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# A5_2 Whatever Floats Your Boat

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**Abstract**

In this article we address the feasibility of using different gases in flotation bags used for marine salvage, and the minimum required volume to begin a salvage lift. Using the details of the SS Edmund Fitzgerald as a basis for the model we found that the minimum volume needed to raise the vessel to be $3.945 \times 10^3 m^3$, relating to 1169 flotation bags. This article does not take into account economic factors of production or isolation of the gases.

## Introduction

On the 10th November 1975 the SS Edmund Fitzgerald, hereafter referred to by the colloquial name the Fitz, sunk in a severe storm approximately 17nmi (nautical miles) outside of Whitefish Bay on Lake Superior, all 29 souls aboard were lost[1]. As a consequence of its sinking, the Fitz split into two pieces spilling the taconite pellets from the cargo hold.

The wreck of the Fitz has only been dived on a handful of times, raising the wreck would allow for a more detailed study and a possible explanation of what decided the fate of the Fitz. The standard procedure would be, as used in this article, to attach flotation devices to the wreck and slowly raise it to the surface. However, this is purely hypothetical for the Fitz as it is the grave site of the crew, and the families wishes are for it not to be disturbed.

## Theory

We investigated the minimum number of flotation bags that would be required to raise one of the sections of the Fitz from the lake-bed, see

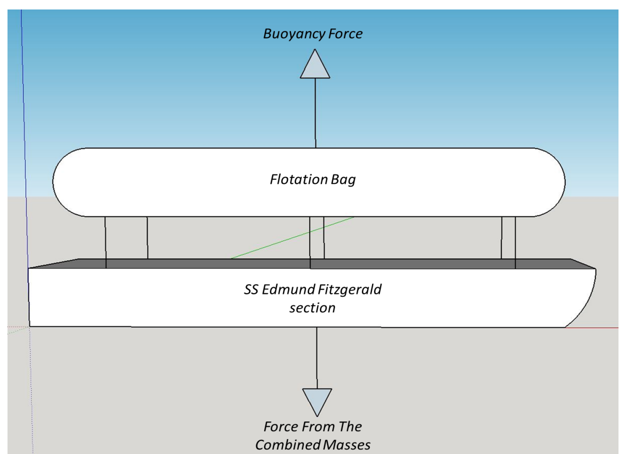


Figure 1: Model for raising the SS Edmund Fitzgerald.

Figure 1 where the single flotation bag shown denotes the total number of bags. We did this for each of the following gases: air, molecular nitrogen, molecular oxygen, carbon-dioxide, argon and methane. We will be using the assumptions that the Fitz split into two equal pieces and all cargo was removed or has fallen from the cargo hold during the sinking, the flotation bags are rigid, cubic in structure, with side 1.5m and negligible mass, and the gases stay in an isobaric state with the surrounding water pressure. We have neglected the effect of drag upon the ship during the raising process as this is does not come to bear on the calculated values. The drag force depends on the speed of the lift, which in turn depends on the magnitude of the lifting force.

By using the buoyancy equation (1), we calculated the lifting force produced by a single bag for each of the different gases.

$$F_{Bag} = \rho_w V g, \quad (1)$$

where $F_{Bag}$ is the buoyancy force for a single flotation bag, $\rho_w$ is the density of water[2] (at 4C as this is the average temperature of Lake Superior[3]), $V$ is the volume of the bag and $g$ is the gravitational acceleration.

These values were then scaled to find the number of bags needed to float the Fitz. The net force $F_B$ was calculated by (2) where $M$ is the mass of the Fitz, 3.94x$10^6$kg (from the Displacement Tonnage)[4] and $m$ is the combined mass of the gases in the bags, calculated from the respective densities at STP (standard temperature and pressure), shown in Table 1[5].

$$F_B > (M + m)g \quad (2)$$

This resulted in the number of bags required to raise one section of the Fitz being 1169 (Air, $N_2$ and $CH_4$) or 1170 (other gases) depending on the chosen gas used. We calculated the number of bags iteratively to produce the minimum amount of bags to give rise to a positive net force upwards on the Fitz.

| Substance | Density (kg/m³) |
|---|---|
| Air | 1.293 |
| $N_2$ | 1.251 |
| $O_2$ | 1.429 |
| $CH_4$ | 0.717 |
| $CO_2$ | 1.977 |
| Ar | 1.784 |
| $H_2O$ | 1000 |

Figure 2: Density Comparison.

## Conclusion

The raising the Fitz from the bed of Lake Superior is physically feasible with a volume of gas between 3.945x$10^3$m$^3$ (Air, $N_2$ and $CH_4$), and 3.949x$10^3$m$^3$ ($O_2$, $CO_2$ and Ar), depending on the chosen gas. This volume is required to lift half of the Fitz; a volume of 3.06x$10^4$m$^3$, calculated as a cuboid from the ship's dimensions[6]. This seemingly low volume of gas required is due to the large disparity between the densities of water and the gases. This method of raising sunken ships appears to have no physical feasibility issues as the volume of gas required is realistic, however as stated in the abstract earlier the economic factors have not been accounted for. The assumptions made earlier may have a significant effect on the required number of bags to elevate the Fitz. We recommend that, for further investigations, pressure change over the lifting process, the compressibility of the gases and flotation bags, as well as the weight of the bags themselves be explored.

## References


[1] National Transportation Safety Board: Report No. NTSB-MAR-78-3

[2] `goo.gl/dXBwrF` accessed on 03/11/16

[3] `goo.gl/XfpNzT` accessed on 03/11/16

[4] `goo.gl/f6UtiL` accessed on 03/11/16

[5] `goo.gl/zf0dtl` accessed on 03/11/16

[6] `goo.gl/hFywHx` accessed on 03/11/16