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ESTIMATION OF DIFFUSION OF AIR IN WATER UNDER UNIFORM FLOW CONDITIONS

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ABSTRACT

In various industrial and chemical processes, attaining uniform flow of liquids is very important for cooling and other requirements. Uniform flow is required in cooling of sodium cooled nuclear reactors and many other chemical processing and open channel flow passage applications. In this paper, a method is proposed to estimate the diffusion rate of air in water as a function of mixing ratio. The experiment was conducted under uniform flow conditions with different lengths of various stream equalizer plates to calculate the variation of velocity along the longitudinal and transverse directions of the rectangular model established for this purpose.

Keywords: stream equalizer plate, velocity measurement, porosity, mixing ratio.

1. INTRODUCTION

In sodium cooled fast breeder nuclear reactors, cooling is done using liquid sodium, where non- uniform flow of liquid sodium leads to the formation of argon cover gas due to disturbances on the surface which results in radioactivity when carried to the core. This liquid sodium and argon gas can be related with water and air hydro-dynamically. Similarly there are various industrial processes and requirements where we need to attain uniform flow for reducing hazards. The setup for obtaining uniform flow in the upstream water consists of a rectangular tank made of Acrylic sheets, the outer sheets are transparent and the separator between upstream and downstream is opaque with greater thickness than others and readings have been marked.

Experiments have been carried out with objective to measure the velocity at various locations of the tank along the longitudinal and transverse directions. The setup consists a tank of dimensions 60cmsx60cmsx15cms with a separation of 5mm at the middle to separate upstream side and downstream side. A submersible pump is used to supply water to the tank, an inlet control valve, flow meter and an outlet control valve. The results are validated with Computational Fluid Dynamics for various types of stream equalizer plate conditions and different flow rates.

2. LITERATURE REVIEW

Patwardhanand Johnson (2001) have applied three-dimensional unsteady CFD model to predict flow and mixing in jet-mixed water tank. It was clearly shown that the convention scheme can have an effect on the tracer distribution and that improvements were accomplished in comparison of the CFD results.

Michael Marek, *et al.* (2005) have presented A three-dimensional unsteady RANS CFD model was used to predict flow and mixing in jet-mixed water tanks. The predicted mixing time and concentration profiles were compared to experimental measurements for different jet velocities and nozzle angles. The numerical mode predicted the overall mixing time very well, however apart from one probe location the predicted concentration profiles are generally not in good agreement with the experimental measurement. It was clearly shown that the convention scheme can have an effect on the tracer distribution and that improvements were accomplished in comparison to the CFD results from patwardhan (2002).

Hyungseokkang and chulhwa song (2010) have investigated the velocity and temperature of a turbulent jet in a sub cooled water pool are very important because the behaviour of the turbulent jet give direct effect to the local temperature of the sub cooled water i.e. entrained into a stream jet; and this behaviour consequently effects the overall pattern of thermal mixing in a pool. If the local temperature of the entrained water increases above a certain limit, unstable condensation may occur and damage the integrity of the internal structures and the wall of the pool.

3. EXPERIMENTAL PROCEDURE

The experimental set up is as shown in the Figure-1. The test loop consisted of submersible pump, spillway model. The spillway model is given with an inlet and the outlet valves which are used to adjust the water level in the upstream and downstream sides. The inlet of the model is fitted with a gate valve thereby controlling the inlet flow rate on the upstream side. A float type rotameter of range 50 lpm to 250 lpm is used to measure the flow rate in the circuit. The sides and the rear portion of the model are made of transparent acrylic sheets with graduations to enable direct reading of the height. The width of model is 15cms. The radial gap of the upstream and downstream is 75 mm.

The experiment is conducted with the aid of a submersible pump in an water sump, the pump is operated by electric power the outlet of the pump is connected to inlet of the spillway model with an control valve and flow meter (used to measure the flow rate). The pump is switched on and the flow is controlled by managing the control valve.

The stream equalizer plate can be located in such a way that its height from the bottom can be adjusted from 10mm to 100mm in steps of 10mm. The plate is perforated with circular holes of 5mm diameter in a rectangular array of 30x5mm in order to test the effect of porosity of plate

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and flow uniformity. Experiments had been conducted for various heights of 0mm to 500mm and for various flow rates 100lpm, 200lpm. The interaction between falling water and the air leads to entrainment of air into water and strong air water mixing. A propeller turbine type anemometer was used to measure the velocity of the jet in the upstream in various co-ordinate locations.

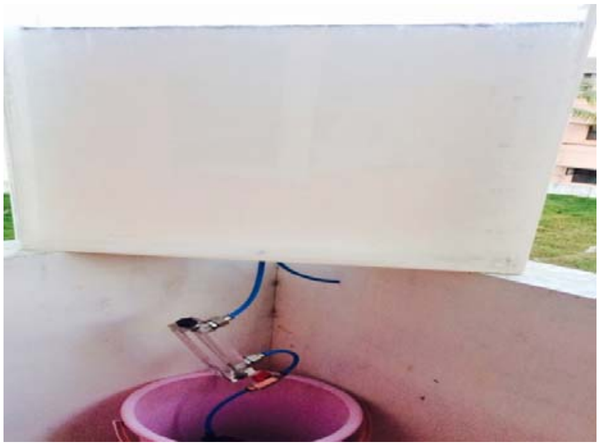


Figure-1. Experimental setup.

4. RESULT AND DISCUSSIONS

For velocity measurements various attempts were made to find suitable measuring device as the magnitude is small and is in the order of 0.001m/s to 0.01 m/s various water turbine type devices are tested for velocity measurements. Finally propeller turbine type anemometer is designed and manufactured by a rapid prototyping technique which suits the requirements.

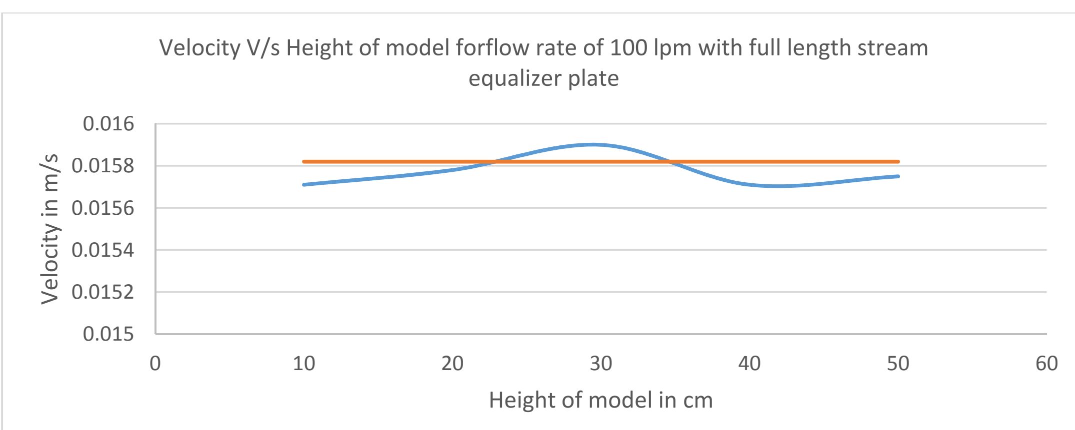
It consists of a fan which is made of light weight material, easily designable and sensitive. It is manufactured in plastics and especially a kind with density slightly more than water which reacts to water movement the fan designed is basically inspired from the fan body of water flow meter, Francis and Kaplan turbine and the ship propeller.

The fan consists of a hollow nozzle head and a tail. The head is inclined at an angle of 45deg from shaft axis and the tail ends and the shaft at 28deg. The fan has four blades placed radially equidistant from each other. The values of velocities at various locations are tabulated as following.

Table-1. Velocity (m/s) for flow rate 100 lpm with full length of stream equalizer plate.

Height (cm)	**Length of the passage** (cm)							**Mean velocity** (m/s)	**Theoretical velocity** (m/s)	**Mixing ratio**
	0	**10**	**20**	**30**	**40**	**50**	**60**			
50	0.0168	0.0156	0.0153	0.015	0.0154	0.0156	0.0156	0.01575	0.01582	0.000525
40	0.0173	0.0156	0.0156	0.0156	0.0156	0.0156	0.0156	0.01571	0.01582	0.000595
30	0.0172	0.0156	0.0156	0.0156	0.0154	0.0156	0.0156	0.0159	0.01582	0.000576
20	0.0167	0.0156	0.0156	0.0157	0.0152	0.0156	0.0158	0.01578	0.01582	0.000427
10	0.0162	0.0156	0.0158	0.0156	0.015	0.0156	0.0159	0.01571	0.01582	0.000341

The values of velocities along the longitudinal and transverse directions of the rectangular model for the flow rate of 100 lpm with full length stream equalizer plate are tabulated. From the above tabulation we can infer that the variation of velocity is less and the lowest mixing ratio can be achieved at 10 cm height of the tank where the stream equalizer plate is located.



Graph is plotted for mean velocities and theoretical velocity

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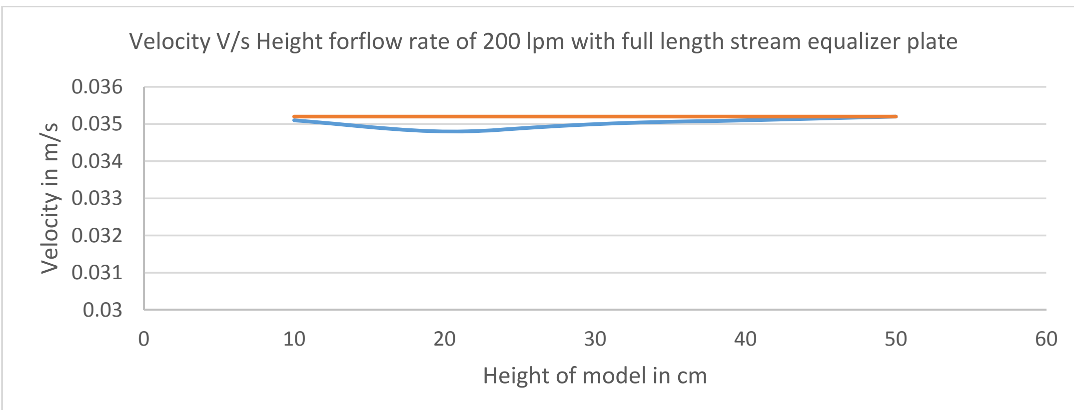
Table-2. Velocity (m/s) for flow rate 200 lpm with full length of stream equalizer plate.

Height (cm)	**Length of the passage** (cm)							**Mean velocity** (m/s)	**Theoretical velocity** (m/s)	**Mixing ratio**
	0	**10**	**20**	**30**	**40**	**50**	**60**			
50	0.0317	0.0304	0.0342	0.0347	0.0349	0.0348	0.0419	0.0352	0.0352	0.003373
40	0.0315	0.0304	0.0342	0.0346	0.0349	0.0336	0.0415	0.0351	0.0352	0.00329
30	0.0313	0.0306	0.0342	0.0345	0.035	0.0333	0.0411	0.0350	0.0352	0.003173
20	0.0309	0.0304	0.0342	0.0344	0.035	0.0329	0.0399	0.0348	0.0352	0.002922
10	0.0307	0.0301	0.0342	0.0343	0.0355	0.0327	0.0395	0.0351	0.0352	0.002934

The values of velocities along the longitudinal and transverse directions of the rectangular model for the flow rate of 200 lpm with full length stream equalizer plate are tabulated. From the above tabulation we can infer that the variation of velocity is less and the lowest mixing ratio can be achieved at 10 cm height of the tank where the stream equalizer plate is located.



Graph is plotted for mean velocities and theoretical velocity

Table-3. Velocity (m/s) for flow rate 100 lpm with half length of stream equalizer plate.

Height (cm)	**Length of the passage** (cm)							**Mean velocity** (m/s)	**Theoretical velocity** (m/s)	**Mixing ratio**
	0	**10**	**20**	**30**	**40**	**50**	**60**			
50	0.0168	0.0156	0.0150	0.0150	0.0154	0.0156	0.0156	0.0159	0.0158	0.00056
40	0.0160	0.0156	0.0156	0.0156	0.0155	0.0156	0.0156	0.0159	0.0158	0.00015
30	0.0172	0.0152	0.0156	0.0156	0.0154	0.0156	0.0152	0.0158	0.0158	0.00064
20	0.0167	0.0148	0.0156	0.0156	0.0152	0.0156	0.0156	0.0159	0.0158	0.000536
10	0.0162	0.0145	0.0156	0.0156	0.0150	0.0156	0.0159	0.0158	0.0158	0.000525

The values of velocities along the longitudinal and transverse directions of the rectangular model for the flow rate of 100 lpm with half length stream equalizer plate are tabulated. From the above tabulation we can infer that the variation of velocity is less and the lowest mixing ratio can be achieved at 10 cm height of the tank where the stream equalizer plate is located.

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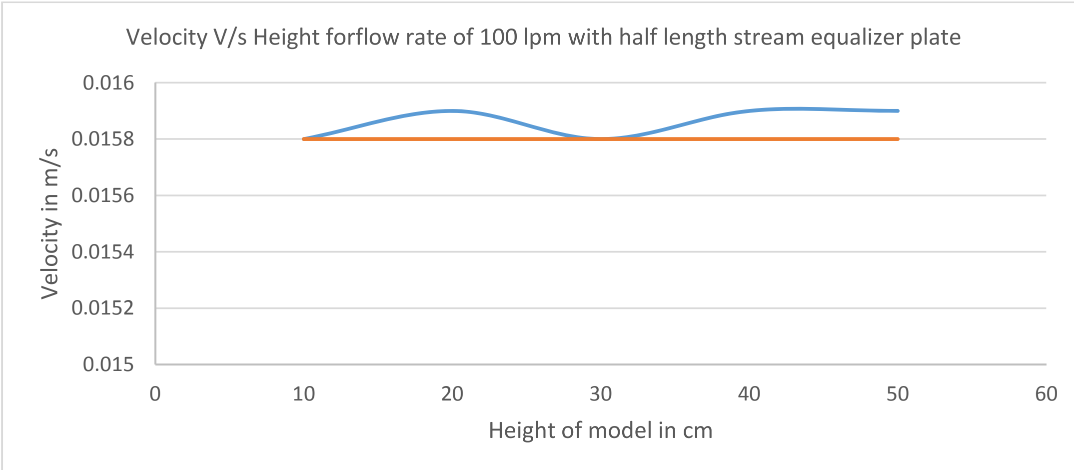
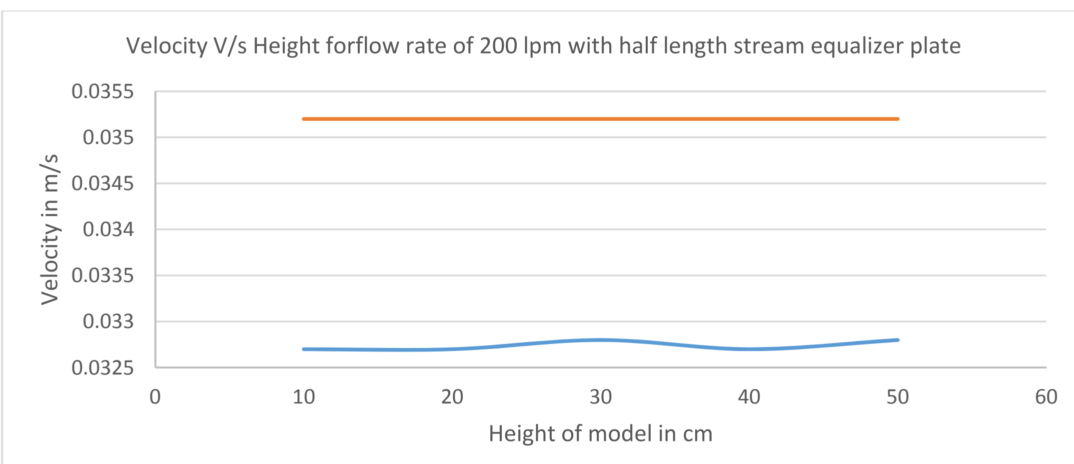


Graph is plotted for mean velocities and theoretical velocity

Table-4. Velocity (m/s) for flow rate 200 lpm with half length of stream equalizer plate.

Height (cm)	**Length of the passage** (cm)							**Mean velocity** (m/s)	**Theoretical velocity** (m/s)	**Mixing ratio**
	0	**10**	**20**	**30**	**40**	**50**	**60**			
50	0.0317	0.0304	0.0342	0.0342	0.0349	0.0342	0.0342	0.0328	0.0352	0.001545
40	0.0315	0.0304	0.0342	0.0342	0.0349	0.0342	0.0342	0.0327	0.0352	0.001577
30	0.0313	0.0306	0.0342	0.0342	0.0350	0.0343	0.0342	0.0328	0.0352	0.001583
20	0.0309	0.0304	0.0342	0.0345	0.0350	0.0342	0.0349	0.0327	0.0352	0.001794
10	0.0307	0.0301	0.0342	0.0342	0.0355	0.0351	0.0342	0.0327	0.0352	0.001978

The values of velocities along the longitudinal and transverse directions of the rectangular model for the flow rate of 200 lpm with half length stream equalizer plate are tabulated. From the above tabulation we can infer that the variation of velocity is less and the lowest mixing ratio can be achieved at 10 cm height of the tank where the stream equalizer plate is located.



Graph is plotted for mean velocities and theoretical velocity

5. CFD ANALYSIS

Computational Fluid Dynamics (CFD) is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyse problems that involve fluid flows. CFD modelling based on fundamental governing equations of fluid dynamics: the conservation of mass, momentum, and energy. CFD helps to predict the fluid flow behaviour based on the mathematical modelling using software tools. Computers are used to perform the calculations required to simulate the interaction of liquid

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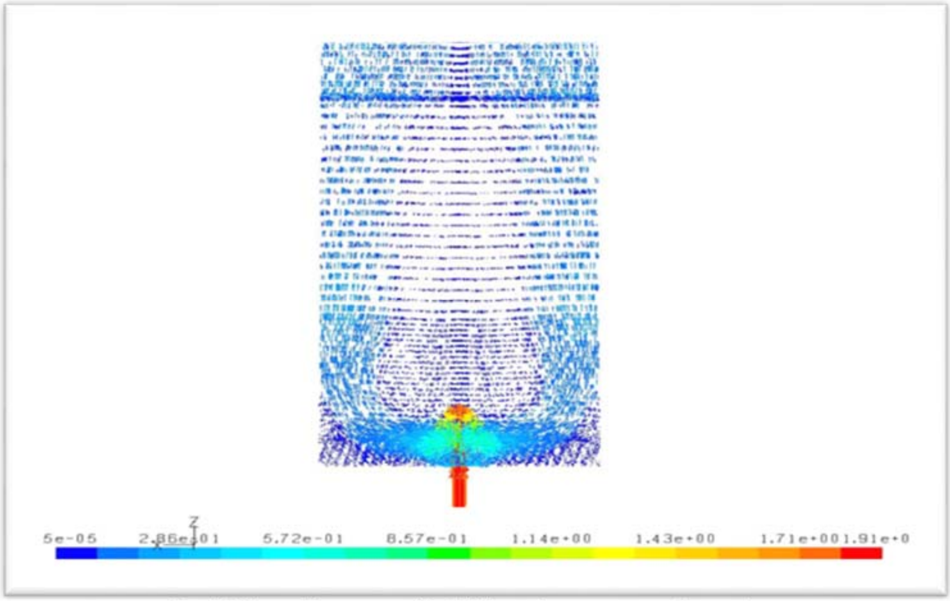
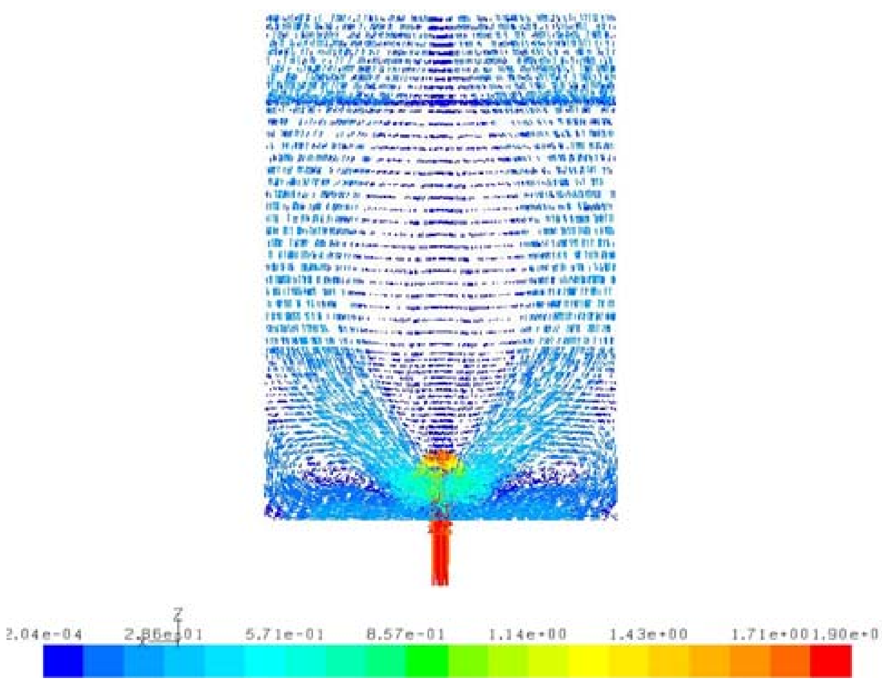
sand gases with surfaces defined by boundary conditions. With high-speed super computers, better solutions can be achieved. On-going research yields software that improves the accuracy and speed of complex simulations scenario such as transonic or turbulent flows.

The results from CFD are obtained as



For 100 lpm flow rate with full length stream equalizer plate



For 100 lpm flow rate with half length stream equalizer plate

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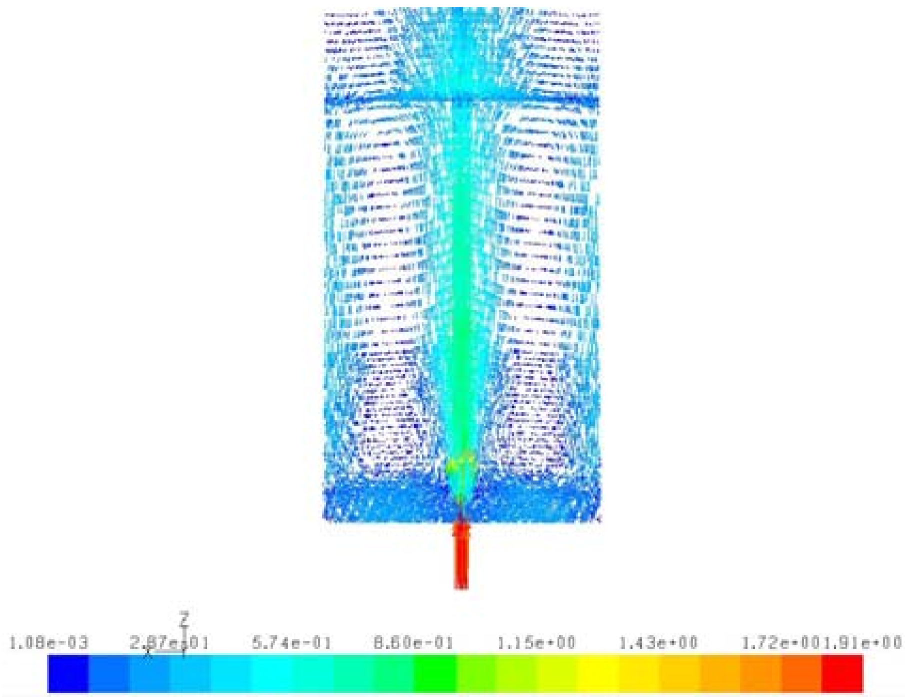

For 100 lpm flow rate without stream equilizer

CONCLUSIONS

The velocity readings, mixing ratios are taken at the different coordinates of x and y and also for half length and full length of stream equalizer plates for different flow rates as inputs. These results show that full length stream equalizer plate gives uniform velocities for flow rates at all coordinates, and mixing ratio is less at elevation of 10 cm i.e. at the location of stream equalize plate.

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