SSRG International Journal of Mechanical Engineering
ISSN: 2348 – 8360 / https://doi.org/10.14445/23942568/IJME-V10I2P102

Volume 10 Issue 2, 9-25, February 2023

Original Article

Mixing Zone of Single Port Submerged Diffuser with Threaded Outlet for Thermal Discharge from Thermal Power Stations

Mofreh A. Hashim[1], Ibrahim R. Teaima[2]

[1]*Water Management Research Institute, National Water Research Center, Egypt.*
[2]*Research Institute Ground Water, National Water Research Center, Egypt.*

Received: 01 January 2023 Revised: 03 February 2023 Accepted: 16 February 2023 Published: 28 February 2023

Abstract *- A lot of Thermal power stations use a once-through cooling system, which causes thermal pollution. That led to changes in the properties of water (physical, chemical and biochemical properties). A single-port submerged diffuser is a method used for the disposal of hot water, and it is in the middle between the surface and the multi-port submerged discharge in comparison with cost and dilution. This study aimed to examine the mixing zone of a single port submerged diffuser with a threaded outlet discharging hot water in ambient water. Three flow rate ratios (Qr) between hot water and ambient water flow were considered (0.2, 0.4, and 0.67). The measurements were at three different water depth ratios; the water depth ratios (H) were 1, 2 and 3. The temperature difference was plotted as* $(\Delta T_f / \Delta T)$ *. The single port submerged diffuser was tested with and without threads, and the results were compared. The study included two types of threads great and fin pitch. The experimental results showed that for a single port submerged diffuser with a great threaded outlet at H =1, 2 and 3 and* Q_r *= 0.2, the mixing zone maximum temperature ratio (*ΔT_{max}*) increased by 1.41%, 1.54% and 62.5%, respectively. The results also showed that, at H =1, 2 and 3 and Qr = 0.4, the* ΔT_{max} *increased by 3.61%, 1.45% and 58.97%, respectively. For Qr = 0.67, the* ΔT_{max} *increased by 6.4%, 1.37% and 18.18%, respectively. The experimental results also showed that, for fin threaded outlet at Qr = 0.2, the* ΔT_{max} *increased by 2.74%, 7.14% and 36%, respectively. Also, at Qr = 0.4, the* ΔT_{max} *increased by 2.35%, 8% and 29.09%, respectively. For Qr = 0.67, the* ΔT_{max} *increased by 1.15%,5.19% and 3.51%, respectively. The results also included the average temperature at the end of measurements (*ΔT_e*) increased by different values in the studied cases. The thread has a bad effect on the temperature distribution in the mixing zone due to the spread obstruction of the hot water in the outlet area. The small thread size has a good effect compared with the great one. Finally, adding a thread at the diffuser outlet does not reduce the mixing zone but increases it and thus reduces temperature dilution.*

Keywords *- Thermal power station, Submerged diffuser, Mixing zone, Temperature distribution.*

1. Introduction

Regarding the Cooling systems of thermal power stations, they use water as a cooling fluid, where cooling water is drawn from any water source, condensed to reject heat and recirculated to the water source (i.e. thermal discharge). This causes thermal pollution, changing the water's chemical, physical and biochemical properties. This reduces the thermal power station efficiency, leading to design limitations that increase cooling system costs. There are two types of cooling systems. These are "once-through cooling systems", where water is drawn from a source and heat is discharged back to the water source as surface discharge or submerged discharge. The mixing zone of thermal discharge is divided into three regions [1]. These regions are near-field, intermediate-region, and far-field regions. The thermal discharge mixing zone characteristics depend on the jet momentum, discharge buoyancy, spreading due to turbulence, ambient density stratification, water-source current configuration, solid boundaries and heat exchange at the surface.

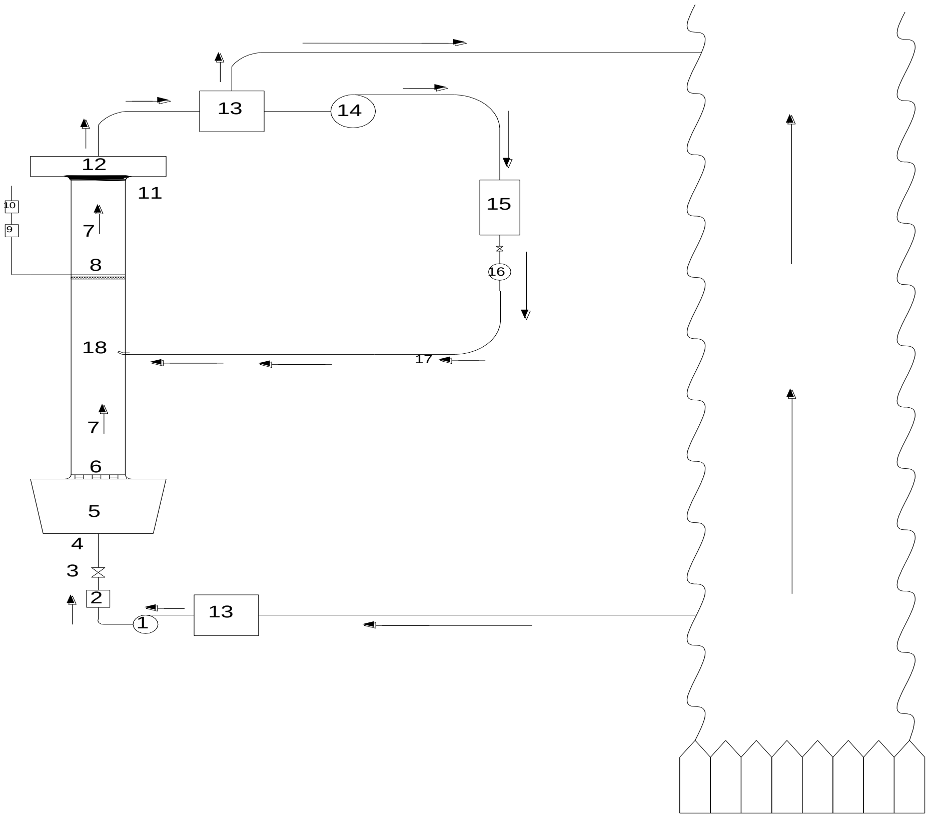
A single-port submerged diffuser is a method used for the disposal of hot water, and it is in the middle between the surface and the multi-port submerged discharge in comparison with cost and heat dilution. Many researchers studied single-port submerged diffuser discharge, such as Ashmawy et al. [2] studied a mixing zone single-port submerged diffuser clogged by the free rotating propeller, and it was found that the propeller increased dilation of hot water discharged from the diffuser. George and Panayotis [3] analyzed dilution from a round vertical jet blocked by a thin concentric disc; results disclosed that blocking the diffuser outlet with a disc increased the dilution rate compared to the unblocked one. Lilun and Lee [5] studied jet blocked with the pierced disc. The results disclosed that using pierced disc raises the dilution rate. Wen-xin et al. [6] studied the buoyant jet from a square diffuser blocked with a square disc discharge in static ambient. Alton et al. [7] scrutinized the thermal plume dilution rate results from a hot water jet discharged vertically from a single port diffuser. The plume height and cross-section area were assessed as functions in nozzle distance, where thermistor probes were implemented to measure the temperature downstream of the diffuser.

Huang et al. [8] scrutinized the dilution of a single-port diffuser. They established 2 semi-practical-equations (i.e. one for centerline dilution and the other for surface dilution). Equations were ruled by the continuity equation and could predict dilution in the near-field area, transition area, and far-field- area. Experiments and measurements designated the constants of the equations. Zeng and Huai [9] conducted experiments to verify a numerical model predicting round buoyant jets in crossflow behavior. Experiments were executed to different cross-jet velocity ratios. Apparent was that the velocity ratio is a very effective parameter for thermal discharge in cross-flow. Marmorino et al. [10] investigated the surface temperature distribution due to the power station cooling system thermal discharge. An infrared camera captured the temperature field. Obviously, in the case of receiving water, the buoyant jet moves symmetrically. In the water current case, the plume stretches downstream. Paik [11] implemented computational fluid dynamics to investigate the mixing of single-port-diffuser thermal discharge. The governing equations were solved by 2nd-order finite-volume. The model was verified against experimental measurements. Apparently, a computational fluid dynamic could simulate thermal discharges with reasonable accuracy.

This study aimed to examine the mixing zone of a single port submerged diffuser with a threaded outlet discharging hot water in ambient water.

2. Experimental Setup and Procedure

A hydraulic research institute built an experimental model to study the adding coarse-thread at the diffuser outlet. The experimental setup and the instruments required to perform the experimental measurements are illustrated schematically in Fig.1, while Fig.2 shows a photograph of the experimental model arrangement.

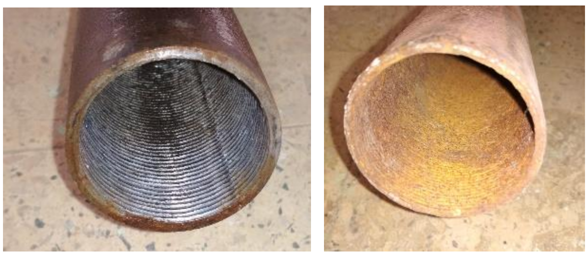


1 Cold water Centrifugal pump
2 Electromagnetic flow meter
3 Gate Valve
4 Inlet ambient cold water pipe
5 Model entrance
6 Screen Box
7 Model
8 Measuring thermistors carriage
9 Scaling units
10 Data logger
11 Revolving tail gate
12 Model exit
13 pumps intake well
14 Hot water centrifugal pump
15 Electric water heater
16 Ultra sonic flow metere
17 Diffuser feed line(5cm diameter)
18 Single port Submerged Diffuser

Fig. 1 Schematic diagram for experimental setup

Experimental model dimensions are 18 m long, 2 m wide, and 1.5m height; the weir has 2 m wide and 0.4 m high. The box contains stones to dissipate energy at the inlet and to avoid any disturbance in the flow. A turning tailgate adjusted the model's water depth by regulating the gate's height. The model ambient water pump flow rate (*Q*) and head (*h*) were 0.07 m^3/s 10 m. The hot water pump flow rate and head were 0.012 m^3/s and 12 m. Electromagnetic and ultrasonic flow meters were used to measure the flow rate of ambient hot water, respectively. The electric water heater worked as a heat source for hot water. To Achieve Flow similarity, the Reynolds number (Re) model was ≥ 2000 and Fr <1 for the model flow [3]. That means the internal friction force can be neglected, so the gravity force is dominant, and all operating conditions were selected to keep satisfactory similarity [4]. Thus similarity between open channel flow and rigid boundaries model is achieved. Experimental work was accomplished to examine the mixing zone of a single port submerged diffuser with a threaded outlet discharging hot water in ambient water. The diffuser outlet diameter is 0.05 m, inclined angle of 30^o in the horizontal direction and 20o in the vertical direction. Water depths above the diffuser surface were one, two and three times the diffuser outlet diameter. The temperature difference (ΔT) between the ambient and hot waters was determined as a constant value of 10 C^o. Surface temperature was measured across the model using thermistors. Fig. 3 shows a single port submerged diffuser with a threaded outlet, and Fig. 4 shows the measurement instruments. Three flow rate ratios (Q_r) between hot and ambient water flow were considered 0.2, 0.4, and 0.67. The temperature difference was plotted as $(\Delta T_f / \Delta T)$. Three water depth ratios above diffuser (*H)* of 1, 2, and 3 were also considered. The single port submerged diffuser was tested with and without thread, and the results were compared.

Fig. 2 The experimental model arrangement



a) **b)**

Fig. 3 Single port submerged diffuser with (a) great threaded outlet (b) fin threaded outlet

a) **b)**

c)

d)

e)

f)

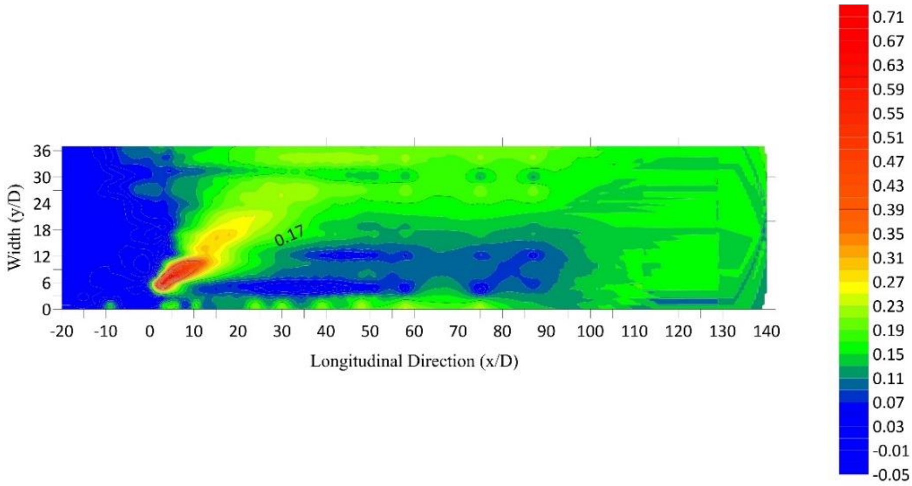
Fig. 4 Measurement instrumentations (a) Temperature measuring system. (b) Measuring sensor box. (c) Sensors connector, Data acquisition. (d) Temperature carriage. (e) Ultrasonic flow meter. (f) Electromagnetic flow meter.

3. Results and Discussion

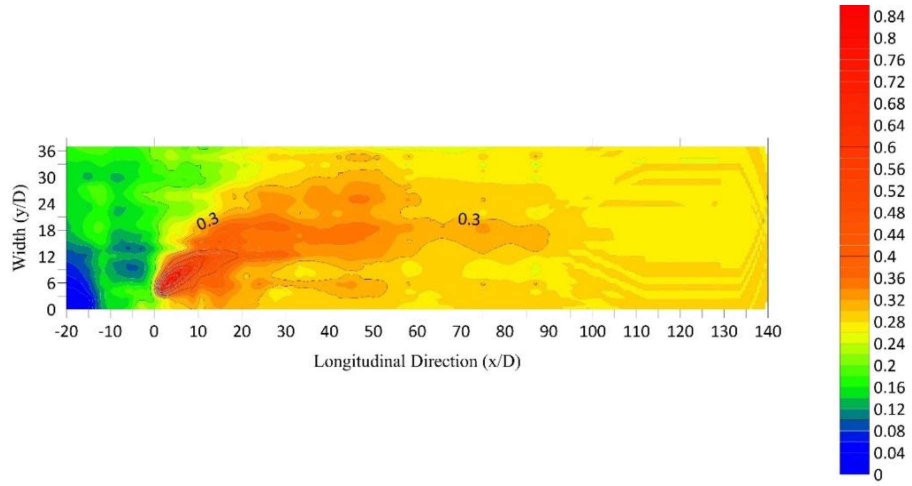
The single port submerged diffuser was tested with and without thread, and the results will discuss in this section. Analysis was executed on the diffuser with threaded results to study the impact of temperature difference on the mixing zone. Hot and ambient water temperatures were continuously measured and adjusted as necessary. The surface temperature distribution was measured across the model using thermistors after reaching steady-state conditions. The surface temperature distribution was measured upstream and downstream of the diffuser. Temperature readings were taken at the selected positions for each experiment. Data acquisition was set to collect temperature measurements three times at each run at each position. In the longitudinal and transverse directions, ΔT was 10 °C. It was apparent that for H = 1, 2, and 3 at ΔT = 10 °C, where 3 flow ratios were considered Qr = 0.2, 0.4, and 0.67. Hot and ambient water temperatures were continuously measured and adjusted as needed. Figures 5, 6 and 7 present the mixing zone temperature distribution for diffusers without threads at H = 1, 2 and 3, respectively and for the three studied flow ratios. The figures clear the variation of the temperature difference $(\Delta T_f / \Delta T)$ in the studied area (mixing zone). The mixing zone length was selected in the longitudinal direction to be *160D* and the vertical direction *36D*. The longitudinal and vertical lengths were sufficient to clear the temperature distribution; after that, the temperature change was not clear. From the figures, it is clear that the increase in the flow ratio at the same depth causes an increase in the water temperature in all areas because of the large amount of hot water amount. The most effective area-to-temperature distribution is from 0 to 100D. The downstream area has small affected by the hot water. The results show the figures also that the temperature difference decreases with the increase of the depth because of the buoyance effect.

The effect of large thread on the temperature distribution is cleared in figures 8, 9 and 10. It is clear from the figures that the thread has a bad effect on the temperature distribution in the mixing zone due to the spread obstruction of the hot water in the outlet area.

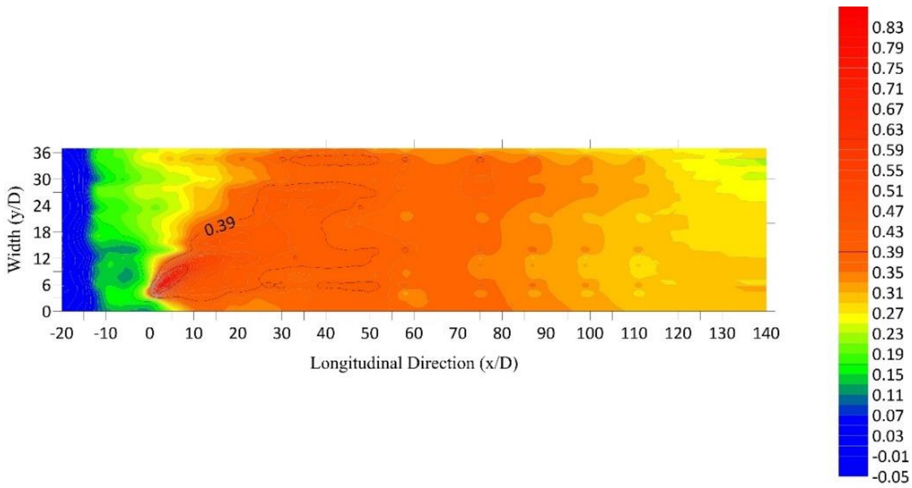
The effect of small thread on the temperature distribution is cleared in figures 11, 12 and 13. It is clear from the figures that the thread has a bad effect on the temperature distribution in the mixing zone due to the spread obstruction of the hot water in the outlet area. The small thread is better than the large thread in temperature distribution.



(a) Q_r =0.2

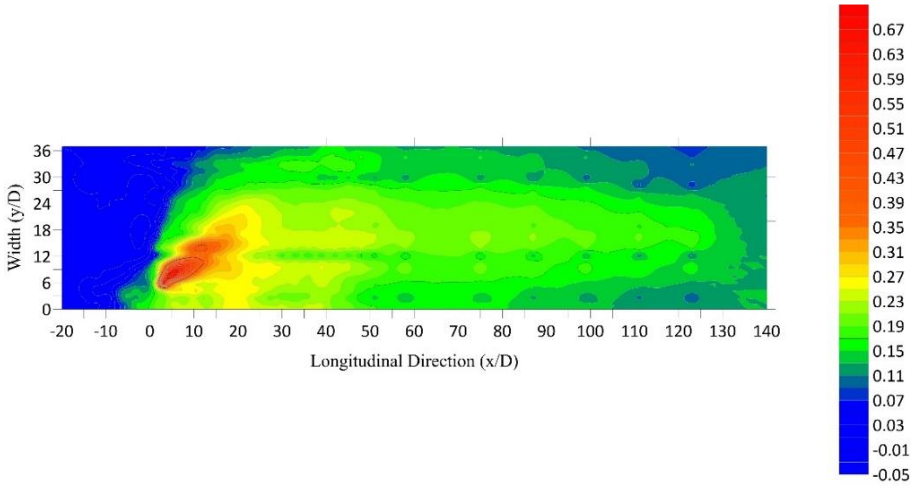


(b) Q_r =0.4

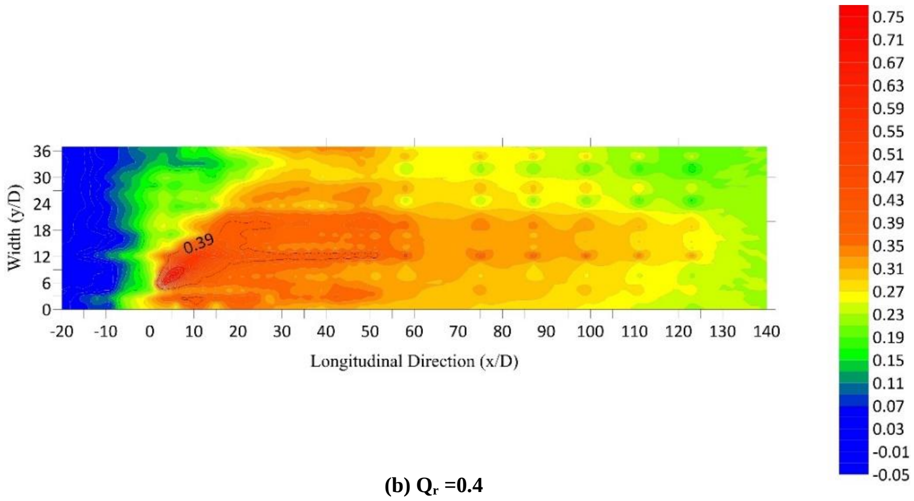


(c) Q_r =0.67

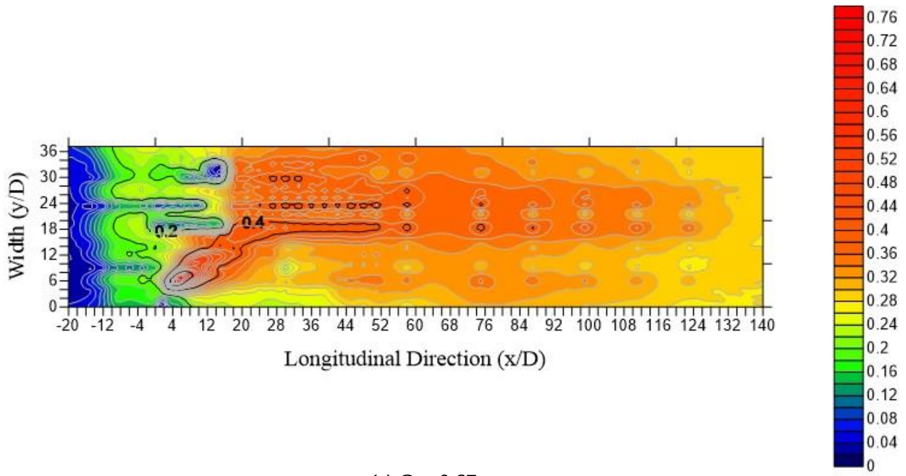
Fig. 5 Mixing zone at H=1 for (a) Qr = 0.2. (b) Q_r = 0.4. (c) Q_r = 0.67



(a) Q_r =0.2

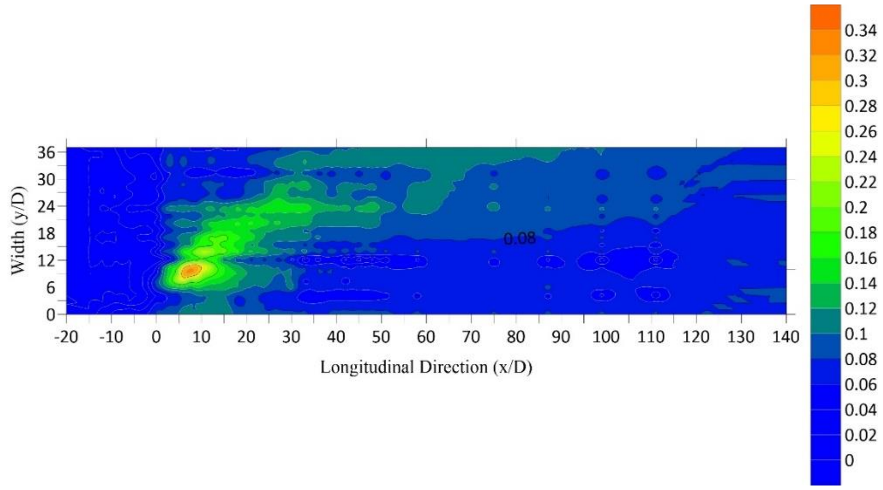


(b) Q_r =0.4

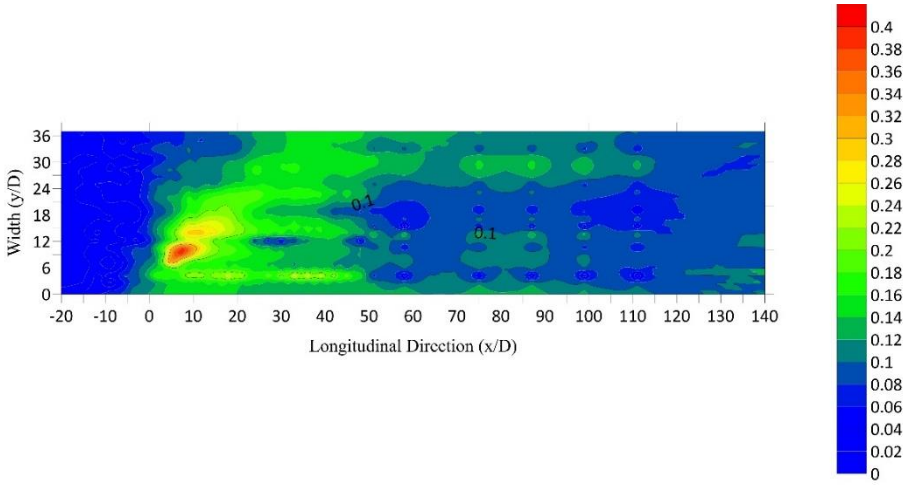


(c) Q_r =0.67

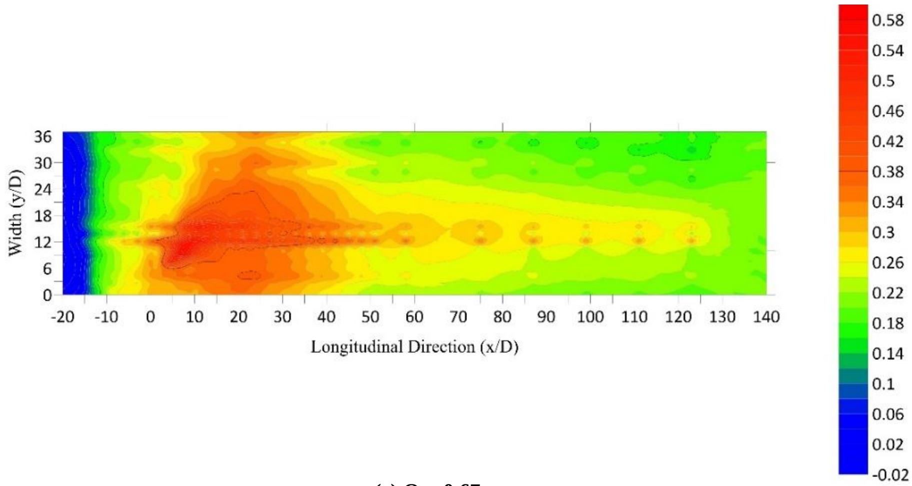
Fig. 6 Mixing zone at H=2 for (a) Q_r = 0.2. (b) Qr = 0.4. (c) Q_r = 0.67



(a) Q_r =0.2

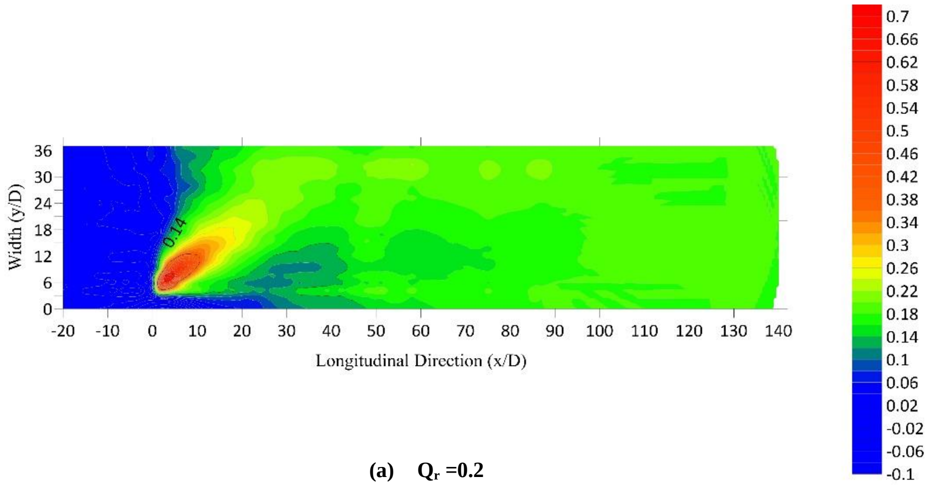


(b) Q_r =0.4

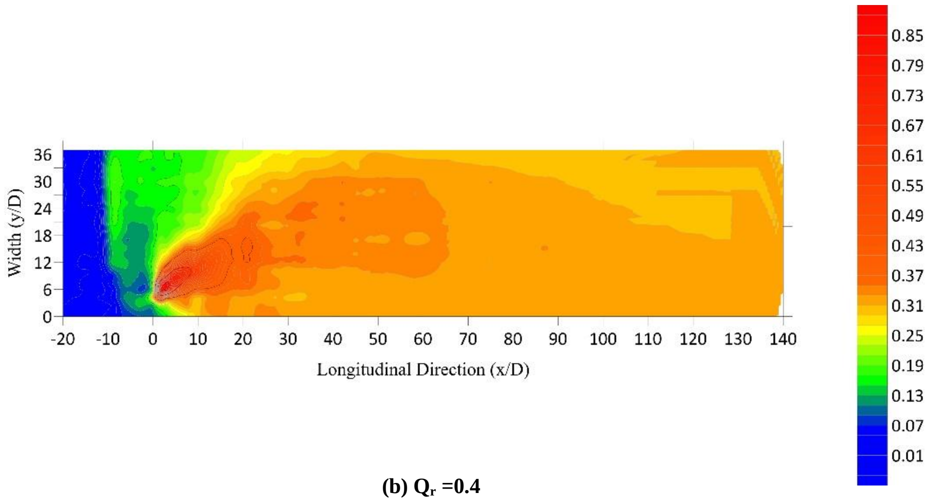


(c) Q_r =0.67

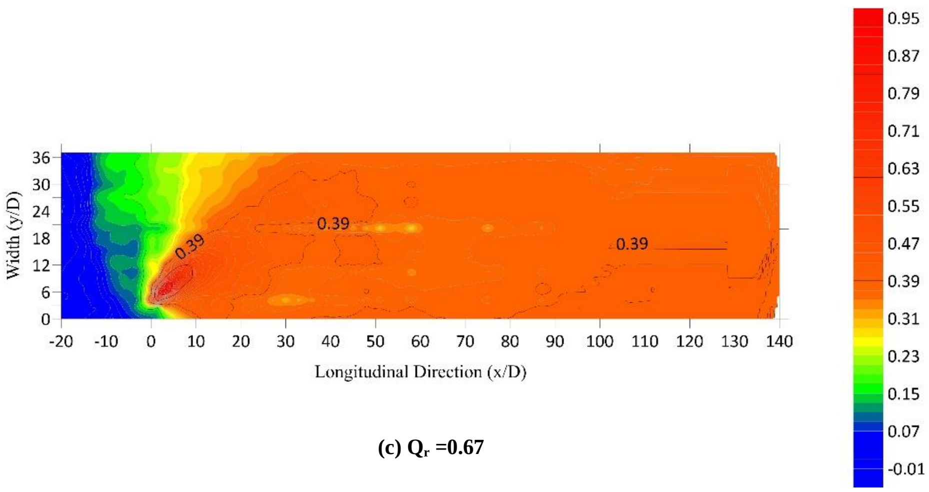
Fig. 7 Mixing zone at H=3 for (a) Q_r = 0.2. (b) Q_r = 0.4. (c) Q_r = 0.67



(a) Q_r =0.2

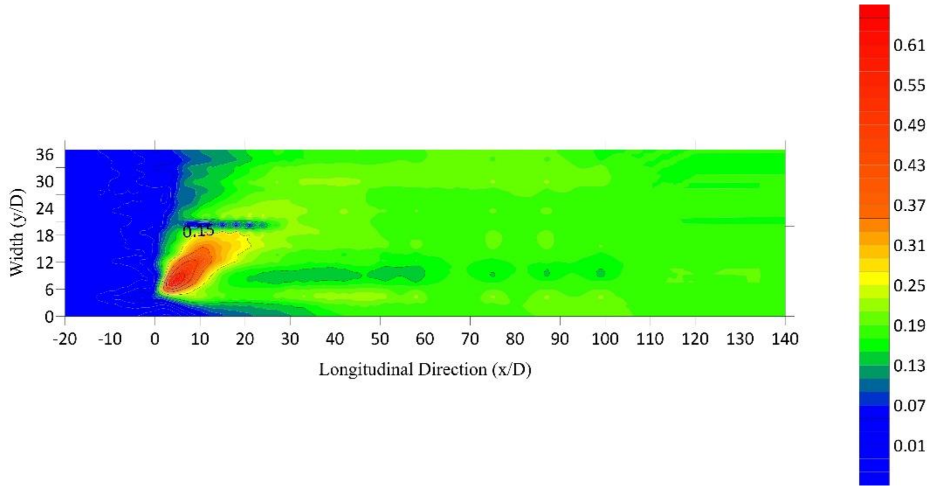


(b) Q_r =0.4

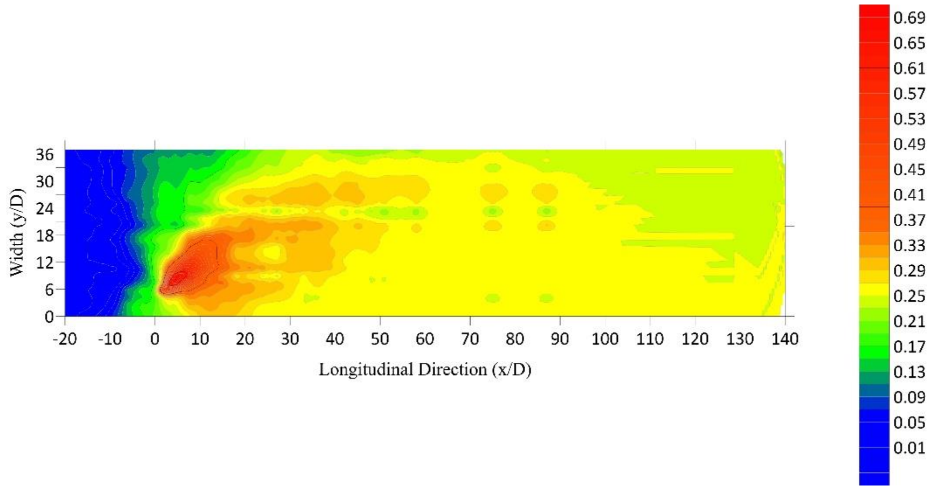


(c) Q_r =0.67

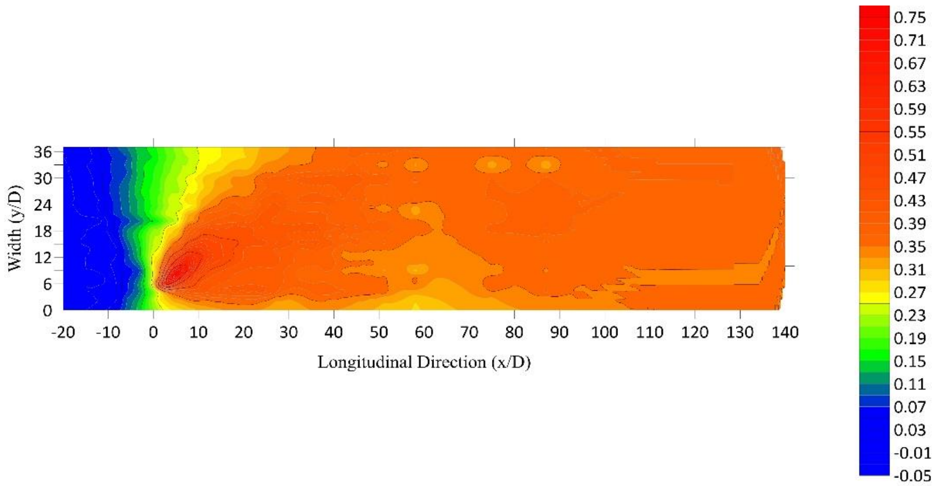
Fig. 8 Mixing zone at H=1 for (a) Qr = 0.2. (b) Q_r = 0.4. (c) Q_r = 0.67 for a diffuser with a large thread



(a) Q_r =0.2

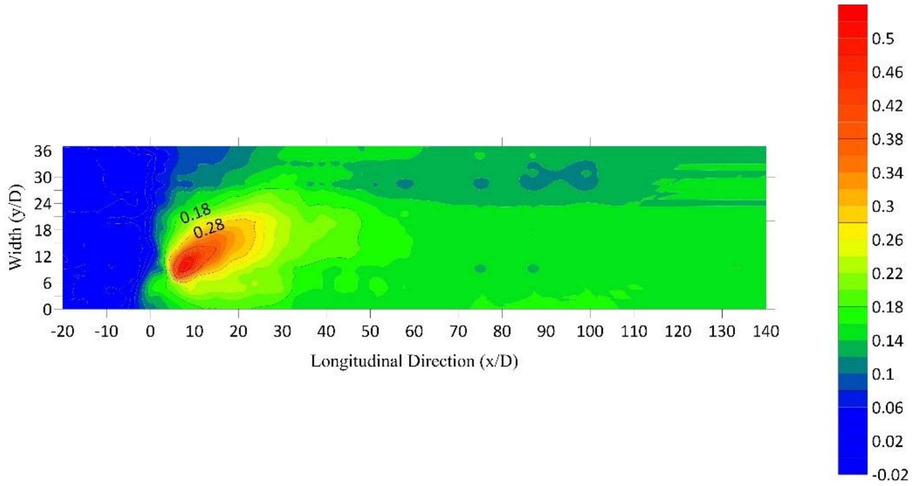


(b) Q_r =0.4

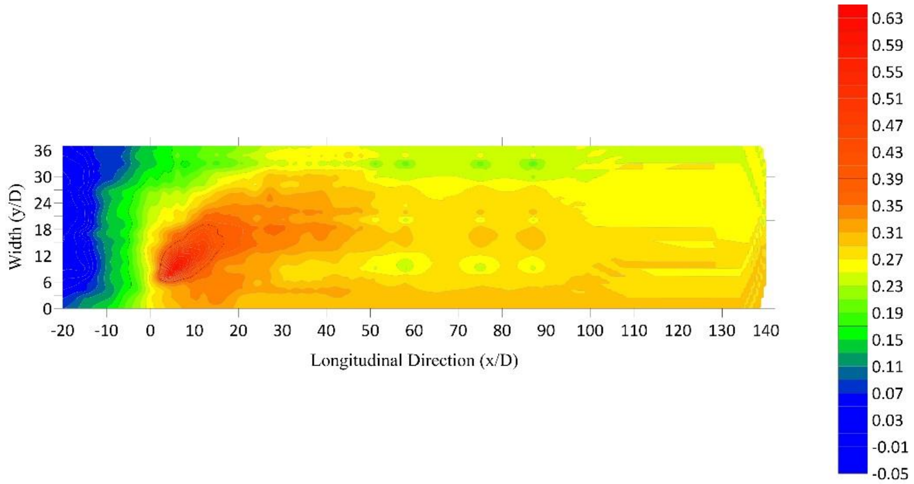


(c) Q_r =0.67

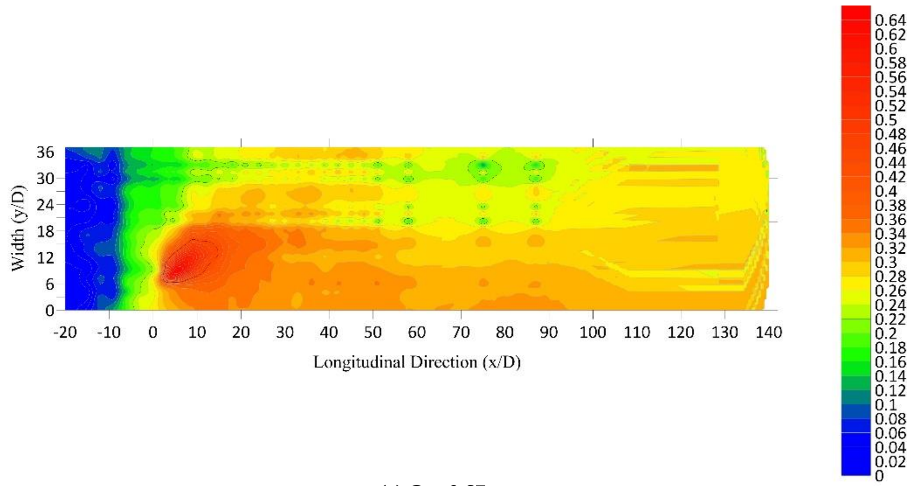
Fig. 9 Mixing zone at H=2 for (a) Q_r = 0.2. (b) Qr = 0.4. (c) Q_r = 0.67 for a diffuser with a large thread



(a) Q_r =0.2

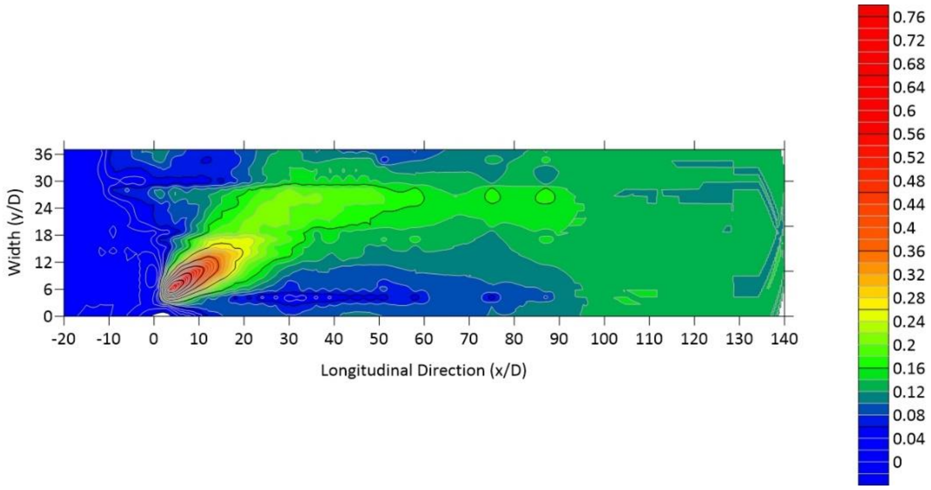


(b) Q_r =0.4

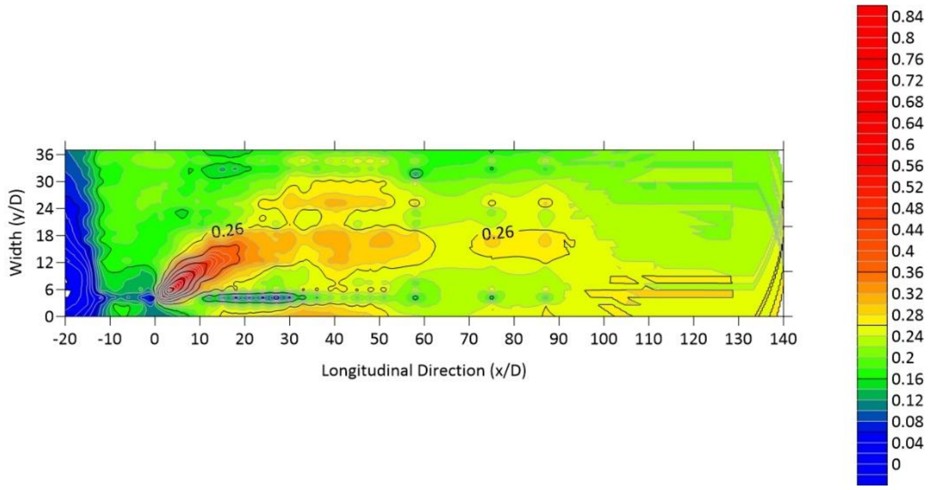


(c) Q_r =0.67

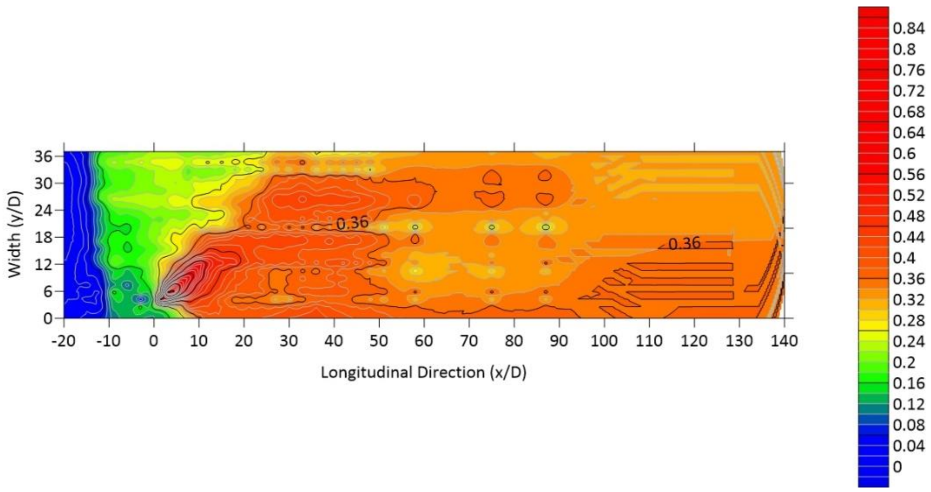
Fig. 10 Mixing zone at H=3 for (a) Qr = 0.2. (b) Q_r = 0.4. (c) Q_r = 0.67 for a diffuser with a large thread



(a) Q_r =0.2

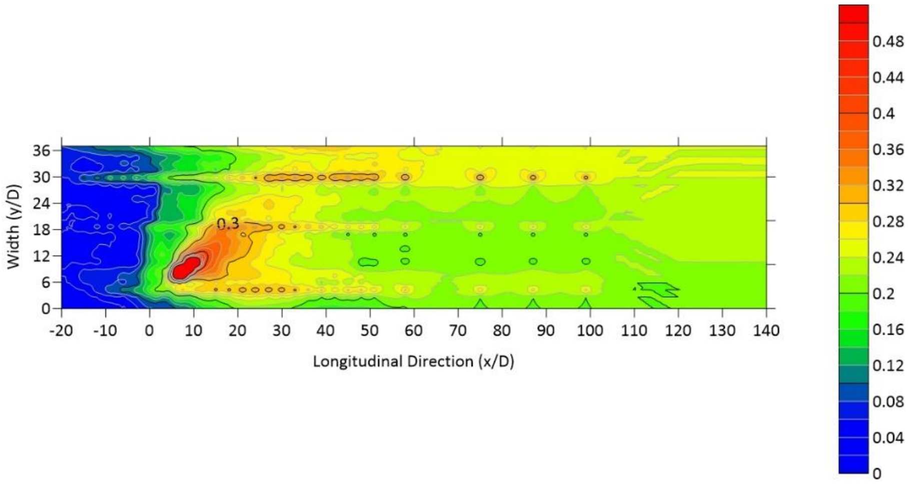


(b) Q_r =0.4

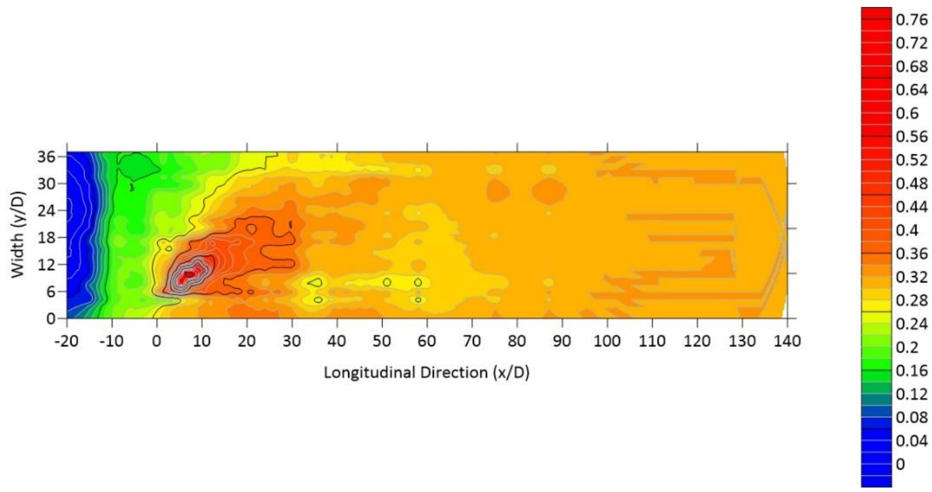


(c) Q_r =0.67

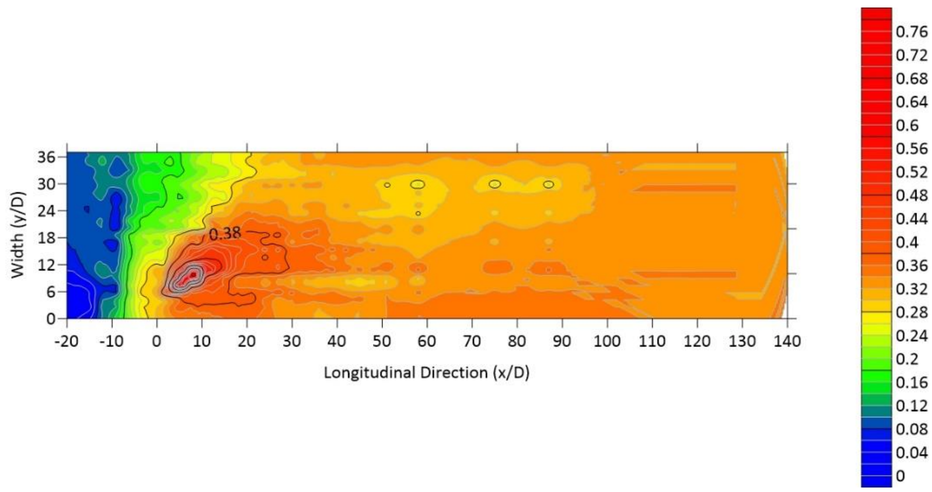
Fig. 11 Mixing zone at H=1 for (a) Qr = 0.2. (b) Q_r = 0.4. (c) Q_r = 0.67 for a diffuser with a small thread



(a) Q_r =0.2

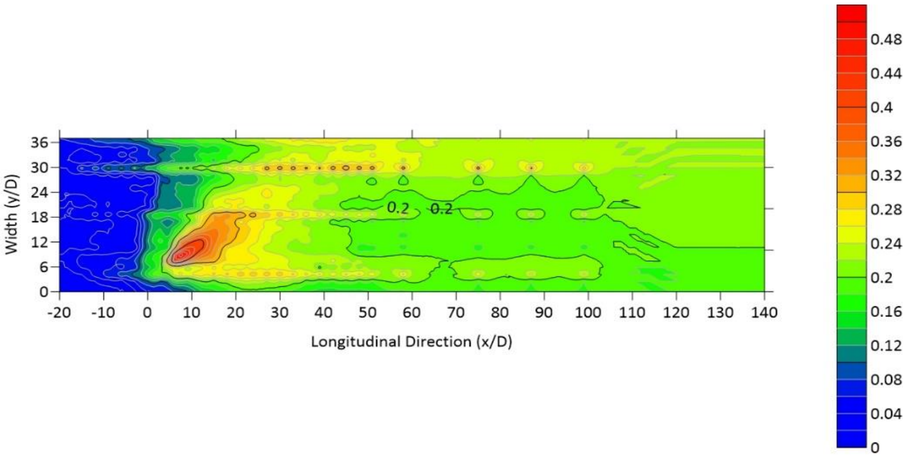


(b) Q_r =0.4

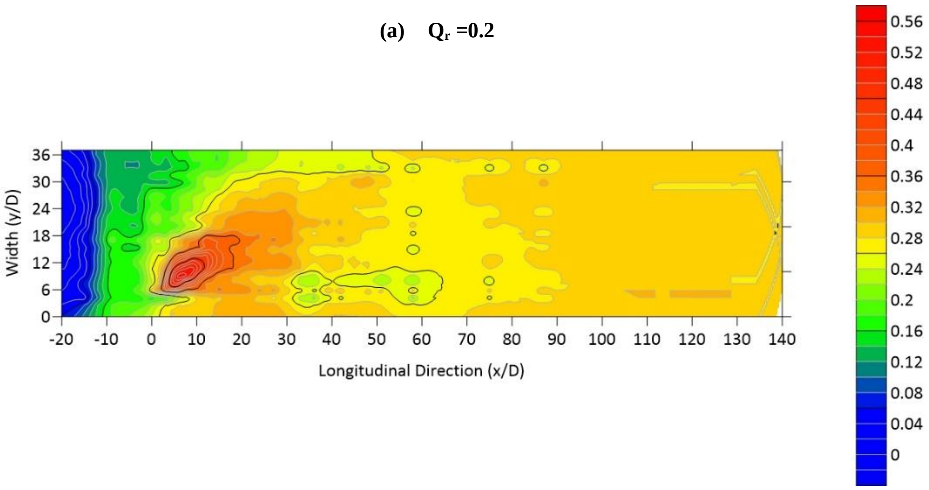


(c) Q_r =0.67

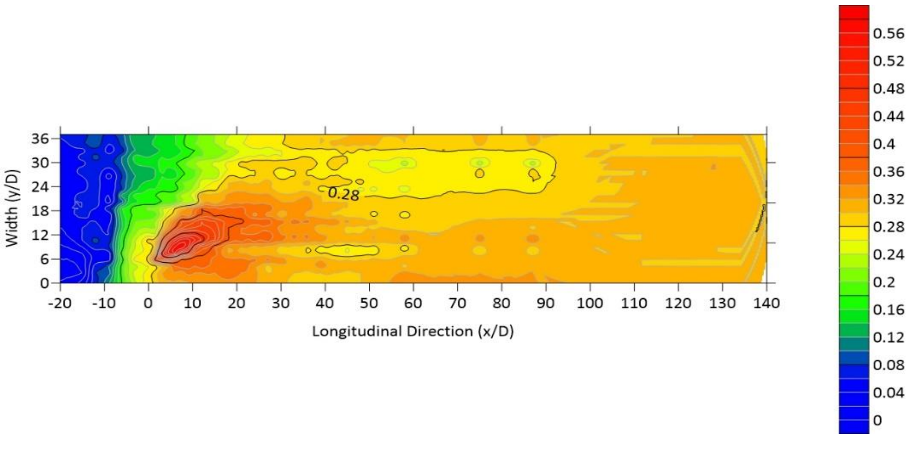
Fig. 12 Mixing zone at H=2 for (a) Q_r = 0.2. (b) Qr = 0.4. (c) Q_r = 0.67 for a diffuser with a small thread



(a) Q_r =0.2



(b) Q_r =0.4



(c) Q_r =0.67

Fig. 13 Mixing zone at H=3 for (a)Qr = 0.2. (b) Q_r = 0.4. (c) Q_r = 0.67 for a diffuser with a small thread

The variation of temperature ratio versus longitudinal direction up to 140D for submerged diffuser without threads for *H*=1, 2 and 3 are clear in figures 14, 15 and 16. From the figures, one can see that the temperature ratio starts upstream with a lower ratio to arrive at the maximum ratio at the diffuser exit, then starts to reduce. The variation of the temperature ratio with longitudinal direction after 100D is clearly small. The variation after 100D can be negligible. It is also clear from the figures that, at the depth increase, the maximum temperature ratio decreases due to buoyance. The results also show that the flow ratio affects the temperature variation in the longitudinal direction; increasing the flow ratio causes an increase in the temperature ratio. Finally, the results clearly show that the fine thread has a lower temperature variation than the great thread. The great threat also has temperature variation lower than the diffuser without thread.

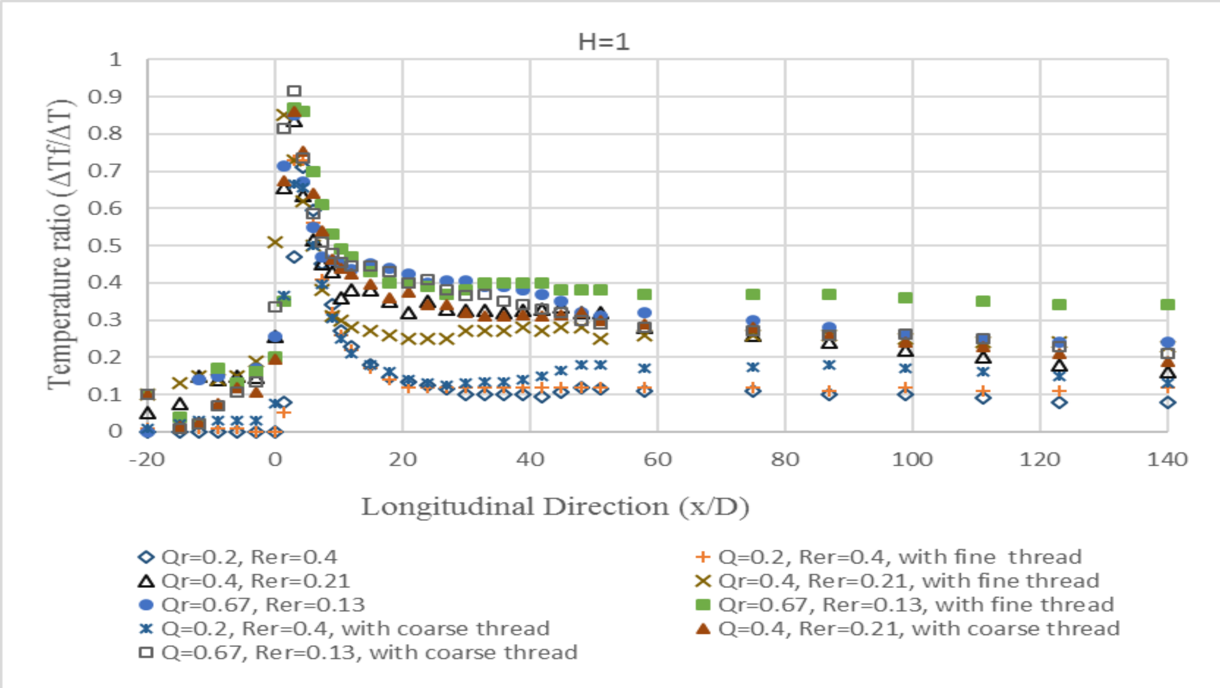


Fig. 14 Comparison between the dilution of plume center temperature ratios at Δ T =10 ℃ at H=1 for the diffuser with and without thread

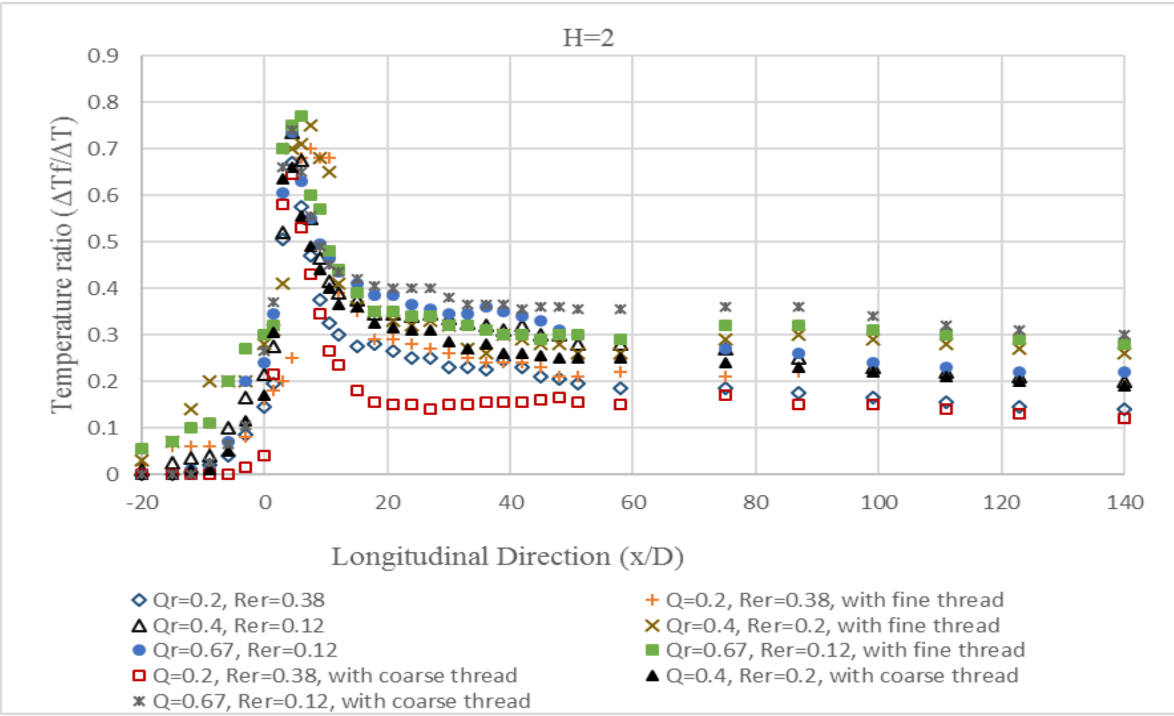


Fig. 15 Comparison between the dilution of plume center temperature ratios at Δ T =10 ℃ at H=2 for the diffuser with and without thread

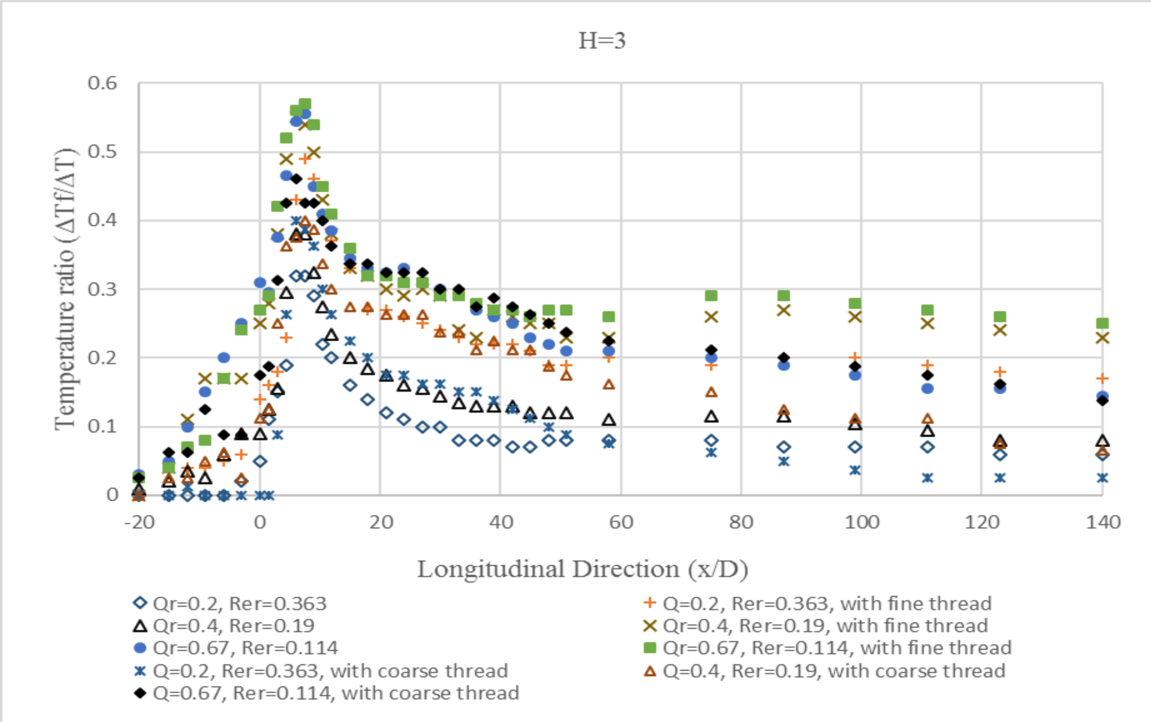


Fig. 16 Comparison between the dilution of plume center temperature ratios at Δ T =10 ℃ at H=3 for the diffuser with and without thread

Table 1. ΔT_m and ΔT_e for diffuser without and with large thread

H	Q_r	Rer	$\Delta T_{m\ thread}$	$\Delta T_{e\ thread}$	ΔT_m	ΔT_e	$\Delta T_{m\ change}$ (%)	ΔTe_{change} (%)
1	0.2	0.4	0.72	0.18	0.71	0.137	1.41	31.39
	0.4	0.21	0.86	0.32	0.83	0.22	3.61	45.45
	0.67	0.13	0.915	0.38	0.86	0.31	6.40	22.58
2	0.2	0.38	0.66	0.18	0.65	0.1	1.54	80.00
	0.4	0.2	0.7	0.26	0.69	0.19	1.45	36.84
	0.67	0.12	0.74	0.36	0.73	0.27	1.37	33.33
3	0.2	0.363	0.52	0.14	0.32	0.07	62.50	100.00
	0.4	0.19	0.62	0.27	0.39	0.09	58.97	200.00
	0.67	0.114	0.65	0.28	0.55	0.18	18.18	55.56

Table 2. ΔT_m and ΔT_e for diffuser without and with fine thread

H	Q_r	Re_r	$\Delta T_{m\ fine\ thread}$	$\Delta T_{e\ fine\ thread}$	ΔT_m	ΔT_e	$\Delta T_{m\ change}$ (%)	ΔTe_{change} (%)
1	0.2	0.4	0.73	0.17	0.71	0.137	2.74	19.41
	0.4	0.21	0.85	0.27	0.83	0.22	2.35	18.52
	0.67	0.13	0.87	0.32	0.86	0.31	1.15	3.13
2	0.2	0.38	0.7	0.22	0.65	0.1	7.14	54.55
	0.4	0.2	0.75	0.29	0.69	0.19	8.00	34.48
	0.67	0.12	0.77	0.37	0.73	0.27	5.19	27.03
3	0.2	0.363	0.50	0.21	0.32	0.07	36.00	66.67
	0.4	0.19	0.55	0.28	0.39	0.09	29.09	67.86
	0.67	0.114	0.57	0.29	0.55	0.18	3.51	37.93

It was found that adding a thread at the outlet of the diffuser based on analysis, plume center temperature ratios (ΔT_m) and average temperature ratio at the end of measurements (ΔT_e) were listed in tables (1) and (2). The flow ratios Q_r = 0.2, 0.4, and 0.67 at Reynolds number ratios (Re_r) are listed in the tables.

From table (1), the results show that for a single port submerged diffuser with a great threaded outlet at H= 1, the mixing zone maximum temperature ratio (ΔT_{max}) increased by 1.41%, 3.61%, and 6.4%, the average temperature at the end of measurements (ΔT_e) increased by (31.39%, 45.45 % and 22.58 %) compared to diffuser without thread.

For *H*= 2, the mixing zone maximum temperature ratio (ΔT_{max}) increased by 1.54%, 1.45%, and 1.37%, and the average temperature at the end of measurements (ΔT_e) increased by 80%, 36.84 % and 33.33 % compared to diffuser without thread.

For *H*= 3, the mixing zone maximum temperature ratio (ΔT_{max}) increased by 62.5%, 58.97%, and 18.18%, and the average temperature at the end of measurements (ΔT_e) increased by 100%, 200 % and 55.56 % compared to diffuser without thread.

From table (2), the results show that it was found that adding a thread at the diffuser outlet increases the maximum temperature of the mixing zone. Temperature ratios across the model were increased compared with the diffuser without thread. The average temperatures at the end of measurements were increased compared with the diffuser without thread. Adding a thread at the outlet of the diffuser does not reduce the mixing zone but increases it and thus reduces temperature dilution.

4. Conclusion

The thermal power stations use a once-through cooling system, which causes thermal pollution. That led to changes in the properties of water. The experimental study was carried out at a single port submerged diffuser with and without thread. The experimental results showed that for a single port submerged diffuser with a large threaded outlet at *H*= 1, the mixing zone maximum temperature ratio (ΔT_{max}) increased by 1.41%, 3.61%, and 6.4%, the average temperature at the end of measurements (ΔT_e) increased by (31.39%, 45.45 % and 22.58 %) compared to diffuser without thread. For *H*= 2, the mixing zone maximum temperature ratio (ΔT_{max}) increased by 1.54%, 1.45%, and 1.37%, and the average temperature at the end of measurements (ΔT_e) increased by 80%, 36.84 % and 33.33 % compared to diffuser without thread. For *H*= 3, the mixing zone maximum temperature ratio (ΔT_{max}) increased by 62.5%, 58.97%, and 18.18%, and the average temperature at the end of measurements (ΔT_e) increased by (100%, 200 % and 55.56 %) compared to diffuser without thread.

Finally, adding a thread at the diffuser outlet increased the maximum temperature of the mixing zone. Adding a thread at the diffuser outlet increased Temperature ratios across the model compared with the diffuser without thread. The average temperatures at the end of measurements were increased compared with the diffuser without thread. Adding a thread at the outlet of the diffuser does not reduce the mixing zone but increases it and thus reduces temperature dilution.

References

[1] Donald S. Miller, and Barbara A. Brighouse, *Thermal Discharge a Guide to Power and Processes Plant Cooling Water Discharges Into Rivers, Lakes, and Seas*, Britch Hydromechanics Research Association, 1984.

[2] Nadeem Ahmad, and Raouf E. Baddour, “Dilution and Penetration of Vertical Negatively Buoyant Thermal Jets,” *Journal of Hydraulic Engineering*, vol. 138, no. 10, pp. 850-857, 2012. *Crossref*, https://doi.org/10.1061/ ASCE HY.1943-7900.0000588

[3] George C. Noutsopoulos, and Panayotis C. Yannopoulos, “Axial Dilution in Obstructed Round Buoyant Jet,” *Journal of Hydraulic Engineering*, vol. 115, no. 1, 1989. *Crossref*, https://doi.org/10.1061/ ASCE 0733-9429 1989 115:1 71

[4] Asu İ., and Kağan C., “Modeling of Near-Field Dilution of Heated Discharges on Tekirdağ Coasts,” *Eurasian Journal of Environmental Research EJERE*, vol. 3, no. 2, pp. 41-46, 2019.

[5] Lilun Wu, and Jiin-Jen Lee “Enhanced Mixing Through Perforated Discs on Round Buoyant Jet,” *Journal of Coastal Engineering*, vol. 1996, pp. 4325-4338, 1996. *Crossref*, https://doi.org/10.1061/9780784402429.335

[6] Huai Wen-xin Doctor, Fang Shen-guang, and Dai Hui-chao, “Behavior of Obstructed Square Buoyant Vertical Jets in Static Ambient II - Analysis on Behavior of Flow Field,” *Journal of Applied Mathematics and Mechanics English Edition* , vol. 27, no. 5, pp. 653-659, 2006. *Crossref*, https://doi.org/10.1007/s10483-006-0511-y

[7] B.W. Alton, G.A. Davidson, and P.R. Slawson, “Comparison of Measurements and Integral Model Predictions of Hot Water Plume Behaviour in a Cross Flow,” *Atmospheric Environment*, vol. 27A, pp. 589-598, 1993. *Crossref*, https://doi.org/10.1016/0960-1686(93)90216-L

[8] Hening Huang et al., “Initial Dilution Equations for Buoyancy Dominated Jets in Current,” *Journal of Hydraulic Engineering*, vol. 124, pp. 105-108, 1998. *Crossref*, https://doi.org/10.1061/(ASCE)0733-9429(1998)124:1(105)

[9] Yu-Hong Zeng, and Wen-Xin Huai “Characteristics of Round Thermal Discharging in a Flowing Environment,” *Journal of Hydro-Environment Research*, vol. 2, pp. 164-171, 2008. *Crossref*, https://doi.org/10.1016/j.jher.2008.08.002

[10] George Marmorino, Ivan Savelyev, and Geoffrey B. Smith, “Surface Thermal Structure in a Shallow-Water, Vertical Discharge from a Coastal Power Plant,” *Environmental Fluid Mechanics*, vol. 15, pp. 207–229, 2015. *Crossref*, https://doi.org/10.1007/s10652-014-9373-0

[11] Joongcheol Paik., “Numerical Simulation of Thermal Discharges in Crossflow,” *IEEE 3rd International Conference on Communication Software and Networks*, pp. 328-332, 2011. *Crossref*, https://doi.org/10.1109/ICCSN.2011.6014906

[12] H K Versteeg, and W Malalasekera, *An Introduction to Computational Fluid Dynamics*, Pearson Education Limited, 2nd edition, 2007.

[13] Naim Sezgin, “Investigation of Horizontal Cold Water Discharge Initial Dilutions at Various Temperature Differences Using Duckbill Valve,” *Desalination and Water Treatment*, vol. 2015, pp. 2437-2445, 2016. *Crossref*, https://doi.org/10.1080/19443994.2015.1022805

[14] Anastasios I. Stamou, and Ioannis K. Nikiforakis, “Integrated Modelling of Single Port, Steady-State Thermal Discharges in Unstratified Coastal Waters,” *Environmental Fluid Mechanics*, vol. 13, pp. 309–336, 2013.
Crossref, https://doi.org/10.1007/s10652-0129266-z

[15] A Ghosh, Partha S.Chakraborty, and K. Balakannan, "Effects of Coal Based Thermal Power Plant in India," *International Journal of Engineering Trends and Technology*, vol. 69, no. 5, pp. 62-68, 2021.
Crossref, https://doi.org/10.14445/22315381/IJETT-V69I5P211

[16] Daniela Malcangio et al., “Computational Simulation of Round Thermal Jets in an Ambient Cross Flow Using a Large-Scale Hydrodynamic Mode,” *Journal of Hydraulic Research*, vol. 2019, pp.1-18, 2019.
Crossref, https://doi.org/10.1080/00221686.2019.1684392

[17] Ameer Sadath K.T, P.Senthil, and Elayaraja.R, "Investigation and Development of Waste Heat Recovery for Sea Water Desalination," *SSRG International Journal of Mechanical Engineering*, vol. 7, no. 1, pp. 17-31, 2020.
Crossref, https://doi.org/10.14445/23488360/IJME-V7I1P103

[18] D. Malcangio, M. Ben Meftah, and M. Mossa, “Physical Modelling of Buoyant Effluents Discharged into a Cross Flow,” *IEEE Workshop on Environmental, Energy, and Structural Monitoring Systems*, pp. 1-6, 2016.

[19] Maneesh Punetha, Jignesh P. Thaker, and Jyotirmay Banerjee, “Experimental and Numerical Analysis of Dispersion of Heated Effluent from Power Plants,” *5th International and 41st National Conference on Fluid Mechanics and Fluid Power*, pp. 1-8, 2014.