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Radar observation of thunderstorms from a cyclonic disturbance

H. J. ASTHANA

Regional Meteorological Centre, Nagpur

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ABSTRACT. The details of radar echoes at reduced gain settings of severe convective storms have been studied with the help of 3 cm Selenia radar. Instances of the appearance of protuberance like 'Finger', and 'Hook' shape echoes associated with squall line types of severe thunderstorms have been discussed and reported. The study showed that it is not necessary that hail or tornado should always occur with severe thunderstorms when these special echo features are seen.

1. Introduction

A full manifestation of thunderstorm activity was observed on 27 October 1968 at Bhubaneswar (Orissa) with strong cumulonimbus clouds accompanied with heavy rain and gusty winds with average speed of 25 kt reaching 50/60 kt in association with cyclonic storm of Bay of Bengal which was moving towards Orissa coast and was centred at 1130 IST near Chilka lake. The radar photographs were taken on 27 October 1968 with 3 cm Selenia radar installed at Bhubaneswar observatory with a view to study the echo details of severe thunderstorms which occurred with cyclonic disturbance.

However, the present study reveals some interesting characteristic echoes like hook and protuberance (finger type) associated with severe squall line thunderstorms. Severe thunderstorms accompanied with squalls caused immense damage and vast devastation which was widely reported in press.

2. Radar observations

(a) *Thunderstorm activity overhead*

The radar observations were taken with 3 cm Selenia radar when the severe cyclonic storm was in close proximity of the station near Chilka lake on 27 October 1968. Under the influence of severe cyclonic storm of Bay of Bengal the thunderstorm activity was noticed at Bhubaneswar observatory. At lower elevations no significant echoes were seen on the radarscope at 1125 IST on 27 October but the radar PPI photograph taken at higher elevation of 9 deg. (shown in Fig. 1a indicates that the solution was embedded in a vary large and extensive area of heavy precipitation. The echoes appeared similar to those associated with thunderstorm echoes of bright intensity with well defined edges.

The radar picture taken subsequently at 1145 IST just after 20 minutes at low elevation angle (2 deg.) and at 0.7 of receiver gain (Fig. 1b) reveals entirely different echo pattern with following noteworthy features:

(*i*) A well developed bright patch of strong thunderstorm echoes was seen elongated towards northeast extending to 24 km from the radar station.

(*ii*) A bright patch of strong thunderstorm echoes with formation of 'Fork' like echo (*see* arrow Fig. 1b) on the left side of echo was noticed in southeast sector.

(*iii*) A typical configuration of thunderstorm echoes, arranged in curved line was observed in the northwest sector of scope.

(*iv*) Some weak scattered cells were also present in southwest and southeast sectors of PPI.

Many of the above cells were in the cumulus stage of development. The typical formation of echo cells in the northwest sector is a kind of squall line presumably associated with the cyclone disturbance.

Following the suggestion of Battan (1959) that the operation of radar receiver at reduced gain favours the detection of echo details, another radar picture (Fig. 1c) was attempted at 1150 IST at reduced gain keeping the same elevation which revealed interesting echo feature. A finger shape echo protruding southward with dimension of about 10 km as shown by arrow in Fig. 1(c) was observed. The same echo was seen as 'Fork' at higher gain. Such characteristic echo could not be detected at higher gain as it was masked by surrounding weak echoes. These finger type of protrusions are indicative of the presence of severe thunderstorm activity which might have been triggered due to approach of cyclonic disturbance.

(b) *Hook shape echo and protuberance*

By 1245 IST, the pattern had reorganised and Fig. 1(d) shows the sequence of cloud masses approaching the station rapidly. A number of thunderstorm cells were found to have clustered and arranged to form a squall line extending from south to northeast of the PPI scope. The thunderstorm activity increased as the squall line approached the station. The squall line was about 60 km long and 8 km wide and was at 16 km from the station. Byers and Braham (1949) of the thunderstorm project have made extensive study of thunderstorms with 3 cm radar and have described the typical thunderstorm as an agglomeration of cells. Stout and Hiser (1955) also studied the radar echo pattern of lines of thunderstorms.

The bright patch at the station at 1145 IST seemed to have further intensified. The pattern underwent considerable change and the curved line echoes previously observed in northwest sector (Fig. 1b) might have either disappeared or merged with main echo over the radar station. The scattered cells in southwest sector had intensified to become solid patch of bright convective echoes and represented a new region of thunderstorm activity. These cells could be seen in fully developed stage and had combined themselves with central echo to form a large area of thunderstorms. Thus, it may be noticed that there are two distinct and separate regions of thunderstorm activity, one at the station extending towards southwest upto 35 km and another extending from south to northeast sector.

A close examination of Fig. 1(d) reveals a well defined 'Hook' developed in squall line thunderstorm echoes shown by arrow. This was a noteworthy development and could easily be attributed to severe squalls. Subsequent radar picture taken just after five minutes (1250 IST) at reduced gain reveals the existence of another finger like protuberance (*see* arrow Fig. 1e). The jutting out of this finger like intense convective echo towards northeast upto 15 km from the radar station is another evidence of severe weather activity.

Many authors have studied hook activity. Browning and Ludlam (1962) have studied severe local storms associated with tornado and hail. Mull and Kulshrestha (1962) and Sharma (1965) have also noticed hook echoes in association with hailstorms. Fujita (1963) while studying on proposed mechanism of hook echo formation mentioned that the most thunderstorms associated with tornadoes give rise to radar echoes that have a 'hook' or 'Figure 6' shaped protuberance in the right rear quadrant of the storm. Hardy (1965) observed a hook echo formed in squall line echoes associated with a tornado at Fort Cobb, Oklahoma.

Battan (1959) while reviewing the work on use of radar in Mesometeorology also mentioned that the rapid development of intense thunderstorm echoes with the extension of echo protuberance should be taken as evidence that severe thunderstorms may be developing. Protuberances and appendages have also been discussed by Mathur and Kulshrestha (1966) while studying the classification and interpretation of radar weather echoes in India. They were of the view that such characteristic echoes are generally associated with severe weather and hailstorm.

In the present study neither tornado nor hail was reported. The hook and protuberances observed in the present case are thus associated with severe thunderstorms producing squally weather. This confirms with the earlier views of Battan (1959) and Mathur and Kulshrestha (1966).

Similar view has also been reported in WMO (1966) and some of the features of special interest in this connection are (*i*) characteristic of most convective type echoes and that many such protuberances have not been associated with hail, (*ii*) similar protuberances occur with many echoes from thunderstorms which have no tornadoes associated with them, and (*iii*) it has also been mentioned that any thunderstorms and tornadoes which occur with tropical storms usually occur with these cells and in general the associated weather is squally.

(c) *Bright band phenomenon — Dissipating phase of the storm*

Towards the evening of 27 October 1968 at about 1730 IST the radar picture (Fig. 1f) depicted a different situation. It is interesting to note that a line of thunderstorm echoes that extended from south to northeast of the station had disappeared and convective activity around the station decreased considerably. These cells were seen decreasing both in area and intensity. This indicates that the decay of the storm had begun. No radar watch was maintained after 1730 IST. Next day on 28 October 1968 the radar picture was attempted at 0905 IST (Fig. 1g), when the cyclonic storm has weakened and moved in land near Puri. This was clearly indicated by the presence of another echo feature 'Bright Band'. The height was estimated to be about 4.5 km which was confirmed as the height of 0 deg. C isotherm. That means that convective activity around the station had ceased by 28th morning giving rise to stable weather.

Austin and Bemis (1950) observed the phenomenon after convective activity had subsided. In India the phenomenon was observed over Pune (Gupta *et al.* 1955) and Dum Dum (De 1962).

3. Associated cyclonic track and rainfall

(a) *Cyclonic storm track*

Fig. 2 shows the track of the storm based on official bulletins, issued by the India Meteorological Department.

A depression formed in the Bay of Bengal developed into a severe cyclonic storm on the morning of 24 October 1968 with a core of hurricane winds and started moving northnortheastward, at 8 kt towards Orissa coast. The

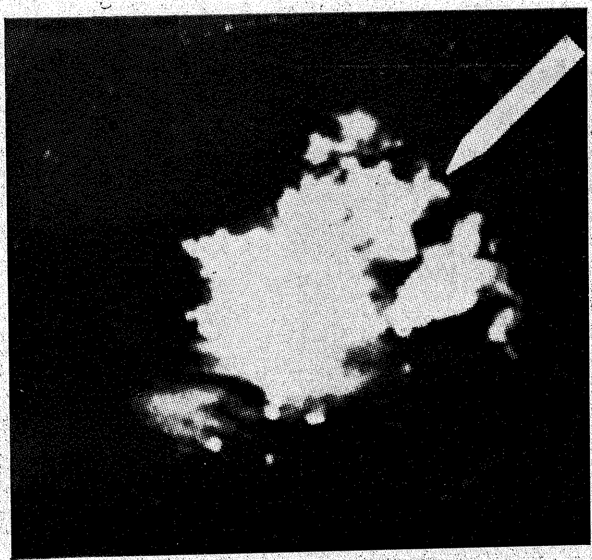

Fig. 1(a). Widespread precipitation associated with thunderstorm echoes on PPI (27 October 1968, 1125 IST, El. 9°, R-40 km)

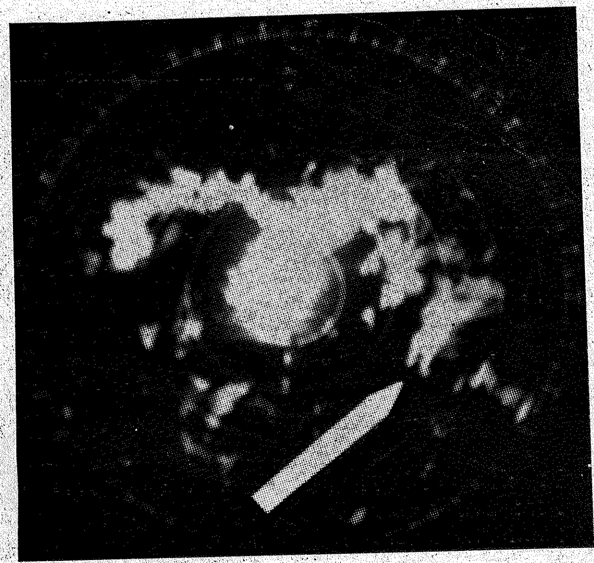

Fig. 1 (b). PPI display showing thunderstorm echoes in curved line pattern (27 October 1968, 1145 IST, El. 2°, R-40 km)

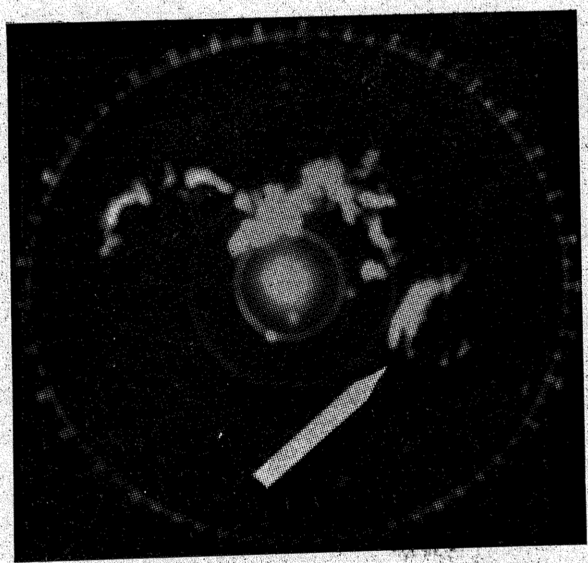

Fig. 1 (c). PPI display with reduced receiver gain. The location of the finger shape echo is indicated by an arrow (27 October 1968, 1150 IST, El. 2°, R-40 km)

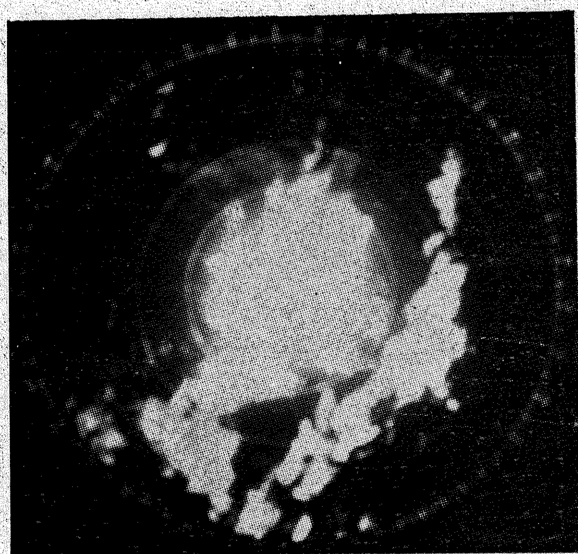

Fig. 1 (d). Typical line thunderstorm echoes associated with squall (a hook shown by an arrow) on PPI presentation (27 October 1968, 1245 IST, El. 2°, R-40 km)

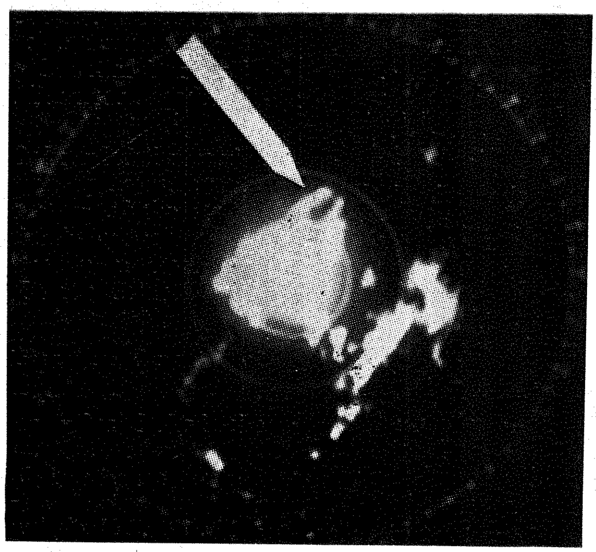

Fig. 1 (e). PPI (Fig. 1d) with receiver gain reduced. A protuberance shown by an arrow (27 October 1968, 1250 IST, El. 2°, R-40 km)

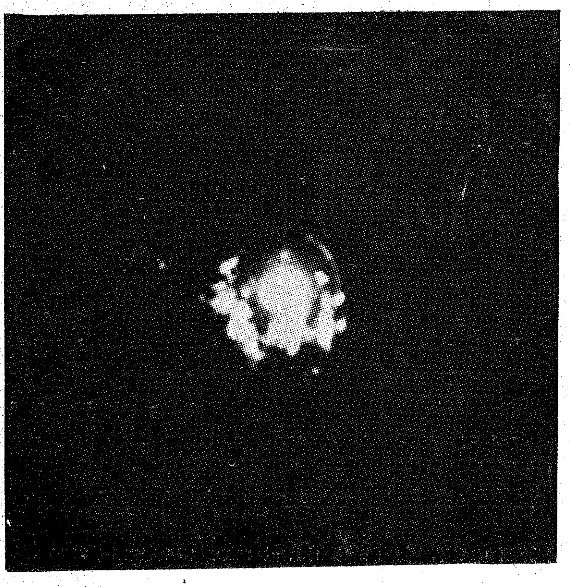

Fig. 1 (f). PPI showing reduced activity of thunderstorms (27 October 1968, 1730 IST, El. 2°, R-40 km)

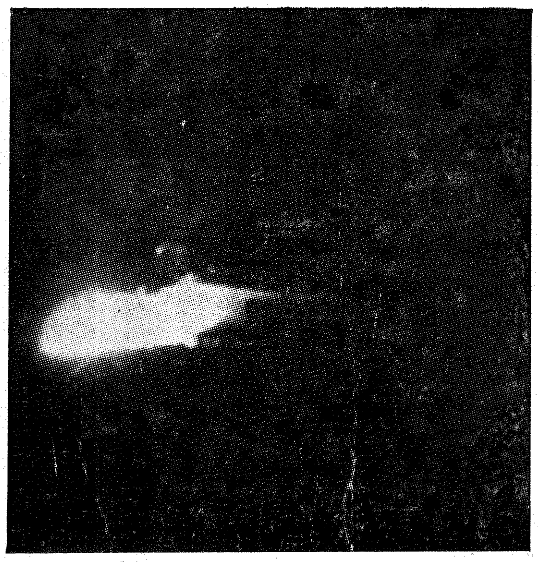

Fig. 1 (g). RHI showing bright band (28 October 1968, 0905 IST, R-40 km)

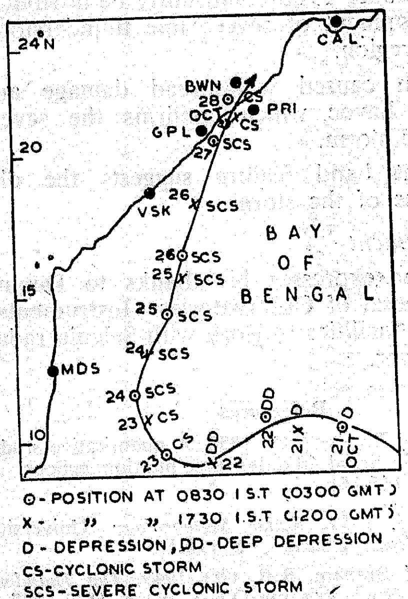

Fig. 2. The track of the cyclonic storm of Bay of Bengal

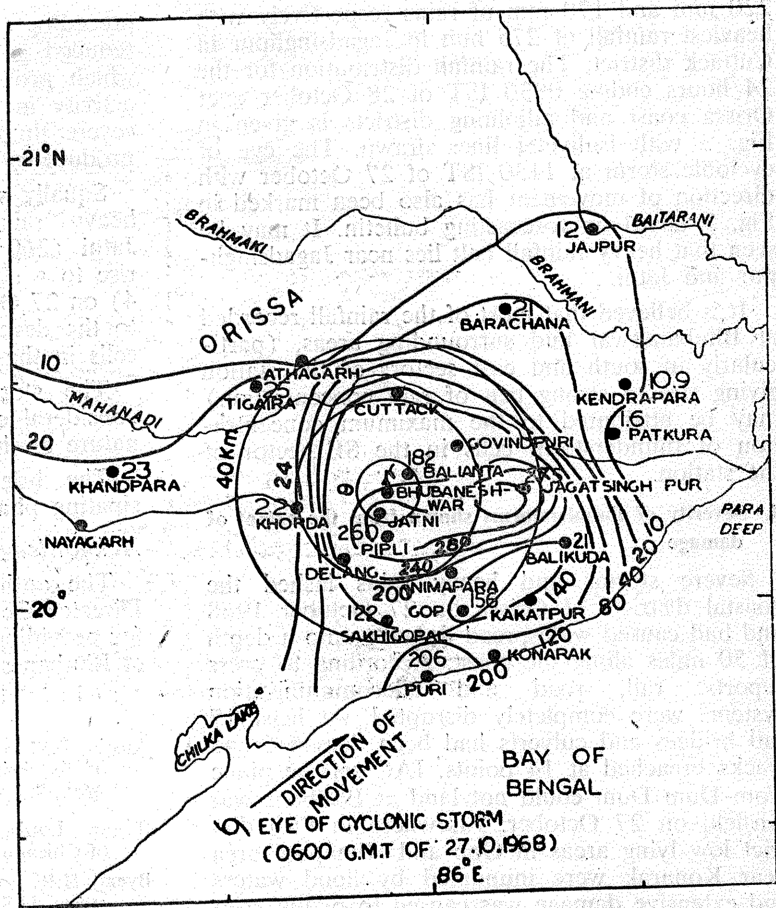

Fig. 3. Rainfall distribution for the last 24 hours ending 0830 IST on 28 October 1968 over Orissa coast and adjoining districts with isohyetal lines

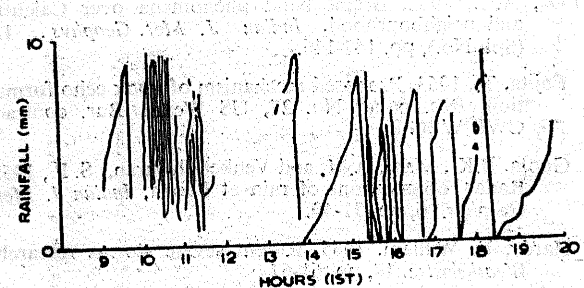

Fig. 4. Autographic rainfall record at Bhubaneswar Observatory on 27 October 1968

storm centred at 0830 IST on 27 October, about 70 km southeast of Gopalpur and by 1130 IST of 27 October, the centre was found near Lat. 19.5 deg., Long. 85.5 deg. E. The severe cyclonic storm weakened into a cyclonic storm and was close to Orissa coast near Puri at 0830 IST of 28 October. Deep depression remained practically stationary and weakened further into a depression centred near Bhubaneswar at 1730 IST the same day. The depression weakened further without any appreciable movement.

Thus at the time of taking radar observations the centre of severe cyclonic storm was near Chilka lake 19.5 deg. N, 85.6 deg. E (Fig. 3) and the storm had not moved in land. Under the influence of northnortheastward movement of cyclonic storm accompanied with a core of hurricane winds towards the Orissa coast, the incursion of moisture must have resulted in creating ripe conditions for violent convective activity such as the development of severe line thunderstorm with squally weather around the station as evident from a series of PPI photographs (Figs. 1a-e).

(b) *Rainfall*

From the autographic record of rainfall of 27 October 1968 of Bhubaneswar observatory (Fig. 4), it was estimated that an amount of 84.2 mm of rainfall between 1130 IST to 1730 IST (six hours), showing strong intensity of rainfall during the period when radar pictures under study were attempted. The above rainfall might have fallen from severe line thunderstorm cells situated in SE sector at 1245 IST that reached the station later around 1530 hr.

Bhubaneswar and Cuttack recorded 80 mm and 60 mm of rain upto 0830 hr of 27 October but for the next 24 hours the rain activity increased considerably and these places recorded

220 mm and 170 mm of rains respectively with heaviest rainfall of 275 mm in Jagadsinghpur in Cuttack district. The rainfall distribution for the 24 hours ending 0830 IST of 28 October over Orissa coast and adjoining districts is given in Fig. 3 with isohyetal lines drawn. The eye of cyclonic storm at 1130 IST of 27 October with direction of movement has also been marked in Fig. 3 based on forecasting bulletin. It may be seen that heavy rainfall belt lies near Jagadsinghpur and Jatni.

It is believed that most of the rainfall recorded at Bhubaneswar and surrounding areas, (particularly in south and east sectors of the station giving rise to strong belt of rain concentration) may be attributed to the maximum concentration of thunderstorm cells in the SE sector of the station.

4. Severity of thunderstorms shown from the extent of damage

Severe storms and heavy rains lashed the coastal districts of Orissa on 27 October 1968 and had caused widespread damage upto a depth of 50 miles along the coast. According to press reports, rail, road and telecommunication systems were completely disrupted. At least 17 rail bridges and culverts had been damaged and tracks breached at 14 points. IAC service plane from Dum Dum could not land at Bhubaneswar Airfield on 27 October. Elsewhere in Puri district low lying areas in Gop and Nimapara area near Konarak were inundated by flood waters and extensive damage was caused to paddy crop which was almost ready for harvesting. A large number of house tops were blown off. Heavy damage to coconut orchards in the same district had been reported. Giant Banyan and Pipal trees were dislodged by the severe storms accompanied with high velocity winds. The Jagadsinghpur subdivision over which squall lines formed was the worst hit zone where many government and private houses and wide acreage of paddy crop had been damaged.

According to press report, at one spot on the Tapang-Nirakarpur section, a 600 ft long bank of 15 feet high washed away on both the up and down lines and both the tracks literally shifted by 50 ft. This could happen only due to severe squally weather in the region.

5. Conclusions

From the foregoing discussions, it is interesting to emphasise that observations made in the present investigations have revealed the following features:

That under severe thunderstorm activity, precipitation echoes on PPI presentations are characterised by areas with sharply defined contours and high echo intensity indicating the strongly convective nature of clouds present throughout.

That the characteristic echoes like hook shape and protuberances (finger like) described in the preceding paragraphs could be detected at reduced gain settings with 3 cm Selenia radar which provided the evidence of severe weather activity in association with squall line types of severe thunderstorms and might not necessarily produce hail or tornado.

Squally weather at the station and a part of heavy rainfall at Bhubaneswar (220 mm), Jatni (260 mm) and surrounding areas giving rise to a strong belt of rain concentration (Fig. 4) on 27 October 1968 could fairly be attributed to the development of severe line thunderstorm cells in the region.

The storm caused widespread damage and considerable havoc which confirms the severe nature of the storm.

The bright band feature suggests the dissipating phase of the storm.

Acknowledgement

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