

Eureka Journal of Education & Learning Technologies (EJELT)

ISSN 2760-4918 (Online)

Volume 2, Issue 4, April 2026



This article/work is licensed under CC by 4.0 Attribution

<https://eurekaoa.com/index.php/2>

ANALYSIS OF LIMITATIONS, UNCERTAINTIES AND DRAWBACKS OF RESIDUAL WATER RETURN SYSTEMS FROM FIRE HOSE LINES

Nurmuhammad Maxkamov

Academy of Emergency Situations of the Republic of Uzbekistan

Azizbek Sadirov

Academy of Emergency Situations of the Republic of Uzbekistan

e-mail: azamafia7@gmail.com

Abstract

This paper presents a comprehensive analysis of the limitations, uncertainties, and drawbacks associated with residual water return systems from fire hose lines based on vacuum methods. The key factors affecting the efficiency of water recovery are examined, including hydraulic losses, two-phase flow behavior, hose deformation, and operational conditions. Measurement uncertainties and their impact on experimental results are also evaluated. It is shown that the effectiveness of water return strongly depends on the hose length, configuration, and technical condition of the equipment. The obtained results highlight the need for improved modeling approaches and more reliable system designs.

Keywords: Fire hose; residual water; vacuum system; hydraulic losses; two-phase flow; uncertainty; fire apparatus.

Eureka Journal of Education & Learning Technologies (EJELT)

ISSN 2760-4918 (Online)

Volume 2, Issue 4, April 2026



This article/work is licensed under CC by 4.0 Attribution

<https://eurekaopenaccess.com/index.php/2>

Introduction

Efficient use of water resources is a critical aspect of firefighting operations, especially in conditions of limited water supply. Fire tankers often serve as the primary water source during the initial stages of fire suppression. However, a significant portion of water remains unused due to residual volumes in tanks and hose lines.

The problem of residual water is particularly important in real operational environments, where hose layouts are irregular and hydraulic conditions are far from ideal. Existing methods for water removal are often inefficient and do not allow the recovery of water back into the system.

The aim of this study is to analyze the key limitations, uncertainties, and technical drawbacks of residual water return systems, particularly those based on vacuum principles.

Limitations of Hydrodynamic Models

The classical approach to describing fluid motion in hose lines is based on the Bernoulli equation:

$$\Delta p = \rho gh + \Delta p_{\text{loss}}$$

This model assumes:

- single-phase flow;
- constant density;
- absence of air;
- stable geometry.

However, in real firefighting conditions, these assumptions are not valid. As a result, theoretical predictions often deviate from experimental observations.

Influence of Two-Phase Flow

During the water return process, a two-phase flow consisting of water and air is formed. This significantly affects system performance.

Eureka Journal of Education & Learning Technologies (EJELT)

ISSN 2760-4918 (Online)

Volume 2, Issue 4, April 2026



This article/work is licensed under CC by 4.0 Attribution

<https://eurekaopenaccess.com/index.php/2>

The effective density of the mixture can be expressed as:

$$\rho_{\text{eff}} = \alpha\rho$$

where:

α — filling coefficient of the hose.

A decrease in α leads to:

- reduced driving force;
- formation of air pockets;
- unstable flow behavior.

Thus, two-phase flow is one of the main factors limiting the efficiency of water return.

Hose Deformation and Stability

When vacuum is applied, the hose is subjected to external atmospheric pressure. If the critical pressure is exceeded, deformation occurs.

The stability condition can be written as:

$$K = \frac{p_{\text{cr}}}{\Delta p}$$

If $K < 1$, the hose collapses, leading to:

- reduction of cross-sectional area;
- increased hydraulic resistance;
- interruption of flow.

This phenomenon significantly limits the allowable vacuum level.

Influence of Hose Geometry

The configuration of the hose line plays a crucial role in water return efficiency. Hydraulic losses increase proportionally:

$$\Delta p \sim \frac{L}{d}$$

Eureka Journal of Education & Learning Technologies (EJELT)

ISSN 2760-4918 (Online)

Volume 2, Issue 4, April 2026



This article/work is licensed under CC by 4.0 Attribution

<https://eurekaopenaccess.com/index.php/2>

where:

L - hose length,
d - diameter.

Additional factors include:

- bends and elevation changes;
- surface irregularities;
- partial filling of hoses.

These factors create local zones where water cannot be removed.

Measurement Uncertainties

Experimental studies of water return systems are affected by measurement errors:

- pressure: $\pm 1-2\%$
- flow rate: $\pm 2-5\%$
- volume: $\pm 3\%$

Total uncertainty may reach:

$\pm 5 - 8\%$

These uncertainties must be considered when validating models and interpreting results.

Operational Constraints

Practical application of return systems is limited by:

- hose wear and condition;
- operator skill level;
- time constraints during firefighting.

Complex systems may reduce usability in real emergency conditions.

Eureka Journal of Education & Learning Technologies (EJELT)

ISSN 2760-4918 (Online)

Volume 2, Issue 4, April 2026



This article/work is licensed under CC by 4.0 Attribution

<https://eurekaopenaccess.com/index.php/2>

Discussion

The analysis shows that water return efficiency is determined by a combination of hydrodynamic and operational factors. Existing simplified models fail to fully describe real processes.

In particular, the lack of models accounting for:

- two-phase flow;
- hose deformation;
- real operating conditions

remains a key research gap.

Conclusions

1. Classical hydrodynamic models have limited applicability in real conditions.
2. Two-phase flow significantly reduces water return efficiency.
3. Hose deformation is a critical limiting factor.
4. Measurement uncertainties affect experimental accuracy.
5. Further research is required to develop improved models and reliable systems.

References

1. Idelchik, I.E. Handbook of Hydraulic Resistance. Moscow: Mashinostroenie, 1992. 672 p.
2. Chugaev, R.R. Hydraulics. Moscow: Energiya, 1982. 672 p.
3. Molchadsky, I.S., Terebnev, V.V. Fire Engineering Equipment. Moscow: Academy of State Fire Service, 2012. 432 p.
4. Terebnev, V.V. Fire Vehicles. Moscow: Academy of State Fire Service, 2006. 365 p.
5. Terebnev, V.V., Podgrushny, A.V. Fire Technical Equipment. Moscow: Academy of State Fire Service, 2015. 390 p.
6. National Fire Protection Association NFPA 1901: Standard for Automotive Fire Apparatus. Quincy, MA: NFPA, 2022.

Eureka Journal of Education & Learning Technologies (EJELT)

ISSN 2760-4918 (Online)

Volume 2, Issue 4, April 2026



This article/work is licensed under CC by 4.0 Attribution

<https://eurekaopenaccess.com/index.php/2>

7. National Fire Protection Association NFPA 1961: Standard on Fire Hose. Quincy, MA: NFPA, 2020.
8. Grimwood P., Sanderson I. A performance-based approach to defining and calculating adequate firefighting water. *Fire Safety Journal*, 2015, Vol. 78, pp. 155–167.
9. Kaufman M.M., Rosencrants T. GIS method for characterizing fire flow capacity. *Fire Safety Journal*, 2015, Vol. 72, pp. 25–32.
10. Svensson S. A study of tactical patterns during fire fighting operations. *Fire Safety Journal*, 2002, Vol. 37, pp. 673–695.
11. Fox, R.W., McDonald, A.T., Pritchard, P.J. *Introduction to Fluid Mechanics*. 8th ed. Wiley, 2011.
12. White, F.M. *Fluid Mechanics*. 7th ed. McGraw-Hill, 2011.