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Analysis of the influence of the wind conditions on the possibility of using various SAR crafts in the summer season on the west coast of Poland

Analiza wpływu warunków wiatrowych na możliwości wykorzystania różnych jednostek poszukiwawczo-ratowniczych w sezonie letnim w zachodniej strefie brzegowej Polski

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Key words: search and rescue, wing-in-ground-effect, wind force, Baltic Sea

Abstract
Effective maritime rescue bases on both surface units and aviation. The different types of units are selectively chosen according to their performances. The main operational limitations of a particular unit are weather conditions and vehicle characteristics. In addition to standard units, for purposes of search and rescue, a WIG craft is also applicable. The craft uses so called Ground Effect, therefore is characterized by relatively high speed and low fuel consumption. The article attempts to determine the statistical operational effectiveness of different search and rescue units. The analysis is based on data on wind force and direction, in the period from May to October, in the west coastal zone of Poland. The results of the study allow to compare operational effectiveness of various rescue units. The findings can be used to support planning of search and rescue forces' dislocation and their efficient use.

Słowa kluczowe: ratownictwo morskie, ekranoplan, siła wiatru, Morze Bałtyckie

Abstrakt
Efektywne ratownictwo morskie wykorzystuje zarówno jednostki nawodne, jak i lotnicze. Ze względu na swe właściwości eksploatacyjne poszczególne typy jednostek są selektywnie dobierane do aktualnej sytuacji. Głównymi ograniczeniami operowania daną jednostką są warunki pogodowe oraz cechy pojazdu. Do celów poszukiwania i ratownictwa, oprócz standardowych jednostek, zastosowanie znaleźć mogą również ekranoplany, czyli pojazdy wykorzystujące efekt przypowierzchniowy. Pojazdy te wyróżniają się relatywnie dużą prędkością oraz niskim zużyciem paliwa. W artykule podjęto próbę określenia statystycznej skuteczności operacyjnej poszczególnych jednostek ratowniczych. Analiza bazuje na danych dotyczących siły wiatru w okresie od maja do października w zachodniej strefie brzegowej Polski. Rezultaty badania pozwalają na porównanie stopnia skuteczności operacyjnej różnych jednostek ratowniczych. Wyniki mogą posłużyć do wspomagania planowania rozmieszczenia sił służb ratowniczych oraz ich efektywniejszego wykorzystania.

Introduction

Spring and summer time is characterized by increased sport and touristic activity along polish sea coast. Higher sea and air temperatures, as well as continuously developing water sport industry encourage practicing water sports. In this period, in coastal zone has been observed bigger number of diving and fishing boats, yachts, scooters and also windsurfers and kite surfers, hang-gliders and parachuters, as well as a bigger number of passengers travelling on board ferries and other vessels.

The main risk for these persons are events as follows: fallen overboard, unit capsizing or need of medical transport ashore due to health condition. Along polish coast actions of search and rescue or medical evacuations are more than half number (53–57% in years 2009–2011) of all procedures carried out by the Maritime Search and Rescue Service. The average 75% of these accidents happen in the second and the third quarters of the year [1].

The Maritime Search and Rescue Service (Morska Służba Poszukiwania i Ratownictwa – MSPiR) perform these tasks in cooperation with Maritime Department of Border Guard, Polish Navy and search and mining company LOTOS PetroBaltic SA. The MSPiR consist of water, as well as aerial crafts. Each of them can operate in strictly define weather conditions. For the water crafts most often weather operational criteria is the sea state which is maximal wave height at which the craft can participate in action. For the aerial units the most important criteria are visibility, height of base of cloud, speed and wind direction of during start. Most susceptible to the influence of the wave are RIB Boats which are restricted by the sea state 4 (height of wave up to 2.5 meters), which corresponds to wind speed of 8–10 m/s. SAR Service uses for purpose of search and rescue also different vessels which can operate up to sea state 5–7, as well as boats without any weather restrictions.

The study conducted in article attempts to define operational effectiveness of rescue units which are presently used by MSPiR, as well as new generation units WIG crafts (Wing-In-Ground-Effect Craft) in summer season from May till October on the west part of the polish coast on the basis of wind speed data. For this purpose the coefficient *Summer Operational Effectiveness* (*SOE*) has been used. This coefficient is a value which express amount of time in summer season when there is possibility to use the craft, in aspect of their weather limitation.

Also, other factors such as performance affect the total operating efficiency of the unit. In this article, the authors take only the aspect of influence of wind and sea state.

Characteristic of rescue action and rescue units

The western part of polish coast is coastline from the border with Germany (about 014°13.5' E) to meridian 017°12' E. In this zone the location of rescue stations are as follows: Marine Rescue Sub-Centre in Świnoujście (SWI), Marine Rescue Stations in Dziwnów (DZI), Kołobrzeg (KOL), Darłowo (DAR) and Ustka (UST).

To determine the number of actions carried out by these stations in summer season 2009–2011 the table 1 has been prepared. The term rescue action means any operation executed by the station which include apart of saving life and medical evacuations also accidents connected with saving of property (towing, fire fighting, pulling off from shallow water, etc.), as well as oil pollution prevention.

Table 1. The number of rescue operations conducted in the second and third quotes of 2009–2011 (number for entire year in brackets) from rescue stations: Świnoujście (SWI), Dziwnów (DZI), Kołobrzeg (KOL), Darłowo (DAR), Ustka (UST) [1]

Tabela 1. Liczba akcji ratowniczych prowadzonych w sezonach letnich w okresie 2009–2011 (w nawiasie podano liczbę dla całego roku) z miejsc bazowania jednostek MSPiR: Świnoujście, Dziwnów, Kołobrzeg, Darłowo, Ustka [1]

	Summer season			Sum of the rescue actions	Percentage of actions on west coast
	2011	2010	2009		
Świnoujście	9 (12)	9 (12)	9 (14)	27 (38)	17.3 (18.8)
Dziwnów	10 (13)	7 (7)	7 (11)	24 (31)	15.4 (15.3)
Kołobrzeg	22 (25)	24 (26)	15 (23)	61 (74)	39.1 (36.6)
Darłowo	7 (10)	9 (12)	15 (17)	31 (39)	19.9 (19.3)
Ustka	3 (4)	4 (9)	6 (7)	13 (20)	8.3 (9.9)
				156 (202)	

From (Tab. 1) results that in the last three years number of rescue actions conducted by MSPiR stations was 202, which 156 of them happened in summer season (sum of the second and third quarters of each year). The largest number of action were conducted from the Kołobrzeg station (61 in seasons, 74 within whole three years) and the least form Ustka station (accordingly 13 and 20).

On the basis of these data diagram (Fig. 1) have been prepared. Diagram shows percentage number of rescue actions for the particular MSRS stations.

It can be seen from the graph that average value for the considered stations varies in limits of 70–80%. The maximum is 100% (Dziwnów, 2010), minimum value, which is exceptional, is 44% (Ustka, 2010). It's confirmed that the most rescue actions on west part of the polish coast occurred in summer season.

By making more detailed analysis of quantity of the actions, it can be seen a large disproportions. The highest operation activity belongs definitely to Kołobrzeg. For the period of the last three years more than 39% in summer seasons (nearly 37% in whole years) of all actions conducted on the west

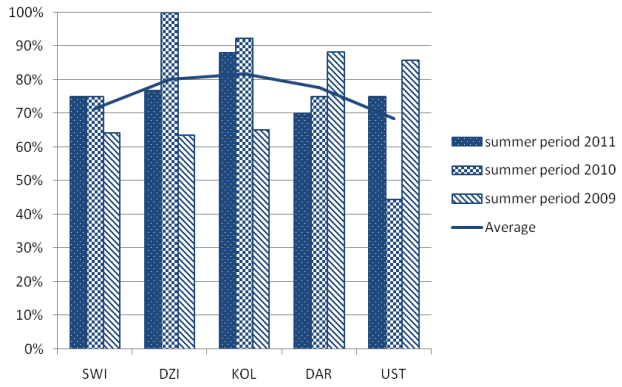

Fig. 1. The percentage rate of rescue operations in the second and third quotes of 2009–2011 conducted from rescue stations: Świnoujście (SWI), Dziwnów (DZI), Kołobrzeg (KOL), Darłowo (DAR), Ustka (UST)
Rys. 1. Procentowy wskaźnik akcji ratowniczych półrocza letniego w okresie 2009–2011 prowadzonych z miejsc stacjonowania jednostek MSPiR: Świnoujście (SWI), Dziwnów (DZI), Kołobrzeg (KOL), Darłowo (DAR), Ustka (UST)

part of the coast were done by Kołobrzeg Station. In stations of Świnoujście, Dziwnów and Darłowo similar number of actions in limits of 15–20% have been noticed. Least active were units in Ustka (average 8% in summer season, 10% in whole years).

Application of any rescue unit in specific type of action depends on the distance between the place of event and rescue station, as well as rescue unit particulars (seaworthiness, speed, autonomy time). Large number of rescue actions conducted by the units from Kołobrzeg station can be explained by its central location, facilitated to take up action both on the east and the west side. On the statistical data of the Central Statistical Office (*pol. Główny Urząd Statystyczny GUS*) [2] arises that Kołobrzeg is the biggest tourist center on the west coast, it means the highest number of people spend time in neighborhood.

Another reason of that disproportion is differentiation of accessible resources. Along west part of the polish coast more than 20 crafts is located. The vehicles belong to MSPiR, but also Polish Navy, Polish Border Guard. Another support comes also from Police, Polish Fire Brigade also Life Guards Organization, but their means are not under consideration. These crafts possess definitely differ operational possibilities, equipment and also assignment.

Each station is equipped with at least two different crafts, which one of them has no weather restrictions (e.g. rescue boats type SAR-1500, SAR-3000 or patrol vessel type SKS-40). Commonly used are also fast boats type RIB (seaworthiness up to sea state 4), but only for short range actions. Other crafts are characterized by weather restrictions up to sea state 5, 6, or 7 (patrol vessels, boats against fire fighting, unit against fighting with oil pollutions). The biggest number of crafts is located in Świnoujście and Kołobrzeg. Additional functions of some units are possibilities of towing, conducting underwater operations, assurance of medical care or equipment transportation. In extremely difficult hydrometeorological conditions the final decision on the involvement of a particular craft for action takes the Rescue Coordination Center in consultation with the master of the unit.

The air crafts are also often applied in search and rescue actions. Polish SAR Service uses helicopter of the Polish Navy and the airplanes (Polish Navy and Polish Border Guard). Their main tasks are mainly search of people or missing objects. Helicopters can also provide direct assistance by picking up injured. Anaconda helicopter has also possibilities to settle on the water.

New generation vehicles which has never been used on the polish coast, but in another parts of the world are WIG Crafts (*Wing-In-Ground Effect Crafts*) also called *Ekranoplanes*. These vehicles use the ground effect phenomenon for flight. The height of the flight is several meters above the water, land or fast ice and depends on wing span. Ground effect is a phenomenon of dynamically air bag which is created between the hull and flat surface. Flight of the unit in such conditions is characterized by relatively high speed in limits between 30–80 knots and at the same time small fuel consumption [3].

WIG Crafts have important advantage above others rescue units, they are faster than water crafts, can land and maneuver in the water, pick up several survivors and also posses ability to raise on higher altitude (WIG Craft type B). Their main restriction are weather conditions. During the flight in influence of ground effect the wave height is very important. The limit of 2.5 m (sea state 4) is the limit for smaller vehicles. Analysis carried out in article checks in what degree these units can be applied on the polish coast.

Study materials

The basic materials used in article were worked out and published in [4] and [5] as monthly sum of days with winds of speed equal or greater than 10 m/s in period 1961–1990 for three survey stations in Świnoujście, Kołobrzeg and Ustka. These information have been applied for calculation of average number of storm days and also for assignation of statistical lower limit of operational effectiveness of rescue units up with seaworthiness up to sea state 4 in summer season.

In article are also used detailed data about wind speed in years 2000–2010 provided by Institute of

Meteorology and Water Management (IMGW). These information include monthly average of wind speed for the whole period, as well as data on wind speed in hourly intervals for summer period of year 2010 (May – October) [6]. These data allow to determine the operational effectiveness of different types of rescue units in summer season in 2010 (Tab. 2).

Table 2. Part of survey data [6]
Tabela 2. Fragment danych pomiarowych [6]

Station	Year	Month	Day	Hour	Wind speed m/s
Świnoujście	2010	5	1	0	3
Świnoujście	2010	5	1	1	2
Świnoujście	2010	5	1	2	2
Świnoujście	2010	5	1	3	3
Świnoujście	2010	5	1	4	3
Świnoujście	2010	5	1	5	3
Świnoujście	2010	5	1	6	3
Świnoujście	2010	5	1	7	3
Świnoujście	2010	5	1	8	3
Świnoujście	2010	5	1	9	4
Świnoujście	2010	5	1	10	4
Świnoujście	2010	5	1	11	4
Świnoujście	2010	5	1	12	3
Świnoujście	2010	5	1	13	3
Świnoujście	2010	5	1	14	4
Świnoujście	2010	5	1	15	3
Świnoujście	2010	5	1	16	3
Świnoujście	2010	5	1	17	2
Świnoujście	2010	5	1	18	6
Świnoujście	2010	5	1	19	1
Świnoujście	2010	5	1	20	2
Świnoujście	2010	5	1	21	1
Świnoujście	2010	5	1	22	2
Świnoujście	2010	5	1	23	1

Survey stations of IMGW are mainly situated in unsheltered waterside coast of The Baltic Sea. For purpose of analysis it was assumed that the speed and direction of winds noted on survey stations can be applied for narrow zone of the coast, despite of presence of friction coefficient or station altitude difference. That coastal area is place of the most number of tourist accidents.

Table 3. Table of wind speed and sea state (own study on the basis [7])
Tabela 3. Tabela prędkości wiatru i stanu morza (opracowanie własne na podstawie [7])

Wind speed [m/s]	0	1–3	4–5	6–7	8–10	11–13	14–17	18–21
Beaufort Number	0	1–2	3	4	5	6	7	8
Sea State	0	1	2	3	4	5	6	7
Wave Height [m]	0	< 0.1	0.1–0.5	0.5–1.25	1.25–2.5	2.5–4.0	4.0–6.0	6.0–9.0

Data on the sea state over such a long period of time were not archived by IMGW, therefore its value is approximately determined on the basis of wind speed (Tab. 3.)

Operational effectiveness of rescue response forces in the western part of the Polish coast

On the basis of obtained results the statistical calculations and comparative analysis to determine the summer operational effectiveness of rescue crafts was performed. The study was divided into the following steps:

1. Designation of the statistical lower limit of the summer operational effectiveness of rescue units for the crafts up to sea state 4, done by analyzing the number of stormy days of occurring in the summer season over the period 1961–1990.
2. Designation of actual summer operational effectiveness in 2010 for crafts of varying seaworthiness, through the analysis of wind force in hourly surveys and comparison with the analysis of the number of stormy days in the summer season of this year.

Based on data from the period of 30 years (1961–1990) the average number of stormy days per summer season and a percentage indicator of their occurrence in different survey stations has been determined. For the calculations, the following formula (1) was applied:

$$W_y = \frac{y'}{y} \tag{1}$$

where:

y – studied period of time;
y' – number of observations of stormy days in studied period;
W_y – rate of occurrence of stormy days.

The studied period of time y is 5520 days long, which is a product of number of days that occur during summer season from May to October (184 days), a studied time interval of 30 years (1961–1990). The value y' corresponds to the number of stormy days occurred in the studied period of time. The stormy days mean these days in which at least once reported wind's speed greater than or equal to 10 m/s. Wind of such strength, in accordance with (Tab. 3) corresponds to the wind force 5°B and sea state 4 (wave heights up to 2.5 m). These conditions are extreme for the use of "weakest" rescue units (for example RIB Boat, WIG Craft). Analysis of the number of stormy days allow to calculate lower limit of the operational effectiveness of the vehicle (formula (2)), because it was assumed that the day

is stormy, no matter how many hourly surveys of wind force of ≥ 10m/s was in reality. Therefore, daily statistics corresponds to hourly statistics, with 24 surveys of the wind force of stormy strength:

$$EO_y = 1 - W_y \quad (2)$$

where:

EO_y – operational effectiveness,

W_y – rate of stormy days in summer season.

From a logistical viewpoint of planning use a particular craft it is important to determine the statistical lower limit of operational effectiveness, saying that the time of application of this unit most likely will be not shorter than the calculated value. However, thanks to the precise hourly data it is possible to designation real time of its usability for sample period. The fact that on that day there was stormy wind does not mean that these conditions were existed through the whole day and night and the unit cannot be applied in the rest of the day or night. This is particularly important for smaller vehicles whose autonomy is limited by operational parameters such as fuel supply (e.g. RIB boat – only 4 hours).

For the period 1961–1990 the authors have data on the number of stormy days. Thus, these data allow to analyze daily analysis and to determine the lower limit of operational effectiveness of rescue crafts with seaworthiness up to sea state 4 (Average SOE_d). The results are shown in (Tab. 4).

Table 4. Summer Operational Effectiveness SOE of rescue units of seaworthiness up to sea state 4

Tabela 4. Letnia efektywność operacyjna SOE jednostek ratowniczych o dzielności morskiej do stanu morza 4

	1961–1990	2010	
	Average SOE_d	Daily Analysis SOE_d	Hourly Analisis SOE_h
Świnoujście	0.9141	0.8750	0.9620
Kołobrzeg	0.9018	1.0000	1.0000
Ustka	0.9104	0.7446	0.9262

Based on the results, it can say that average SOE of RIB boat or WIG crafts (generally units up to sea state 4) for Świnoujście and nearby water areas stands at 0.914. That means the vehicles could be used on waters adjacent to Świnoujście by 173 days (for 184 days representing the summer season). Very similar results were obtained for stations in Kołobrzeg (166 days – 0.9018) and Ustka (167 days – 0.9104).

Results obtained from analysis of the summer season of 2010 are presented in the second part of, table 4. In terms of daily analysis ($SOE_{d\,2010}$), the operational effectiveness in Świnoujście is 0.875. In comparison, for those result with the average SOE_d (period 1961–1990) the difference of 0.04 can be seen. However, comparison between daily statistyc for 2010 ($SOE_{d\,2010}$) and hourly static in 2010 ($SOE_{h\,2010}$) show that the real potential time of application of those crafts was equal 0.962 of summer time. In 2010 in Kołobrzeg, there has been no surveys wind exceeding 10 m/s, hence result of SOE is 1. For Ustka Station deviation between the average lower limit and the result of daily analysis in 2010 is relatively high (about 0.17). However, the real SOE is greater than the statistical average and amounts to 0.9262.

It can be concluded from the above that the potential time of application of units with seaworthiness up to sea state 4 in the summer season is high and the lower limit remains at 0.90–0.915 for all rescue stations located in the western part of Polish coast.

In order to determine the operational effectiveness of the other rescue units, characterized by various values of seaworthiness, the authors have used hourly data for 2010. These data allow to plot diagrams of distribution of wind speed (Fig. 2) and of operational effectiveness (Fig. 3).

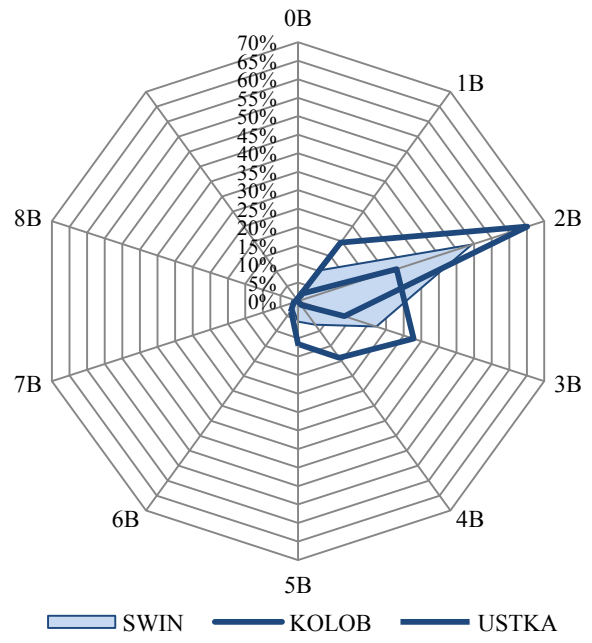

Fig. 2. The frequency of winds from May to October 2010 at the monitoring stations Świnoujście (SWIN), Kołobrzeg (KOLOB), Ustka (USTKA)

Rys. 2. Częstość występowania wiatrów w okresie od maja do października 2010 roku na stacjach pomiarowych Świnoujście (SWIN), Kołobrzeg (KOLOB), Ustka (USTKA)

Figure 2 shows that in summer 2010 on the western coast were prevailing calm wind conditions. The weather station in Świnoujście for more than 70% of the time has observed winds of force 2–3 °B. In Kołobrzeg winds of 2 °B (65% of the

time) were dominated, whereas in Ustka 2–4 °B (almost 80% of the summer season). Such weather conditions conduct to both the large number of people residing in coastal zone and hence the greater number of accidents involving them.

These weather conditions allow also to use other types of rescue units in very wide range. Figure 3 provides the distribution of operational efficiency in 2010 for the western part of polish coast for search and rescue crafts characterized by seaworthiness up to sea state 4, 5, 6 and 7.

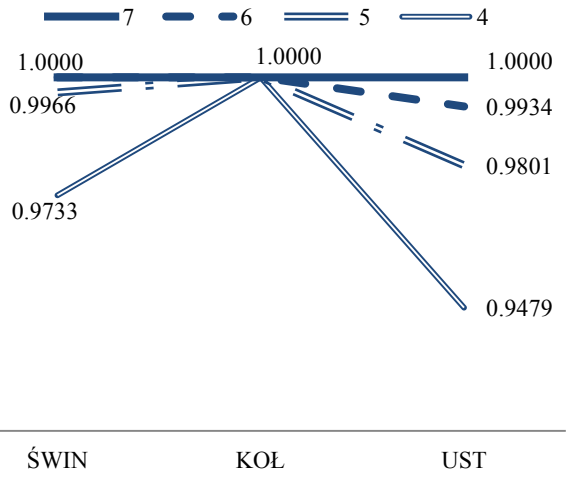

Fig. 3. Summer operational effectiveness in 2010 for rescue units with different seaworthiness on the west part of Polish coast

Rys. 3. Letnia efektywność operacyjna w 2010 roku, jednostek ratowniczych o różnej dzielności morskiej w zachodniej części polskiego wybrzeża

The probability of application units of seaworthiness of 6 and 7 were all over the western part of coast close or equal to 1. More varied results were obtained for crafts characterized by limitation up to sea state 5 (for Świnoujście at 0.9966 to 0.9801 Ustka). While SOE for units with limit up to sea state 4 is set at the level of 0.9733 for Świnoujście and of 0.9479 for Ustka). Due to the very low wind speeds recorded in Kołobrzeg all rescue units stationed there could have been used throughout the summer season 2010.

Summarizing the results of both analyzes, it can be said that even the smallest RIB boats or WIG crafts, which can operate only for a wave height of 2.5 m, are characterized by high summer operational effectiveness in the western part of Polish coast. The statistical average SOE of these crafts is estimated, as shown above, at 0.90–0.915 and their effectiveness in 2010 ranged 0.9479–1.0000 depending on the location.

In the case of WIG crafts, it should be also noted that their effectiveness in the summer season will be even higher, because at the time of the rapidly deteriorating weather conditions, there is the possibility of their independence from the influence of waves by changing altitude.

Although the obtained results, it should be emphasized that the calculations are based on data of wind parameters from the land weather station, so coastal conditions at a greater distance from the shoreline can be characterized by volatility and operating effectiveness also can be changed.

Conclusions

The analysis of wind speed during the summer periods of 1961–1990 and summer of 2010 in the western part of the Polish coast shows that the wind conditions over the entire length of the western part of Polish coast from May to October are similar.

Number of people at risk of potential accidents in the coastal zone increases from year to year, and the modernization of the Rescue response forces should follow it. As demonstrated in the study, for this purpose the WIG crafts can be successfully used. Their weather effectiveness in the summer season is as high as the RIB boat, but they have a great advantage of operating speed and time autonomy. The best location for WIG crafts on the west coast of the Poland is Kołobrzeg.

This is confirmed by two main facts, the largest number of accidents and the middle position on the western shoreline, which allows to cover water areas from Świnoujście to Ustka. Estimated arrival time from Kołobrzeg to Świnoujście or to Ustka would be around 40–60 minutes, in comparison time of SAR-1500 in this path is about 2–2.5 hours, and for patrol boats even up to 3 hours. Due to low autonomy, the RIB boats would take no action in this regard. Therefore, reasonable for efficient rescue systems appears to seeking for innovative technological solutions.

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