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On the techniques of forecasting fog/stratus over the Dundigal airfield of Hyderabad

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सार — इस शोधपत्र में कोहरा/स्तरीय मेघ के पूर्वानुमान के लिए एक "विलोपन की तकनीक" नामक नई विधि को प्रस्तुत किया गया है जिसमें कोहरा/स्तरीय मेघ बनने से पूर्ववर्ती रात्रि के दौरान आपेक्षिक आर्द्रता द्वारा आवश्यक संतुष्ट होने वाली दशा की कसौटी का उपयोग किया गया है। स्तरीय मेघ की घटनाओं का समावेश करके टेलर की "कोहरा पूर्वानुमान आरेख" तकनीक में संशोधन किया गया है और यह दिखाया गया है कि नवम्बर और दिसम्बर के महीनों में कोहरा/स्तरीय मेघ का पूर्वानुमान उनके होने से पहले दिन, इतनी अधिक शीघ्रता से कि 1730 बजे भा०मा०स० तक सम्भव है। मध्य रात्रि में आर्द्र बल्ब अवनमन की प्रवृत्ति की संगणना की गई है और यह दिखाया गया है कि कोहरा/स्तरीय मेघ उन्हीं अवसरों में अधिकांशतः बनते हैं जब इस प्रकार अनुमानित अवधि निम्नतम ताप के प्रसामान्य घंटे के अन्दर पड़ते हैं। डुन्डीगल में कोहरा/स्तरीय मेघ बनने के लिए अनुकूल सिनॉप्टिक स्थितियों का भी अध्ययन किया गया है।

ABSTRACT. In this paper a new technique named 'Technique of Elimination' has been introduced for the forecasting of fog/stratus which utilizes the criterion of condition necessary to be satisfied by relative humidity during night prior to the formation of fog/stratus. Taylor's technique of 'fog prediction diagram' has been modified by including the incidence of stratus also and it has been shown that it is feasible to give a forecast of fog/stratus as early as 1730 IST of the previous day in the months of November and December. Tendency of wet bulb depression at midnight has been computed and it has been shown that fog/stratus formed on most of the occasions when the interval of time so guessed fell within the normal hour of minimum temperature. Synoptic situations favourable for the formation of fog/stratus at Dundigal have also been studied.

1. Introduction

'It is unwise to attempt an exact definition of fog', says Byers in his book '*General Meteorology*.' It is difficult to find a more adequate beginning. When a cloud consisting of tiny water drops envelopes the observer and restricts his horizontal visibility to less than one kilometre, the international definition of fog has been satisfied. No weather phenomena other than fog and stratus depend so much upon the location of the observer. A motorist may on one occasion encounter dense fog in the valleys of a hilly terrain and perfectly clear air as he tops the ridges. On another occasion when there is stratus, he may be in the clear air only in the valleys and in fog on the ridges.

There are three airfields located in Hyderabad within a radius of 22 km, namely, Begumpet (BGP), Hakimpet (HKP) and Dundigal (DGL). The incidence of fog and stratus during winters is very high over these airfields which constitutes a very serious aviation hazard. The objective of the present paper is to study and evolve objective techniques of forecasting fog and stratus over DGL airfield of Hyderabad. The study has been carried out on the data of winter months of November to February for the 10 years period 1974-1983.

2. Earlier studies

Taylor (1917) was probably the first meteorologist to study the incidence of fog in great depth for Kew observatory of England and made the fog prediction diagrams. Chakravortty (1948) studied the incidence of fog for Calcutta. Chandiramani (1958) studied the various phenomena of fog/stratus over the Begumpet airfield of Hyderabad.

3. Behaviour of relative humidity during night prior to the formation of fog/stratus

The frequencies of relative humidity (RH) of various ranges during nights on the 80 occasions of fog/mist and 189 occasions of stratus (4 okta or more at 0.3 km or below) at DGL for the 10-year period of study are shown in Table 1. It is evident from this table that RH at 1730 IST of the previous day showed a distinct pattern. As the night progressed the RH increased and a clear cut pattern emerged. At 2330 IST, the RH was more than 50% on 78 out of 80 occasions of fog/mist while at 0530 IST of the day it was more than 80% in 77 cases. Similarly out of 189 cases of stratus, the RH was more than 50% in 185 cases at 2330 IST while more than 80% in 183 cases at 0530 IST. On the other

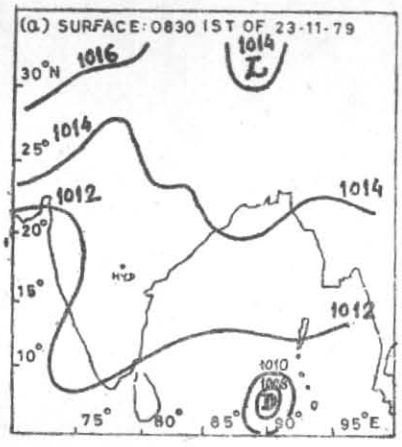

Fig. 1(a). Surface chart, 23 Nov '79 (03 GMT)

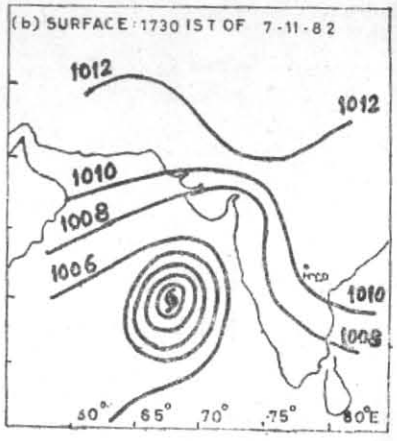

Fig. 1(b). Surface chart of 7 Nov '82 (12 GMT)

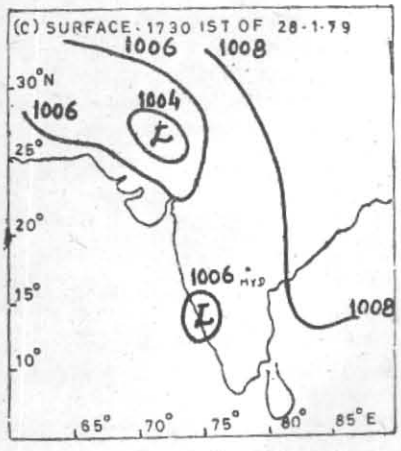

Fig. 1 (c). Surface chart, 28 Jan '79 (12 GMT)

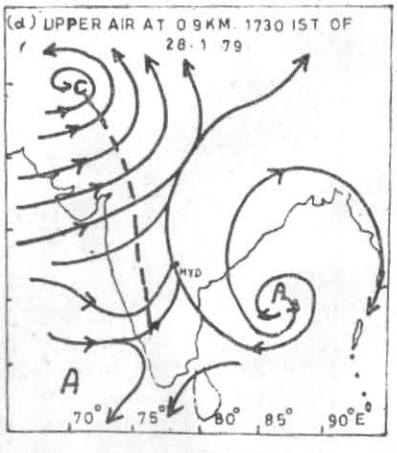

Fig. 1(d). Upper air (0.9 km) chart of 28 Jan '79 (12 GMT)

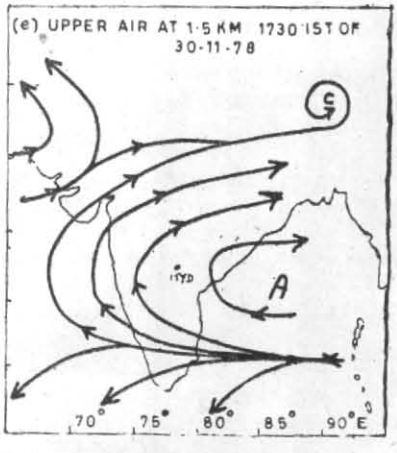

Fig. 1(e). Upper air (1.5 km) chart of 30 Nov '78 (12 GMT)

Figs. 1(a-e). Surface charts : (a) 23 Nov '79 (03 GMT), (b) 7 Nov '82 (12 GMT) & (c) 28 Jan '79 (12 GMT) and stream analysis charts at (d) 3000 ft, 28 Jan '79 (12 GMT) and (e) 5000 ft, 30 Nov '78 (12 GMT)

hand a large number of cases were observed during the period of study when no fog, mist or stratus formed at DGL even though the RH at 0530 IST was much above 80% as shown in Table 2. The following can thus be concluded from these tables :

(*i*) No fog or stratus forms at DGL in the morning hours if the RH was 50% or less at 2330 IST of the previous day or is 80% or less at 0530 IST of the same day though the *vice versa* is not always true.

(*ii*) Fog or stratus does form in the morning hours of Dec, Jan & Feb if the RH at 0530 IST of the same day is 95% or more, though it is not so in the month of Nov.

(*iii*) Occurrence of fog cannot be differentiated from the formation of stratus on the basis of RH.

4. Favourable synoptic situations

The four synoptic situations which have been found to be favourable for the formation of fog/stratus over the airfields of Hyderabad have been described below :

(i) Formation of a vortex over southwest Bay of Bengal

Dense fog set in over DGL on 24 Nov '79 at 0620 IST in which the visibility deteriorated to 50 m. It lasted till 0745 IST. Stratus persisted between 0745 and 0810 IST. Fog prevailed over HKP also on this day between 0600 and 0700 IST. Fig. 1 (a) depicts the surface chart of 0830 IST of 23 Nov '79 which shows that a depression lay over southwest Bay of Bengal. Associated cyclonic circulation extended up to 1.5 km above mean sea level (amsl). The system advected moisture over Hyderabad region.

(ii) Formation of a vortex over central Arabian Sea

Fog set in both at DGL and HKP on 08 Nov '82 in which the visibility reduced to zero at both the places. It persisted for a very short duration of 20 minutes up to 0720 IST at DGL followed by stratus that prevailed till 1000 IST. Fig. 1 (b) shows that a severe cyclonic storm with a core of hurricane winds lay in the central Arabian Sea advecting moisture over Hyderabad region.

TABLE 1

Frequencies of relative humidity of various ranges during night prior to the occurrence of fog/mist and stratus at DGL

RH (%)	Fog/mist at time (IST)				Stratus* at time (IST)			
	1730	2030	2330	0530	1730	2030	2330	0530
0-10	0	0	0	0	0	0	0	0
11-20	3	0	0	0	0	0	0	0
21-30	9	3	0	0	4	0	0	0
31-40	13	1	2	0	13	3	1	0
41-50	22	11	0	1	32	5	3	0
51-60	17	11	9	0	53	20	4	0
61-70	8	30	17	0	33	48	23	2
71-80	4	8	22	2	20	40	36	4
81-90	2	6	18	14	22	31	60	30
91-100	2	5	12	63	12	42	62	153
Total	80	75	80	80	189	189	189	189

NOTE 1. The DB and DP were not recorded at 2030 IST in January & February '74, hence the RH could not be worked out for these two months for this synoptic hour in this table.

2. Stratus* indicates stratus independent of fog/mist.

TABLE 2

Number of cases during 10 years period of study when no fog, mist or status formed at DGL

RH(%) at 0530 IST	Nov	Dec	Jan	Feb
90 or above	61	19	27	20
95 or above	24	2	3	3

TABLE 3

Result of the forecasts for the period Nov '84-Feb '85 on the basis of technique of elimination

Parameter	Nov	Dec	Jan	Feb
No. of days in the month	30	31	31	28
No. of days for which forecasts could be issued	23	23	12	23
No. of correct forecasts	23	22	10	20
Percentage of occasions for which forecasts could be issued	77	74	39	82
Percentage accuracy	100	96	83	87

TABLE 4

Result of the forecasts for the period Nov '84-Feb '85 on the basis of technique of prediction diagram

Parameter	1730 IST		2030 IST		0530 IST		
	Nov	Dec	Nov	Dec	Nov	Dec	Jan
No. of days in the month	30	31	30	31	30	31	31
No. of days for which forecasts could be issued	27	25	29	26	29	29	22
No. of correct forecasts	27	24	29	24	28	27	20
Percentage of occasions for which forecasts could be issued	90	80	97	84	97	94	71
Percentage accuracy	100	96	100	92	96	93	91

(iii) Passage of western disturbance at low latitudes

Fog set in over DGL on 29 Jan '79 at 0710 IST and lasted till 0800 IST in which the visibility reduced to 800 m. Fog prevailed over HKP also on this day between 0530 and 0800 IST reducing the visibility to 800 m. Stratus persisted between 0400 and 0600 IST at DGL. Fig. 1(c) shows that an induced low pressure area lay over Rajasthan and adjoining west Madhya Pradesh. Associated cyclonic circulation extended upto 0.9 km amsl as shown in Fig. 1(d). A trough of low extended southwards from the centre of low pressure.

(iv) Existence of an anticyclone over north/central Bay of Bengal in the lower troposphere

Thick fog set in over DGL on 01 Dec '78 at 0400 IST and lasted till 0830 IST in which the visibility became zero. Stratus appeared at 0800 IST and remained till 0840 IST. BGP recorded mist on this day. Fig. 1(e) shows the streamline chart of 1730 IST of 30 Nov '78 at 1.5 km amsl which indicates that an anticyclone lay over north and central Bay of Bengal incurring moisture over the Hyderabad region.

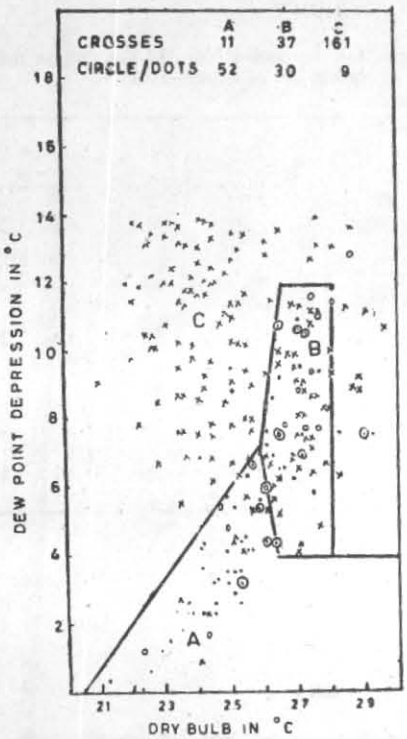

Fig. 2. Fog/stratus prediction diagram November (1730 IST)

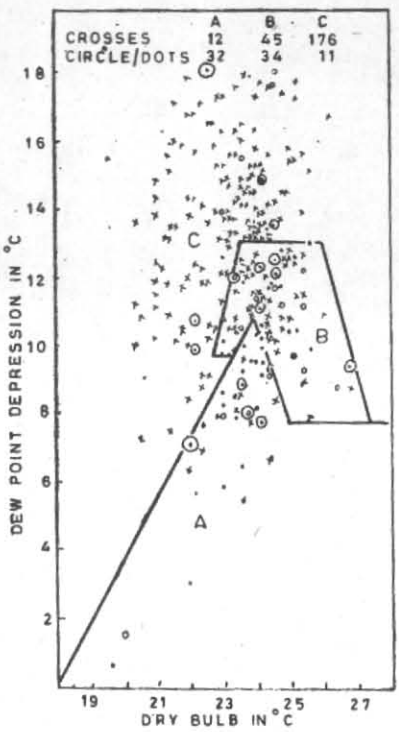

Fig. 3. Fog/stratus prediction diagram December (1730 IST)

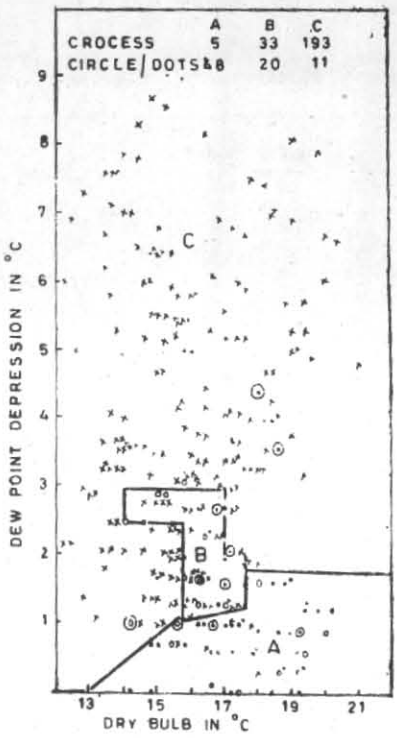

Fig. 4. Fog/stratus prediction diagram January (0530 IST)

TABLE 5

Result of the forecasts for the period Nov '84-Feb '85 issued on the basis of amalgamated technique

Parameter	Nov	Dec	Jan	Feb
No. of days in the month	30	31	31	28
No. of days for which forecasts could be issued	29	29	22	23
No. of correct forecasts	28	27	19	20
Percentage accuracy	96	93	86	87
Skill score	0.74	0.72	0.84	0.68

The synoptic patterns described above can be present alone or in association with one another. For example, when fog/stratus formed over the airfields of Hyderabad on 29 Jan '79, not only an induced low pressure was seen over Rajasthan and adjoining Madhya Pradesh as described earlier but also a well marked anticyclone was seen lying over north and central Bay of Bengal [Fig. 1(d)].

5. Techniques of forecasting

The problem of forecasting fog/stratus was attacked from many angles. The techniques employed will now be described.

5.1. *Technique of elimination*

A forecast for the non-occurrence of fog/stratus on many days can be obtained by employing the technique of elimination which utilizes the criterion of conditions necessary to be satisfied by meteorological elements like surface wind speed, direction and RH etc during night prior to the formation of fog/stratus.

The first two conditions of RH mentioned in Sec 3 can be gainfully employed to predict the occurrence or otherwise of fog/stratus at DGL. This technique was employed during the winter months of Nov '84-Feb '85. The results are shown in Table 3 which indicates that the forecasts could be issued on more than 70 % occasions in the months of Nov, Dec and Feb while only on 39 % occasions in Jan. A look at the daily values of RH of these months showed that the month of Jan '85 was quite humid while the other three months were dry. This suggests that this technique is more useful in the dry season. It is also evident from this table that the percentage accuracy of the forecasts so issued is very high for all the months of winter.

5.2. *Technique of prediction diagram*

Taylor (1917) marked each case of calm and clear night on a diagram representing the state of air by points marking the temperature (DB) as abscissae and the dew point depression (DPD) as ordinate. Occurrence of fog was marked by a dot while non-occurrence by a cross. A line was then drawn separating the crosses from the dots. This diagram was then used for forecasting.

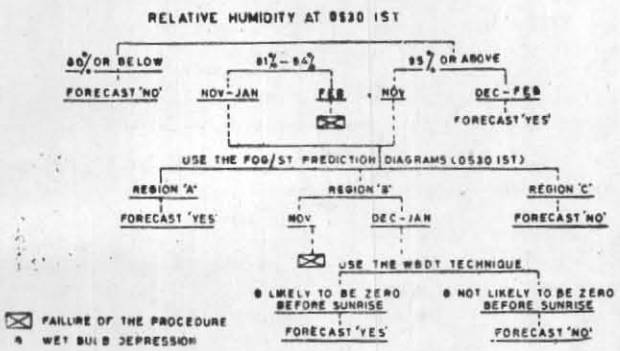

Fig. 5. Procedure to be followed for day-to-day forecasting of fog/stratus at DGL during winter (November-February)

It would be unwise to prepare the fog prediction diagram for DGL because of the very small frequency of fog, the maximum frequency being in the month of December or January — only 22 cases of fog during the 10-year period of study. It is virtually impossible to get a separation of 22 dots from 288 crosses. Since very thin line separates fog from mist and stratus, it is decided to treat all the three at par to increase the number of dots in the prediction diagram. Since HKP is located at a distance of 15 km only from DGL, a composite diagram was made for DGL & HKP. The occurrence of fog/mist was marked by a circle while that of stratus by a dot. In case of weather at HKP, the dot or circle was encircled to distinguish it from weather at DGL. The diagram was then divided into three regions :

(*i*) Region 'A' containing mainly the dots with a mixture of unavoidable crosses.

(*ii*) Region 'B' where separation between the dots and the crosses was not feasible.

(*iii*) Region 'C' containing mostly the crosses.

The area was demarcated such that the points lying on the line separating region 'A' from 'B' or 'C' belonged to 'A' while those on the line separating 'B' from 'C' belonged to 'B'. The number of crosses/dots lying in the three regions have also been shown in the diagram.

A separate diagram was made for each month for the synoptic hours of 1730, 2030, 2330 & 0530 IST. These diagrams were then tested on an independent set of data for the period Nov '84-Feb '85 by forecasting occurrence of fog/stratus on a day when the point representing the state of air lay in region 'A' and non-occurrence if it lay in region 'C'. No forecast was issued on a day when such point lay in region 'B'. It was found that only the following diagrams were useful for the purpose of forecasting :

(*i*) 1730 and 2030 IST diagrams of Nov and Dec.

(*ii*) 0530 IST diagrams of Nov, Dec and Jan.

The result of the forecasting ability of these diagrams is shown in Table 4. From the table it is evident that it is possible to give a forecast of fog/stratus as early as 1730 IST of the previous day for the month of Nov and Dec on a large number of occasions with a good reliability. The technique becomes less useful in the month of Jan as no reliable forecasts can be given before 0530 IST of the day while it breaks down completely in in the month of Feb. No areal separation was noticed between the points representing the occurrence of fog/stratus at DGL from those of HKP. The 1730 IST diagrams of Nov and Dec and 0530 IST diagram of Jan are shown as Figs. 2-4.

5.3. *Technique of wet bulb depression tendency (WBDT technique)*

Whatever may be the local meteorological elements necessary for the formation of fog/mist, these elements are likely to set in at least a few hours before the condensation except in disturbed weather when a rapid change in meteorological conditions is not ruled out. It is expected that alteast a few hours before the formation of fog/mist the difference between the dry bulb and the wet bulb (WB) will gradually decrease till it becomes zero with the onset of fog/mist. Let θ=DB—WB, then "by" the method of 'finite differences' the first and the second order derivative of θ with respect to time will be :

$$\dot{\theta}_{(\text{midnight})} = \theta_{(0030)} - \theta_{(2330)},$$

$$\ddot{\theta}_{(\text{midnight})} = \dot{\theta}_{(0030)} - \dot{\theta}_{(2330)}$$

$$= \theta_{(0100)} - 2\theta_{(\text{midnight})} + \theta_{(2300)}$$

where the figures in bracket indicate the time in IST.

Knowing the values of θ, $\dot{\theta}$ and $\ddot{\theta}$ near about midnight from the relations given above, it can be found out whether θ is tending towards zero after midnight and if so, the interval of time it is likely to take to attain the zero value. The month of Jan '79 was chosen for trying this technique as this was the month of maximum frequency of fog at DGL. Following the above principle, the thermograms and hygrograms of DGL for this month were examined. It was found that fog/stratus occurred on most of the occasions when the interval of time so guessed fell within the normal hour of minimum temperature. It was also found that fog could not be differentiated from stratus for the purpose of forecasting by this technique. A total of 20 forecasts were found to be correct out of 22 issued.

It will be worth mentioning here that while following this technique, $\dot{\theta}$ and $\ddot{\theta}$ should not be treated plainly as arithmetical figures being used to evaluate the time at which θ would become zero. Judicious discretion should be applied while accepting/rejecting these values.

It will be logical to conclude that this technique will not be valid in the month of November as it has been explained elsewhere in the text that no fog/stratus formed at DGL on a large number of occasions in this month inspite of RH being 95% or more at 0530 IST in the early morning hours.

6. Procedure to be followed for day-to-day forecasting

The three techniques mentioned above have their own limitations. The techniques if employed independently, may not yield any results. On account of this reason, the

three techniques have been amalgamated into one. The flow diagram of the procedure to be followed for day to day forecasting has been prepared and placed as Fig. 5. The procedure was tried during the months of Nov '84-Feb '85. The WBDT technique could not be used as the half-hourly DB and WB temperatures around midnight were not available. The percentage accuracy and the skill score so obtained are shown in Table 5. It is evident from this table that using this procedure a forecast with a percentage accuracy of more than 85% can be obtained in all the four months of the season. The procedure is more useful in the months of Nov & Dec as compared to Jan and Feb on account of the number of forecasts that could be issued using this procedure.

7. Conclusion

The three techniques of forecasting developed have the following limitations :

(*i*) The technique of elimination is useful only if the atmosphere is generally dry.

(*ii*) The technique of prediction diagram has one major handicap — if the point representing the state of air lies in region 'B', no meaningful forecast can be given. Moreover, this technique is less effective in the month of Jan and fails completely in Feb.

(*iii*) Though the WBDT technique works satisfactorily, it cannot be relied upon in the month of Nov.

It has not been found feasible to distinguish fog from stratus for the purpose of forecasting by any of these techniques.

Reasonably good amount of success can be achieved if forecasting techniques are developed for the other airbases also on the similar pattern.

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