Wehrtechnische Dienststelle 71

C r u i s e R e p o r t

r/v ELISABETH MANN BORGESE

Cruise- No. EMB 164

This report is based on preliminary data

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1. **Cruise No.:** EMB 164

2. **Dates of the cruise:** from 05.09.2017 to 18.09.2017

3. **Particulars of the research vessel:**
   Name: ELISABETH MANN BORGESE (EMB)
   Nationality: Germany
   Operating Authority: WTD71

4. **Geographical area in which ship has operated:**
   Sognefjord, Norway

5. **Dates and names of ports of call**
   daily entering and leaving of port of Høyanger, Norway, from Friday, 8th (first entering), to Friday, 15th (last leaving), of September 2017

6. **Purpose of the cruise**
   Purpose of the research cruise *blueFLAME2017* was to gain a deeper scientific understanding of the noise generation mechanisms in the near-field of submerged mechanical structures surrounded by turbulent boundary layers. The research is based on results obtained from the preceding sea trials *yellow*FLAME2013 (EMB056), *blazing*FLAME2014 (EMB084), *cool*FLAME2015 (EMB112), and NovEMBer2016 (EMB144).

7. **Crew:**
   Name of master: Uwe Scholz
   Number of crew:

8. **Research staff:**
   Chief scientist: Dr. Jan Abshagen

   Scientists: Dr. Volkmar Nejedl, Thomas Krönert

   Engineers: Jörg Schulz, Kai Haacks

   Technicians: Rainer Kühl

9. **Co-operating institutions:** University of Kiel, Germany

10. **Scientific equipment**

    - Towed body (FLAME) for measurements of flow-induced noise at towing depth between 90 m and 200 m

    - Freely drifting buoy with underwater sound transducer for sensor calibration of FLAME towed body

    - On-board CTD of RV EMB for measurements of sound speed profiles

11 General remarks and preliminary results

11.1 Introduction

During the measurement period of the research cruise *blue*FLAME2017 (EMB164) from 08^{th} to 15^{th} of September 2017 underwater experiments were conducted with RV ELISABETH MANN BORGESE in central Sognefjord, Norway. The research cruise both started and ended at WTD71 in Kiel on September, 5^{th}, and 18^{th}, respectively.

Figure 1: RV ELISABETH MANN BORGESE in Sognefjord (south of Høyanger), Norway, on Friday, 8th, September 2017.

Pictures of RV ELISABETH MANN BORGESE entering the measurement area south of Høyanger on Friday, 8th, can be seen in Figure 1. The underwater measurements were performed with the FLAME (Flow Noise Analysis and Measurement Equipment) towed body in the same way as in the preceding research cruises *yellow*FLAME2013 [1], and *blazing*FLAME2014 [2], and *cool*FLAME2015 [3] that took place between 2013 and 2015. On three measurement days a drift buoy with an appended underwater transducer was additionally operated in order to calibrate the hydroacoustic sensors on-board of the towed body. Transducer calibration measurements were also performed on two other days during the measurement period.

The primary scientific aim of the research cruise was to deepen the understanding of flow noise generation in the near-field of mechanical structures surrounded by turbulent boundary layer with the aid of advanced sensor technology. A principle description of measurement system and procedure as well as an embedding of the work into the field of research can be found in the cruise reports [1–3] as well as in scientific publications [5–7].

11.2 Course of Research Cruise

After loading RV ELISABETH MANN BORGESE in Kiel at WTD71 on Tuesday, 5th, the research vessel departed on the same day at 7 p.m. and arrived after a journey of two and a half days through the Great Belt, the Kattegat, the Skagerrak, and the North Sea in the measurement area in central Sognefjord, Norway, on Friday, 8th. Towing tests with FLAME towed body were started immediately at arrival and took two days. These test were aimed to the acceptance of the towed body's measurement system that was modified since its preceding operation in the research cruise *cool*FLAME2015 in 2015.

In the following towing experiments with the FLAME towed body and a freely drifting projector buoy were conducted on three measurement days (Sun., 10th, Tue., 12th, Thu.,14th), while on two days (Mon., 11th, Wed., 13th) two different projectors were calibrated. The calibration was performed with different CW pulses and LFM sweeps by letting a projector as well as calibrated hydrophones down from the drifting research vessel. On Friday, 15th, technical work was performed, before RV ELISABETH MANN BORGESE started the return journey to Kiel just before 10 a.m.. It entered the harbor of WTD 71 in Kiel on Monday, 18th, at 7:40 a.m., where it was unloaded on the same day. A time schedule of the research cruise *blue*FLAME2017 is given below:

Date	Harbor	Leaving	Launching (started)	Config.	Runs	Recover (finished)	Entering
05.09.	Kiel	1900		-	-	-	(0740)
06.09.	-	-	-	-	-	-	-
07.09.	-	-	-	-	-	-	-
08.09.	Høyanger	-	0905	towing test	5	1610	1650
09.09.	Høyanger	0730	0900	towing test	3	1505	1540
10.09.	Høyanger	0730	0948	tow.exp./buoy	9	1700	1850
11.09.	Høyanger	0800	1230	calibration	8	1523	1620
12.09.	Høyanger	0730	0945	tow.exp./buoy	7	1629	1740
13.09.	Høyanger	0730	0840	calibration	10	1125	1245
14.09.	Høyanger	0800	1022	tow.exp./buoy	7	1640	1810
15.09.	Høyanger	0800	-	techn. work	-	-	0940
16.09.	-	-	-	-	-	-	-
17.09.	-	-	-	-	-	-	-
18.09.	Kiel	-	-	-	-	-	0740

In total 49 measurement runs have been performed with six different configurations within the measurement period. On each measurement days sound speed profiles were recorded with the on-board CTD probe of RV ELISABETH MANN BORGESE. All of the proposed scientific issues have successfully been addressed during the research cruise.

11.3 Underwater experiments

During the research cruise *blue*FLAME2017 several measurement systems were operated. The main system was the FLAME towed body, that is shown in Fig. 2 (a) during launching from RV ELISABETH MANN BORGESE in Høyanger fjord. Inside and at the surface of this towed measurement system a variety of hydroacoustic and other sensors as well as the data recording system are incorporated. For instance, an electromagnetic velocity sensor (black dot) can be seen in the picture. During the measurement the towed body moved at constant speed on a straight track at a depth between 90 m and 150 m. More details about the measurement system and the measurement procedure can be found in [5–7].

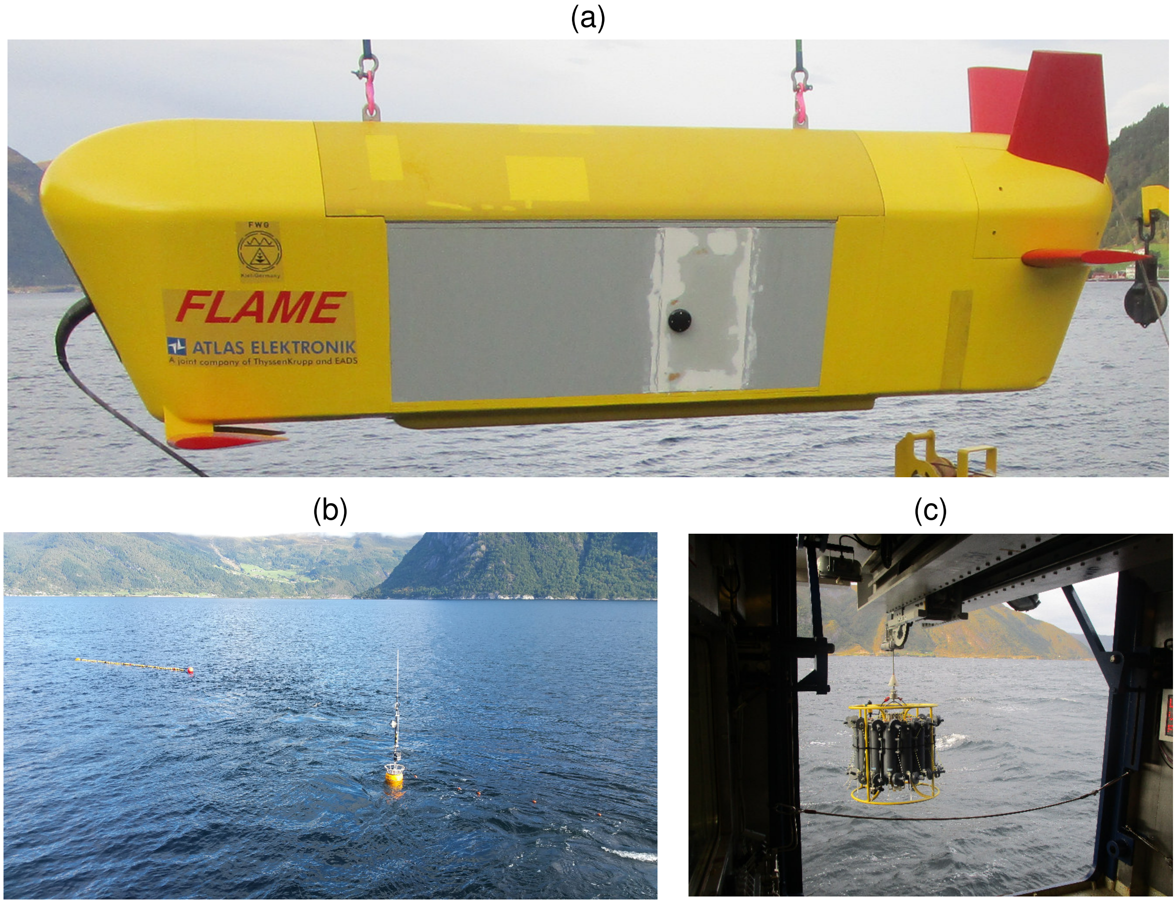

Figure 2: Pictures of measurement equipment used during *blue*FLAME2017: FLAME towed body measurement system during launching in Høyanger fjord (a), freely drifting projector buoy directly before recovering in Sognefjord (b), and CTD probe installed on-board of RV ELISABETH MANN BORGESE (c).

On three measurement days the towed body was operated together with a freely drifting projector buoy in the same was as in preceding research cruises [1–3]. A picture of the buoy system with communication unit (foreground) and the projector unit (below yellow buoy chain in the background) can be seen Fig. 2 (b). The projector is mounted to a submerged electronic unit and operated at about 90 m depth. The drifting buoy system was launched and recovered in Sognefjord before and after the towed body, respectively. Directly before launching of measurement equipment the sound velocity profile was determined on each measurement day with the on-board CTD probe of RV ELISABETH MANN BORGESE (Fig. 2 (c)).

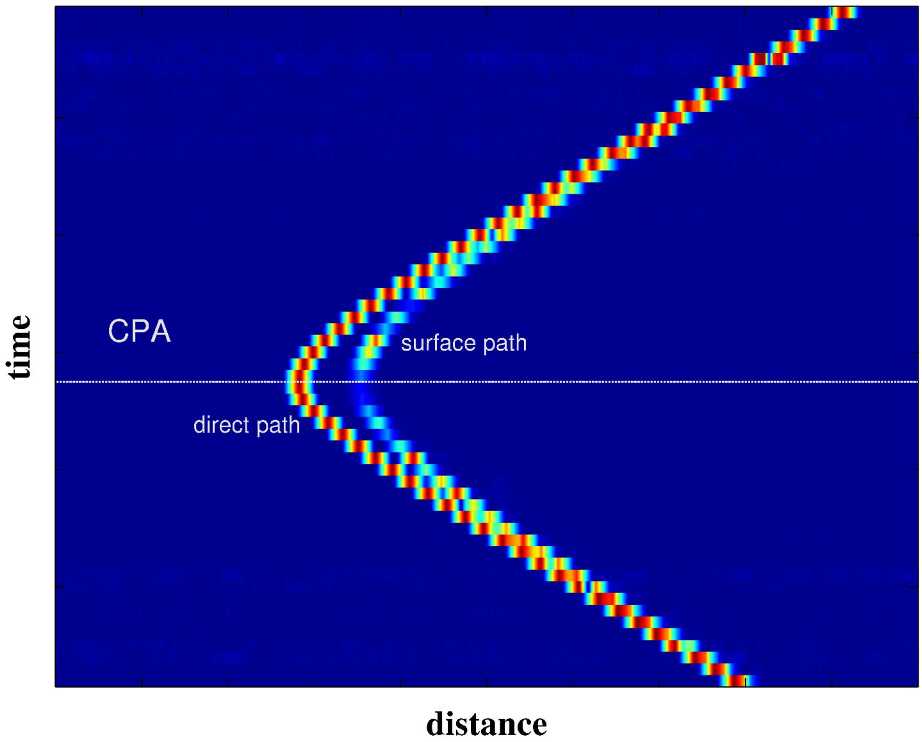

Figure 3: Distance between (drifting) projector buoy and (moving) FLAME towed body while passing the buoy on a straight track. The shortest distance corresponds to the closest-point-of-approach (CPA). In the vicinity of the CPA the surface path is significantly longer than the direct path. Distances are determined from emitted signals with a matched filter.

During a measurement run the FLAME towed body went at constant speed on a straight track at the same depth as the projector. It passed the projector buoy at a minimum distance of about 150 m, the so-called closest-point-of-approach (CPA). During a measurement run hydroacoustics signals (CW pulses of LFM sweeps) were emitted from the freely drifting projector buoy with a GPS controlled repetition rate which allows to determine the distance between (drifting) projector and the (moving) towed body. This distance as a function of time is depicted in Fig. 3 for a typical measurement run.

12 CTD measurements

The knowledge of the sound propagation conditions in the measurement area are crucial for any hydroacoustic measurement. The speed of sound in sea water depends strongly on temperature, salinity, and pressure. Due to the oceanic stratification in Sognefjord the speed of sound can vary significantly with depths. During *blue*FLAME2017 the stratification was determined with the on-board CTD probe of RV ELISABETH MANN BORGESE on each measurement day.

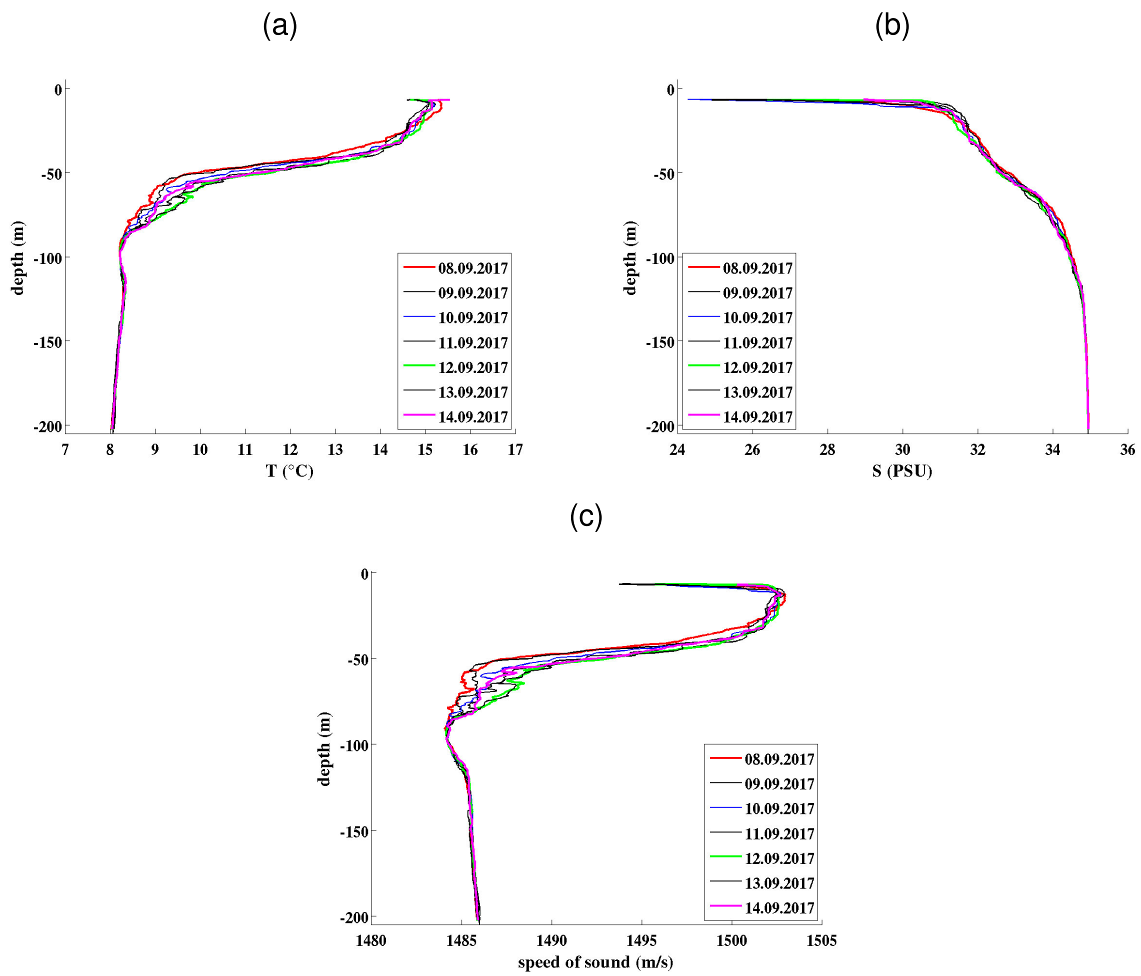

Figure 4: Temperature (a) salinity (b), sound speed (c) profiles of central Sognefjord (south of Høyanger) during the research cruise *blue*FLAME2017.

The vertical temperature and salinity profiles of central Sognefjord during *blue*FLAME2017 are depicted in Fig. 4 (a) and (b), respectively, and the calculated sound speed profiles are shown in (c). From these profile the sound propagation conditions as well the depth of the thermocline are determined. A (weak) variability can be found for each quantity in the water layers above 90 m, the lower boundary of the thermocline, while below the thermocline no significant variability exists. The seven CTD stations were located in central Sognefjord south of the mouth of the Høyanger fjord and measured on successive days from Friday, 8th, to Thursday, 14th, of September. Exact time, position, and depths of the CTD stations are given below:

Date	CTD Station	Time (UTC+2)	Position	Depth (m)	$\bar{c}$ (m/s)
08.09.	0001	06:05:04	61 08.7634N, 5 58.2785E	200.75	1488.37
09.09.	0002	06:08:49	61 08.7909N, 5 58.3153E	200.75	1488.53
10.09.	0003	06:04:03	61 08.7599N, 5 58.3078E	200.75	1488.70
11.09.	0004	06:35:25	61 08.7874N, 5 58.4349E	715.00	1488.71
12.09.	0005	06:06:17	61 08.8184N, 5 58.2988E	200.75	1489.06
13.09.	0006	06:08:20	61 08.7565N, 5 58.3201E	201.00	1488.97
14.09.	0007	06:33:15	61 08.8871N, 5 58.8183E	200.25	1491.03

In Fig. 5 a comparison of the single sound speed profiles (a) and of the mean profiles (b) that were determined in five successive research cruises between 2013 and 2017 is shown.

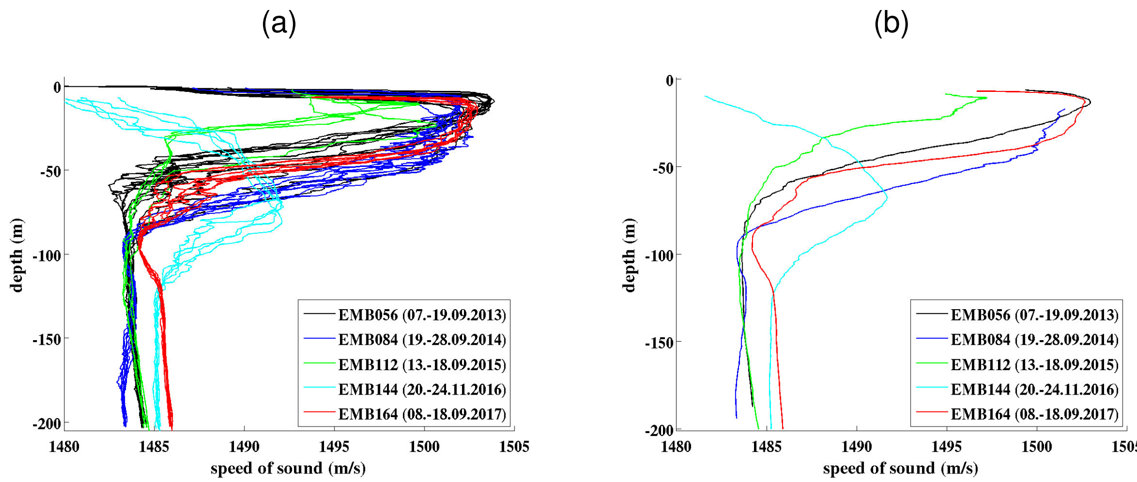

Figure 5: Sound speed profiles of central Sognefjord (south of Høyanger) during the research cruise *blue*FLAME2017 (a) in comparison with profiles from four preciding research cruises [1–4] (b), mean sound speed profiles obtained in five sucessive years.

The measurements were performed each year in September in the same area of central Sognefjord as during *blue*FLAME2017, except in 2016. Those profiles were recorded two months later in the year in November and differ qualitatively from the others. The single sound speed profiles obtained in September are all qualitatively very similar, though above the thermocline they fluctuate significantly on a daily time scale around a mean value. The mean sound speed profile itself varies from year to year, but each year the thermocline was located at about 90 m depths.

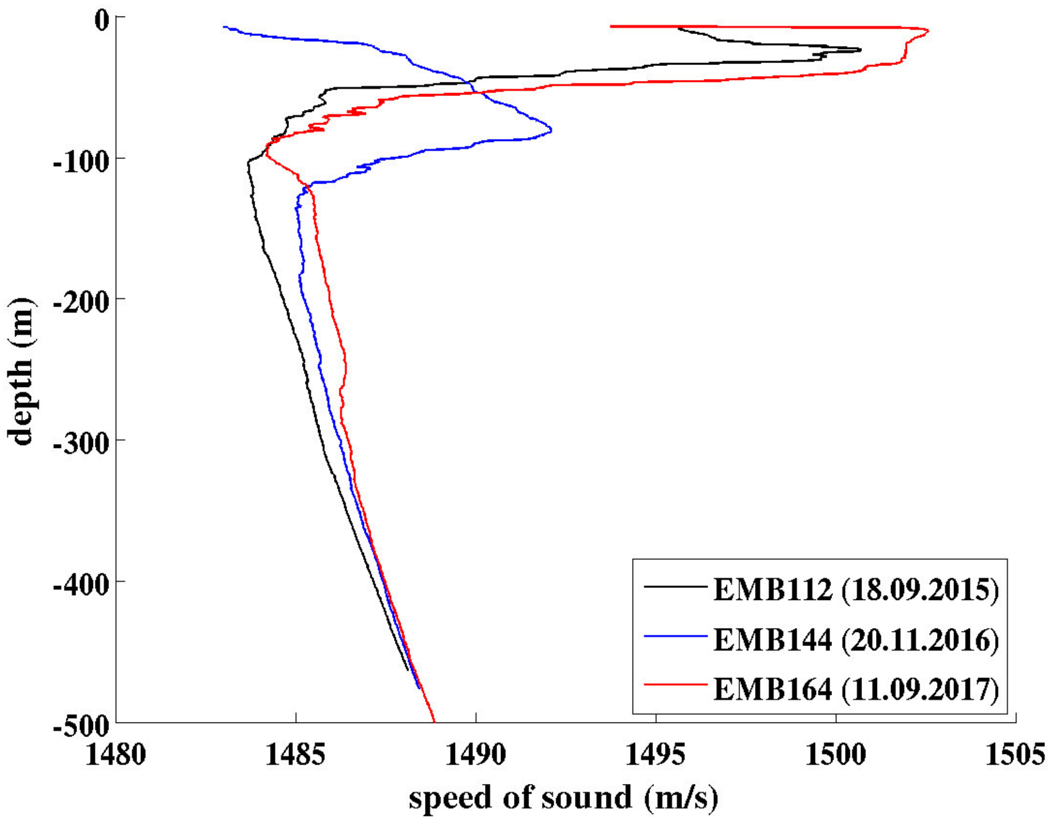

Figure 6: Deep sound speed profiles of central Sognefjord (south of Høyanger) during *blue*FLAME2017 and two preceding research cruises in 2015 and 2016 [3, 4].

A comparison of three deep water profiles depicted in Fig. 6 further reveals a variation in sound speed also below the thermocline in an intermediate water layer that reaches down to a depth of about 300 m. It can seen, however, that the sound speed profiles equalize below 450m. The profiles were determined in three successive year (2015-17).

Acknowledgements

The support from the Captain and all members of the crew of RV ELISABETH MANN BORGESE was again excellent and is gratefully acknowledged.

References

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