for the years 1960 to 1964 are shown in Tables 1 to 6. The associated conditions of visibility and surface winds have also been discussed.

(2) *Visibility* — Table 3 gives the frequency of incidence of visibility below the 5 m minima of 3·2 km under different ranges. During investigation

TABLE 2

Daily incidences of low clouds 4 oktas and more (base 180 m or less)

Date	JUNE					JULY					AUGUST				
	1960	1961	1962	1963	1964	1960	1961	1962	1963	1964	1960	1961	1962	1963	1964
1															
2							9				1				
3							1		6		1				
4															1
5							7	1							
6									14					4	
7								4	2					1	9
8								21	1						
9											3				
10							3							10	
11														1	
12	1							3							
13															
14	1													1	
15					1										
16	3														
17															
18												7			
19															
20															
21							2							1	
22	3						15			1					
23							6			2					
24	1				2		5								
25	2	4					5							3	
26					1		7							2	1
27	4			9	6	8									
28	1			3	8										
29							6		2						
30	1	7			2		1		3						
31															
Total	17	11	—	12	20	8	67	29	28	3	5	7	—	23	11

TABLE 3

Frequency of visibility at Santacruz

	Range (metres)					
	0–500	501–1000	1001–1500	1501–2000	2001–2500	2501–3000
(JUNE)						
1960		9	10	26	10	28
1961		2	5	11	5	10
1962				4	2	3
1963			1	3	7	2
1964		1	4	6	5	2
(JULY)						
1960		3	10	23	11	22
1961	4	12	44	56	27	45
1962	2	14	14	23	19	28
1963	1	4	13	17	9	16
1964		3	4	10	5	4
(AUGUST)						
1960		4	6	21	1	7
1961		2	8	12	5	17
1962			1	4	5	8
1963	2	6	9	26	21	18
1964		2	2	10	6	6

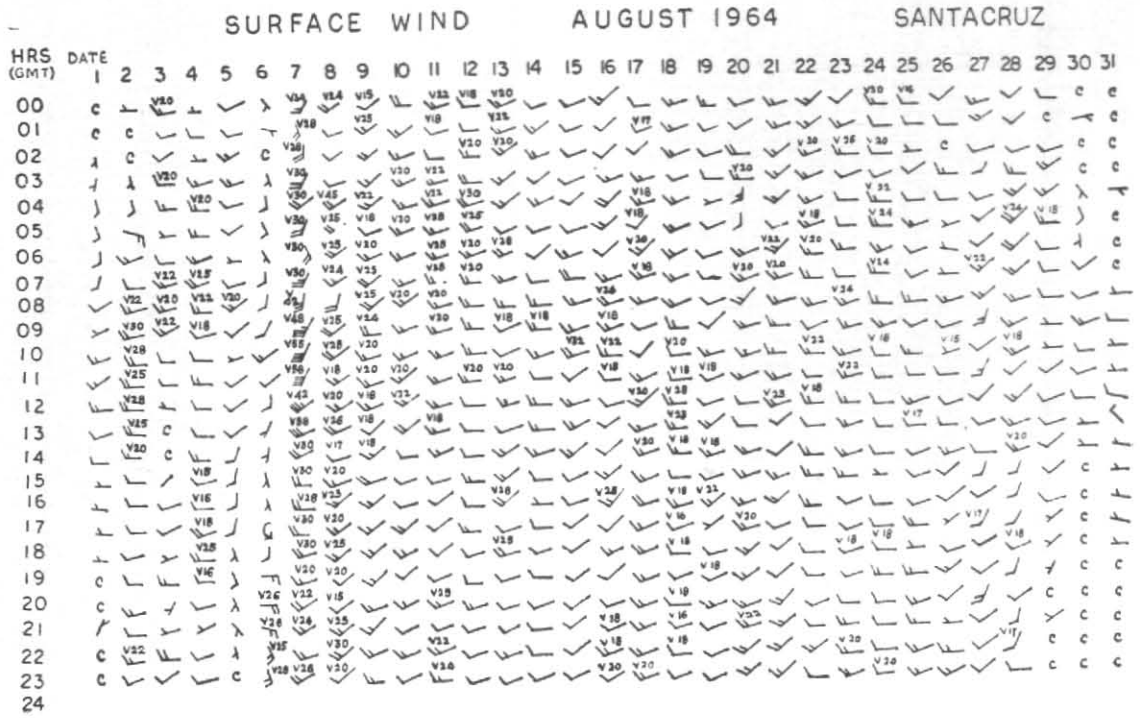

Fig. 3

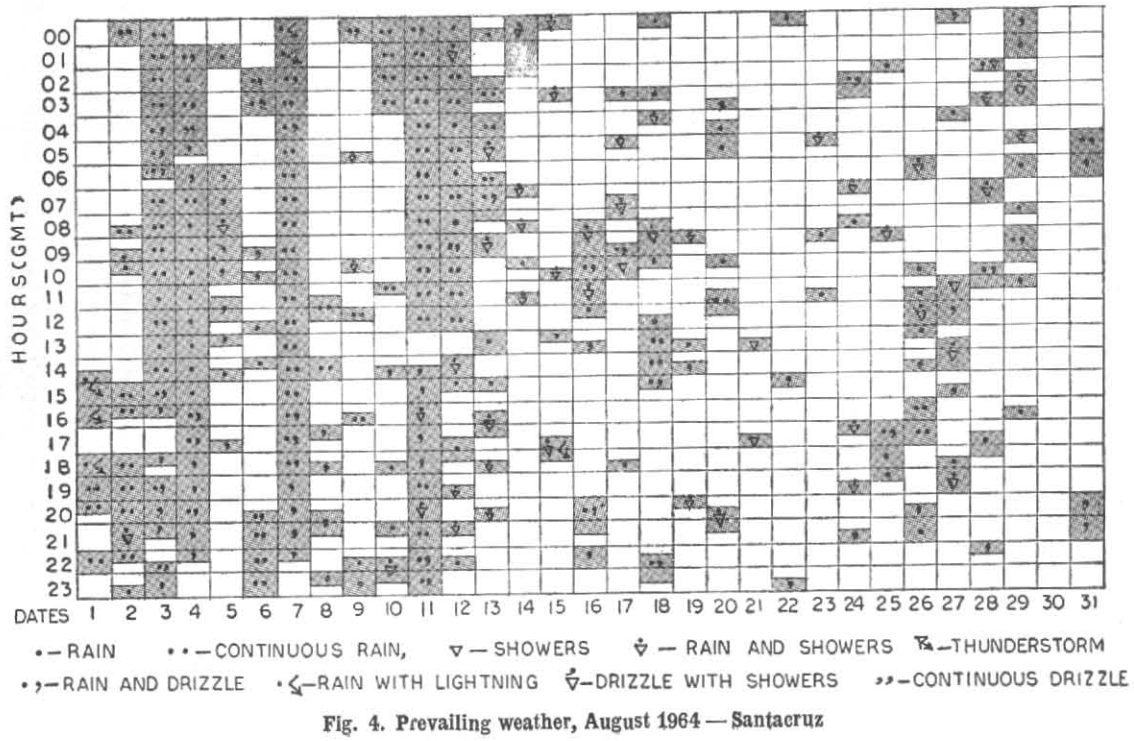

Fig. 4. Prevailing weather, August 1964 — Santacruz

TABLE 4

Daily incidences of low clouds 4 oktas and more (base less than or equal to 240 m)

Date	Hours (GMT) 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
1																									
2			1														1								2
3								2	2	2	1		2	1											10
4		1	2					1	2	2	2	2		2	2	2			1						19
5									1	1	1	2													5
6		2	2		1																				5
7					2	2	2	2	2	2	2	2	2	2	2	2	2		2	2	1	2	2	2	37
8	1																								1
9																									
10		2	2	2	1	2	1																		10
11						2	2	2														2	2	1	11
12				2	2	1		1																	6
13																									
14																									
15																									
16																									
17																									
18																									
19		1																							1
20																									
21																									
22																									
23																									
24				2																					2
25																									
26		1											1												2
27														1											1
28																									
29				1			1		1	1															4
30																									
31																									
Total	1	7	7	7	6	7	6	8	8	8	6	6	4	6	5	4	3	—	3	2	1	4	4	3	116

it was seen that visibility during heavy rain or showers deteriorated often to 1500 to 2000 metres, at times even reduced to about 500 metres, obscuring the runways. However, the study revealed that this kind of deterioration is mostly temporary in character. Formation of a depression in the Bay or the presence of off-shore troughs near Bombay often results in spells of heavy rains over airport. At such times, the deterioration in visibility is likely to last for some time.

(3) *Surface winds* — During monsoon surface winds are usually from southwest to west with an average speed of about 15—20 knots. When monsoon is vigorous the average speed increases to 20—25 knots, occasionally 30 knots in gusts. During premonsoon period violent thunderstorms are experienced usually accompanied by some easterly or southeasterly squalls when speed reaches about 40—50 knots.

5. Discussion of results

From the study of the data it was seen that occurrences of low clouds are almost invariably associated with precipitation. The cloud base becomes very low and visibility very poor in heavy showers. It was also noted that low clouds and poor visibility associated with strong SSE/SSW surface winds occur at certain periods during monsoon as in August 1964. Tables 4 to 6 show the incidences of low clouds and poor visibility, Fig. 3 shows the surface winds and

TABLE 5

Daily incidences of low clouds 4 oktas and more (base 180 m or less in August 1964)

4th — 1 occasion at 02 GMT

7th — 1, 2, 1, 1, 1, 1 and 2 occasions at 04, 05, 06, 07, 08, 10 and 11 GMT respectively

26th — 1 occasion at 02 GMT

No occasions on other dates or hours

TABLE 6

Daily incidences of poor visibility (3 km and less) in August 1964

	Hours (GMT)																							
Date	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
1																									
2																									
3								3	1	1	1		2												8
4								1	2	1				1	2										7
5		1	2																						3
6																									
7										1	2	2	2												7
8																									
9																									
10		2	2	1																					5
11						2	2	2	2	1												2			11
12					2	2							1												5
13							1																		1
14																									
15																									
16									1			1													2
17																									
18																									
19																									
20																									
21																									
22																									
23																									
24																									
25																									
26		1																							1
27					1										1										2
28				1																					1
29																									
30																									
31						1																			1
otal		4	4	2	3	5	3	6	6	4	3	3	5	1	3							2			54

TABLE 7

Frequency of cloud heights observed during August/September 1964

Place of observation	Range of cloud height (metres)									
	300	301 to 400	401 to 500	501 to 600	601 to 700	701 to 800	801 to 900	901 to 1000	1000 to 1200	1200
Middle marker	4	6	3	7	1	9	4	7	1	6
Slide path	1	5	4	9	10	7	8	—	3	3
Localiser	—	2	2	12	4	6	3	3	3	3
Locator	—	1	—	7	4	2	3	3	6	9
RS/RW Bldg.	3	—	6	3	9	3	1	—	3	—

Fig. 4 is a pictorial representation of prevailing weather during the month of August 1964. It will be seen from these that on 7 August 1964 low clouds and poor visibility were associated with strong cross-winds and continuous rain between 0400 and 1100 GMT due to an off-shore depression. During this time the traffic at this airport was disrupted. Aircraft attempting to land on 09/27 runway in such weather conditions may find difficulty to control the swerving of the aircraft. Large amounts of low clouds over or near hill features are themselves a hazard. But low clouds associated with poor visibility and strong cross-winds (which aircraft encounter after breaking through clouds) make the hazard a potential danger to landing operations at the airfield.

On 09/27 runway the aircraft has to pass over middle marker (distance 2972 metres/1·6 n.m.) (bearing 097 degrees from ARP) at a height of about 171 metres/561 ft. On days when 3/4th of the sky is covered with low clouds aircraft approaching 27 end of the runway actually penetrates the cloud layer near middle marker, which itself is surrounded by low hills. Special observations conducted simultaneously at different points in the airport during August/September 1964, revealed that base of clouds are substantially lower over this region than over other parts of the airfield (see Table 7). As such it is safer for aircraft approaching to land 27 end of runway to maintain the fixed level of 561 ft while in transit across middle marker.

The horizontal clearance between highest peak of Trombay hill (distance 8506 metres/4·59 n.m. from ARP) and the approach path on 32/14 runway is quite small being of the order of 1·29 km and hence a good deal of caution will have to be exercised in fixing the glide path of this runway. The top of Trombay hill subtends an angle of 2° 5′ at the ARP position. A glide path angle of 3·3 degrees, if adopted for this runway also as in the case of 09/27 runway, will leave a clearance of about 200 metres (600 ft) while the aircraft traverses close to the top of the Trombay hill. During monsoon the tops of this hill are unusually covered by low clouds and in heavy spell the hill is partially or fully obscured by very low clouds. The visibility is also poor at such times in the surrounding places. Hence it is felt that even a clearance of about 200 metres (600 ft) may not be sufficient for a purely (IMC) instrument meteorological condition approach during bad weather spells. The possibility of turbulence in these clouds during monsoon especially in the vicinity of the hill make this potential hazard noteworthy. Investigation also revealed that frequency of incidence of low clouds and poor visibility is more in the month of July than other months in monsoon season (Tables 1 and 2). It will be seen from Tables 1 and 2 that in the month of July 1961, there had been 286 incidences of low clouds when cloud base was 240 metres or less and 67 incidences when cloud base was 180 metres or less. Incidence of very poor visibility of the range 0 to 500 metres was noticed only during the month of July as will be seen in Table 3. It was also noted that the frequency of incidence of poor visibility during the monsoon months is generally high in the range of 1500 to 2000 metres.

6. Concluding remarks

Finally there is an important feature which is not quite reflected in the statistics presented in this paper. This feature is the *abruptness* with which weather conditions at this airfield can change, especially during monsoon period. Cases are occasionally reported in which wind and

visibility show marked changes in a matter of only a few seconds. A combination of adverse conditions under such circumstances can lead to an extremely difficult situation for incoming aircraft. The only way of coping up with these changes is to ensure, to the extent possible, that the changes are detected and reported to aircraft without any loss of time. Representativeness of the observation (with reference to the locations of the measuring instruments) and suitable techniques of telemetry and communications are, therefore, of prime importance.