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TANK 26 EVAPORATOR FEED PUMP TRANSFER ANALYSIS

D.A. Tamburello
R.A. Dimenna
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DECEMBER 2008

Savannah River National Laboratory
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Prepared for the U.S. Department of Energy Under
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DISCLAIMER

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REVIEWS AND APPROVALS

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Richard A. Dimenna, Engineering Modeling and Simulation, SRNL	Date
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Steve J. Hensel, Level 3 Manager, Engineering Modeling and Simulation, SRNL	Date
Chris Johnson, Customer Review, FTF Closure Project Engineering	Date

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NOMENCLATURE

A_{scour}	Area of scour
C	Empirical parameter for the Weber number
CFD	Computational fluid dynamics
EFP	Evaporator Feed Pump
d_{imp}	Impinging diameter
$d_{imp,a}$	Impinging diameter for the inner column of a "broken" jet
$d_{imp,b}$	Impinging diameter for a broken jet; $d_{imp,b} = \sqrt{\frac{4}{\pi} \cdot \frac{Q_o}{V_{imp}}} + K \cdot T_u^* \cdot V_o \cdot \frac{V_{imp} - V_o}{g}$
d_o	Orifice diameter
d_p	Particle diameter
g	Acceleration due to gravity
h	Tank liquid level (above the sludge layer)
H	Plunge height
k	Turbulent kinetic energy
K	Empirical constant for $d_{imp,b}$
L_c	Jet break-up length; $L_c = C \cdot d_o \cdot We^{\frac{1}{2}}$
Q_o	Volumetric flow rate
SRNL	Savannah River National Laboratory
t_{turbid}	Thickness of the turbid region
T_u^*	Normalized streamwise turbulence of a free-falling liquid jet in a gas
V_{imp}	Impinging velocity; $V_{imp} = \sqrt{V_o^2 + 2 \cdot g \cdot H}$
$V_{imp,a}$	Impinging Velocity for the inner column of a broken jet; $V_{imp,a} = V_{imp}$
$V_{imp,b}$	Impinging Velocity for a broken jet
V_{min}	Minimum particle scour velocity; $V_{\min} = \left(\frac{d_p}{h}\right)^{-0.1} \cdot \sqrt{2.5 \cdot g \cdot d_p \cdot \left(\frac{\rho_p}{\rho_f} - 1\right)}$
V_o	Orifice velocity
V_{total}	Total velocity magnitude; $V_{total} = \sqrt{V_x^2 + V_y^2 + V_z^2}$
V_x	x-component of velocity

V_y	y-component of velocity
V_z	z-component of velocity
Vol_{scour}	Volume of scour
Vol_{tank}	Volume of the supernate in the tank (above the cohesive sludge layer)
We	Weber number; $We = \dfrac{\rho_f \cdot V_o^2 \cdot d_o}{\sigma}$
ε	Turbulent energy dissipation
ρ_f	Fluid density
ρ_p	Particle density
σ	Fluid surface tension

1.0 EXECUTIVE SUMMARY

The transfer of liquid salt solution from Tank 26 to an evaporator is to be accomplished by activating the evaporator feed pump, located approximately 72 inches above the sludge layer, while simultaneously turning on the downcomer. Previously, activation of the evaporator feed pump was an isolated event without any other components running at the same time. An analysis of the dissolved solution transfer has been performed using computational fluid dynamics methods to determine the amount of entrained sludge solids pumped out of the tank to the evaporator with the downcomer turned on.

The analysis results showed that, for the maximum and minimum supernate levels in Tank 26 (252.5 and 72 inches above the sludge layer, respectively), the evaporator feed pump will entrain between 0.03 and 0.1 wt% sludge undissolved solids weight fraction into the eductor, respectively, and therefore are an order of magnitude less than the 1.0 wt% undissolved solids loading criteria to feed the evaporator. Lower tank liquid levels, with respect to the sludge layer, result in higher amounts of sludge entrainment due to the increased velocity of the plunging jets from the downcomer and evaporator feed pump bypass as well as decreased dissipation depth.

Revision 1 clarifies the analysis presented in Revision 0 and corrects a mathematical error in the calculations for Table 4.1 in Revision 0. However, the conclusions and recommendations of the analysis do not change for Revision 1.

2.0 INTRODUCTION

Tank 26 is a feed tank to transfer supernate to another tank or to an evaporator. In either of these transfers, the discharge stream must contain less than a maximum weight percent of sludge solids at any time during the transfer process. An analysis of the liquid transfer to the evaporator has been performed using computational fluid dynamics (CFD) methods to estimate the amount of sludge drawn from Tank 26 through the evaporator feed pump when the downcomer is activated during the transfer process.

Figure 2.1 provides a simplified sketch (not to scale) of Tank 26, which consists of a supernate solution with a settled sludge layer on the bottom of the tank that is approximately 89 inches deep. The sludge particle range in size from 0.1 to 25 μm in diameter, with 20 vol.% of the sludge particles having diameters less than 1 μm [1, 2]. The supernate layer has a maximum height of 341.5 inches above the tank bottom that corresponds to the downcomer discharge height and results in a supernate layer height of approximately 252.5 inches above the sludge. Note that higher liquid levels are possible, but will have little to no influence on the fluid flow patterns near the sludge layer. The minimum supernate layer height is 161 inches above the tank bottom (corresponding to the evaporator eductor orifice height).

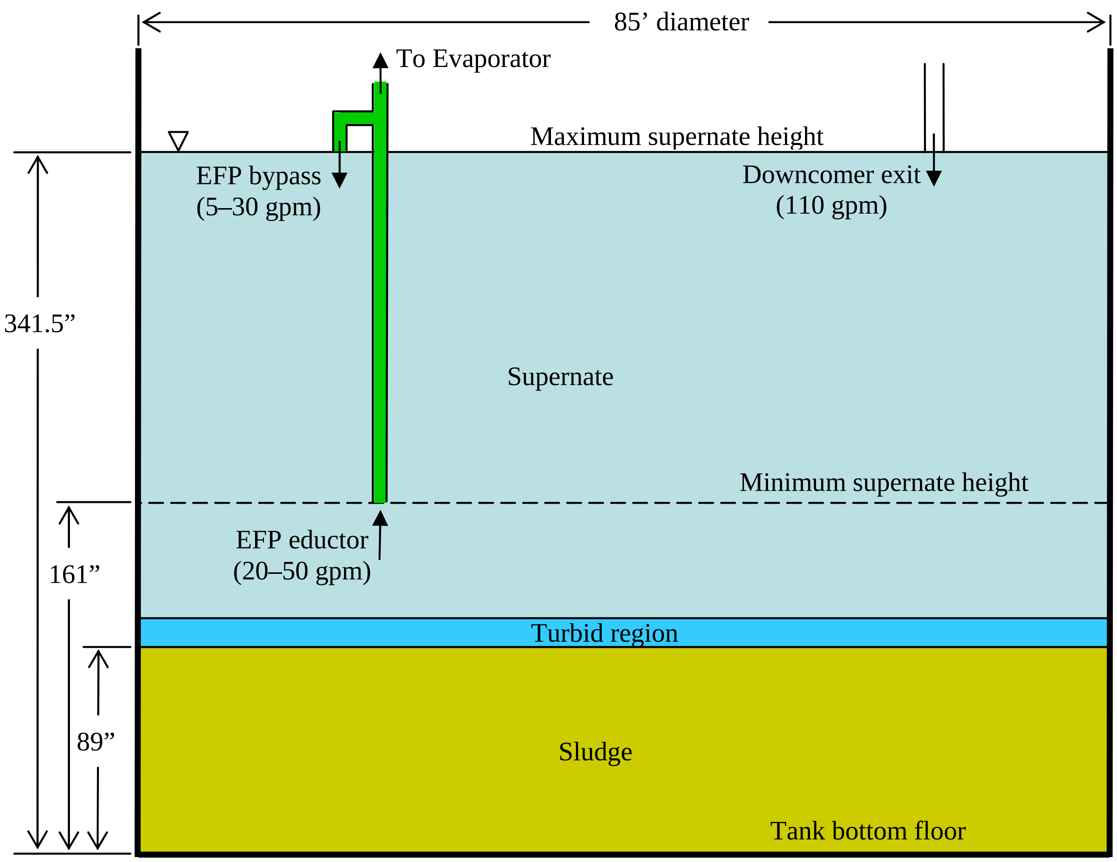

Figure 2.1. Two-dimensional sketch of the simplified modeling geometry. Not to scale.

Under normal conditions, the downcomer would first add liquid to Tank 26. Then, after any sludge particulate that had been stirred up by the downcomer had been allowed to resettle to the bottom of the tank, the evaporator feed pump (EFP) would be activated to transfer supernate to the evaporator. A limit of 1.0 wt.% undissolved solids (UDS) is imposed on fluid drawn out of Tank 26 through the EFP eductor for transfers to the evaporator [3]. As a time-saving (and cost-saving) measure, it has been proposed that both the downcomer and the EFP could be activated simultaneously without violating the UDS limit of 1.0 wt%.

The purpose of this analysis is to estimate the amount of sludge solids in the EFP during the transfer through the eductor located 72 inches above the sludge layer (161 inches above the tank bottom).

3.0 METHODOLOGY

The downcomer and evaporator feed pump are located asymmetrically within the Tank 26, which makes a three-dimensional model appropriate for this calculation. The governing equations solved for each analysis included a mass balance, the three-dimensional momentum equations, and two turbulence equations. The standard, two-equation, k-ε model was used to estimate the fluid turbulence. Figure 2.1 provides a sketch (not to scale) of the geometry that was modeled using the FLUENT™ CFD code, while Table 3.1 lists the modeling conditions that were used.

Figure 3.1 presents a three-dimensional view of the modeling domain created from the sketch in Figure 2.1. For the high supernate level (case 1), the modeling domain is made of approximately 3 million grid elements. Additionally, for the low supernate level (case 2), the modeling domain is made of approximately 1.3 million grid elements.

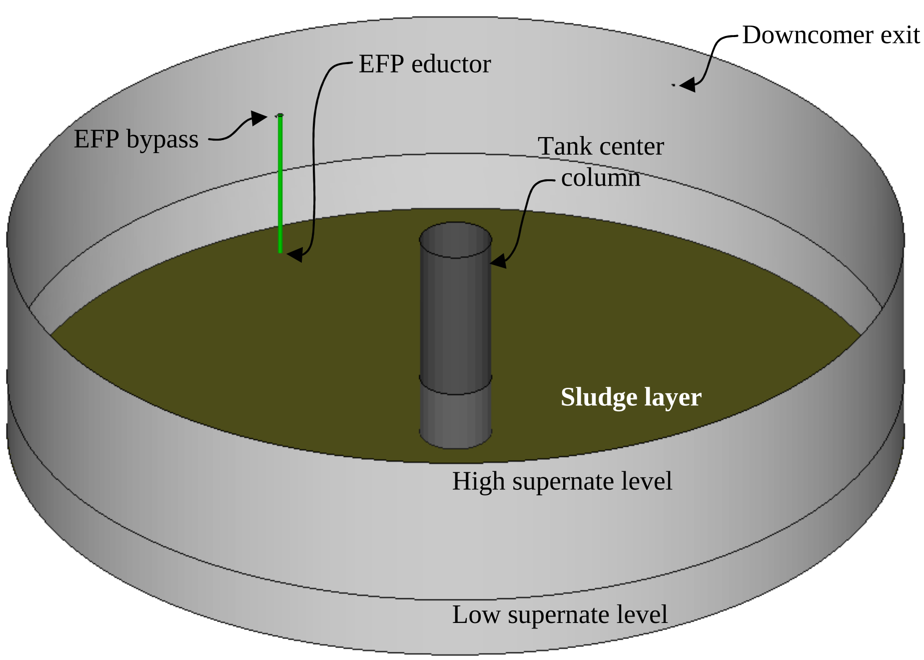

Figure 3.1. Three-dimensional view of the high supernate level model domain.

The following conditions, in coordination with Table 3.1, are used to analyze Tank 26:

- Only the liquid within Tank 26 is modeled. Particle motions are inferred based on the velocity field and the interactions (entrainment, settling, etc.) that would occur because of those velocities.
- Flow rates are set to the highest values for the evaporator feed pump eductor and bypass, which have ranges of 20 – 50 gpm and 5 – 30 gpm, respectively [4].
- When the supernate liquid level is below the downcomer orifice, the downcomer flow and EFP bypass are treated as plunging jets.
- Tank 26 contains primarily cohesive, densely-packed sludge, with a turbid layer approximately 6 inches deep of loosely-packed UDS above the sludge layer [3].
- Based on sampling test results for Tank 40 sludge Batch 3 [2], the typical range of particulate diameters is between 0.1 and 25 μm, with approximately 20 vol.% of the sludge distribution consisting of particles less than 1 μm in diameter.

The following assumptions were made to create this model. In general, every assumption is designed to maximize fluid velocity and/or minimize particle size, and thereby calculate an upper bound for the amount of sludge entrained into the eductor. Additional explanation is provided below for those assumptions requiring clarification.

- Internal tank structures (piping, etc.) are not included for simplification [5].
- The surface waves and instabilities at the supernate surface were neglected, with a pressure outlet boundary condition of atmospheric pressure at the free surface.
- The liquid volume in Tank 26 is assumed to stay relatively constant during the transfer process because the downcomer, which adds liquid at 110 gpm, will increase the fluid height by a maximum of 0.031 inches per minute.
- The fluid properties over the entire region of the tank are the same, with the supernate treated as water at 20^{o}C in the calculation. Previous calculations [6] have shown very little sensitivity to fluid temperature in the resulting flow patterns.
- The sludge layer is modeled as a solid, level surface with a free slip condition.
- Loosely-packed sludge solids in the turbid region are assumed to contain approximately 99 wt% supernate and 1 wt% undissolved solids loading.
- Sample results from the sludge in Tank 40 [2] are used to represent the sludge in Tank 26. No other applicable sample data are available at this time.
- The turbid region is treated as part of the tank liquid space; it is modeled as water without any sludge particles.
- Solids in the sludge layer are homogeneously distributed and are picked up into the flow when the local velocity at the sludge layer surface (at the solid boundary) exceeds the minimum scour velocity required to transport sludge solids.
- The liquid in Tank 26 is homogeneously mixed based on previous results [1] and the resulting flow patterns.

- The plunging jet created by the EFP bypass retains 50% of its fluid flow within the intact center column with the remaining 50% striking the supernate surface as fluid globules in random patterns within the impinging area ($d_{imp,b}$).

The assumptions listed above warrant some clarification. The assumption of water as the working fluid is appropriate because of its relative similarity to supernate in density and viscosity [6]. Previous work for similar analyses [1] has shown negligible impact on the calculated flow patterns between water and supernate.

Table 3.1. Modeling conditions used for the calculations.

Parameter	**Values**	
	Case 1: High tank level	Case 2: Low tank level
Supernate liquid level	341.5 in tank level	161 in tank level
Sludge layer at tank bottom	89 in tank level	89 in tank level
Downcomer jet flow rate (Q_o)	110 gpm	110 gpm
Downcomer exit diameter (d_o) [7]	3 in SCH 10S Pipe (3.26 in ID)	3 in SCH 10S Pipe (3.26 in ID)
Downcomer exit velocity (V_o)	4.23 ft/s (1.29 m/s)	4.23 ft/s (1.29 m/s)
Downcomer plunge height (H)	0.0 in	180.5 in (4.58 m)
Downcomer break-up length (L_c)	0.0 in	309 in – 374 in (7.85 m – 9.50 m)
Downcomer impinging diameter (d_{imp})	3.26 in (82.8 mm)	1.20 in (30.4 mm)
Downcomer impinging velocity (V_{imp})	4.23 ft/s (1.29 m/s)	31.4 ft/s (9.57 m/s)
EFP eductor flow rate (Q_o)	50 gpm	50 gpm
EFP eductor diameter (d_o) [8]	Penberthy LL 2.0 eductor (1.69 in ID)	Penberthy LL 2.0 eductor (1.69 in ID)
EFP eductor velocity (V_o)	-7.15 ft/s (2.18 m/s)	-7.15 ft/s (2.18 m/s)
EFP bypass flow rate (Q_o)	30 gpm	30 gpm
EFP bypass exit diameter (d_o) [8]	1 1/2 in SCH 40 Pipe (1.61 in ID)	1 1/2 in SCH 40 Pipe (1.61 in ID)
EFP bypass exit velocity (V_o)	4.73 ft/s (1.44 m/s)	4.73 ft/s (1.44 m/s)
EFP bypass plunge height (H)	0.0 in	180.5 in (4.58 m)
EFP bypass break-up length (L_c)	0.0 in	95 in – 105 in (2.41 m – 2.67 m)
EFP bypass impinging diameter* (d_{imp})	1.61 in (40.9 mm)	a = 0.221 in (5.61 mm); b = 3.312 in (84.13 mm)
EFP bypass impinging velocity* (V_{imp})	4.73 ft/s (1.44 m/s)	a = 31.5 ft/s (9.60 m/s); b = 0.732 ft/s (0.223 m/s)

Note: * See Figure 3.2 for clarification of a and b

Cohesively packed sludge will behave like a solid surface if the fluid velocity is too low to break the bonds holding the sludge solids together. Any loosely-packed solids along the sludge surface will move along with the fluid in a free slip fashion. The sludge in Tank 26 is primarily composed of cohesive, densely-packed sludge, with a turbid layer of loosely-packed solids (approximately 6 in deep) along the top of the sludge layer [3]. A turbidity probe can reach its maximum value with as little as 0.4 wt% sludge particles and is unable to measure higher values [9]. Thus, the turbid layer could have a wide range of values.

Because the turbid region is not well defined, it cannot be accurately modeled. Instead, several limiting assumptions (as listed above) were employed in the current analysis. A free slip boundary is used at the sludge surface to maximize the velocity at the bottom of the tank. The liquid flow over the sludge region will entrain all UDS that would be suspended by the calculated velocity. For example, a velocity sufficient to entrain 1 μm particles will entrain the entire population of particles that are smaller than or equal to 1 μm within the affected volume. Particles larger than 1 μm are assumed to continue to settle. Given the inactivity of Tank 26, the sludge content of the turbid region is estimated to be 1 wt% sludge particles with a representative size of 1 μm in diameter. Additional calculations have been performed to test the sensitivity of the results to this assumption. The results (Appendix A) show no change in the qualitative conclusions from this report for weight fractions as high as 5 wt%.

In the present study, the sludge solids are not scoured unless the liquid velocity is greater than the minimum scouring velocity (V_{min}) necessary to pick up solids deposited at the sludge layer. For cohesive sludge solids, the minimum scouring velocity is 0.7 m/s (2.27 ft/s) [6, 10]. For loosely-packed solid, the minimum scouring velocity is dependent upon several factors, including: flow velocity, particle size, and the density ratio between the sludge particles and the carrier fluid. Graf [11] published the following empirical correlation for the minimum scour velocity using data available in the literature.

$$V_{\min} = \left(\frac{d_p}{h}\right)^{-0.1} \cdot \sqrt{2.5 \cdot g \cdot d_p \cdot \left(\frac{\rho_p}{\rho_f} - 1\right)}, \qquad (3.1)$$

where d_p is the particle diameter, h is the tank liquid level, g is the acceleration due to gravity, ρ_p is the density of the sludge particles, and ρ_f is the density of the fluid. Typical values of the density ratio (ρ_p / ρ_f) for water and supernate are 2.5 and 1.67, respectively. A range of minimum scouring velocities for sludge particles ranging between 0.1 and 25.0 μm in diameter is provided in Table 3.2.

Table 3.2. Minimum velocities of supernate required to transport solid particles.

Particle size	Case 1 -- High supernate level	Case 2 -- Low supernate level
0.1 μm	0.0254 ft/s (0.00774 m/s)	0.0224 ft/s (0.00682 m/s)
0.5 μm	0.0483 ft/s (0.0147 m/s)	0.0427 ft/s (0.0130 m/s)
1.0 μm	**0.0637 ft/s (0.0194 m/s)**	**0.0561 ft/s (0.0171 m/s)**
5.0 μm	0.122 ft/s (0.0370 m/s)	0.107 ft/s (0.0326 m/s)
10.0 μm	0.160 ft/s (0.0488 m/s)	0.142 ft/s (0.0431 m/s)
15.0 μm	0.188 ft/s (0.0574 m/s)	0.166 ft/s (0.0506 m/s)
20.0 μm	0.212 ft/s (0.0644 m/s)	0.187 ft/s (0.0568 m/s)
25.0 μm	0.231 ft/s (0.0704 m/s)	0.204 ft/s (0.0621 m/s)
Cohesive sludge [6, 10]	2.27 ft/s (0.692 m/s)	2.27 ft/s (0.692 m/s)

According to previous work [1, 2], the sludge layer in the tanks at SRS has a typical range of UDS sizes between 0.1 and 25 μm. According to the literature [1, 2], submicron particles such as 0.1 μm solids do not settle readily since Brownian motion becomes significant for particles with diameters less than 0.5 μm. SRNL test results [2] show that approximately 20 vol.% of sludge for Tank 40 Batch 3 consists of particles less than 1 μm in diameter. Sample results [2] from Tank 40 have been identified as the best source of data available, as no specific sludge data exists for Tank 26 at this time. Thus, the present study assumes a representative particle size of 1 μm in diameter as a conservative estimate of the sludge layer solids.

For the low supernate level model (case 2), both the downcomer and EFP bypass discharge into the air as a free jet before striking the supernate surface as a plunging jet. A liquid jet discharging vertically downward into a gas will begin as a liquid column but will lose coherence and break apart farther downstream below the nozzle exit. Sallam *et al.* [12] provides the following correlation for this distance, known as the break-up length (L_c), for water jet in air.

$$L_c = C \cdot d_o \cdot We^{\frac{1}{2}}, \tag{3.2}$$

where *We* is the jet Weber number and *C* is an empirical parameter having a magnitude on the order of unity. For liquid jets with a Weber of 670 – 13,700 (*We* = 2000 and 1200 for the downcomer and EFP bypass, respectively), *C* is equal to 2.1 with a standard deviation of 0.2 [12]. From Equation (3.2), the downcomer has a break-up length between 309 and 374 inches and, thus, should remain a column until striking the supernate surface because the maximum plunge height is 180.5 inches. Conversely, the EFP bypass at 30 gpm has a break-up length between 95 and 105 inches and, thus, will break apart into large globules of liquid prior to impacting the supernate surface.

For the downcomer, the plunging jet's impinging velocity (V_{imp}) is derived from conservation of energy via the free fall equation.

$$V_{imp} = \sqrt{V_o^2 + 2 \cdot g \cdot H}, \tag{3.3}$$

where V_o is the velocity at the jet exit. The time-averaged plunging jet's impinging diameter (d_{imp}) can then be found using conservation of mass.

$$d_{imp} = \sqrt{\frac{4}{\pi} \cdot \frac{Q_o}{V_{imp}}}, \tag{3.4}$$

where Q_o is the volumetric flow rate leaving the jet exit.

Figure 3.2 provides a schematic of a free-falling liquid jet, which was used to describe the EFP bypass plunging jet that does not remain coherent at the supernate surface. Below the jet break-up length, globules of fluid break off from the jet column—due to gravity, turbulent eddies, and surface tension—as the jet column itself forms breaks at varying distances [12]. From a time-averaged standpoint, the jet column forms a steady pattern as it strikes the supernate surface, with a much smaller diameter than the remainder of the liquid jet. Outside of the inner column, the globules of liquid strike the supernate surface with varying sizes and random locations. However, no data are reported that measure the fraction of liquid remaining in the center column. To avoid underestimating this fraction, and based on the additional fall after break-up length coupled with the break-down process [12], the authors assumed that half of the original flow remained within the column at the supernate surface while the other half fell randomly within the outside diameter of the plunging jet. Castillo [13] published an empirical correlation for the plunging jet thickness at the liquid surface (impinging diameter, d_{imp}) in terms of the geometric dimensions of the jet exit, the fall height, and the relative turbulence of the jet at the jet exit using waterfall data.

$$d_{imp,b} = \sqrt{\frac{4}{\pi} \cdot \frac{Q_o}{V_{imp}}} + K \cdot T_u^* \cdot V_o \cdot \frac{V_{imp} - V_o}{g}, \tag{3.5}$$

where $d_{imp,b}$ is the total plunge jet diameter (outer circle), K is an empirical constant equal to approximately 1.14 for a circular jet [13], T^*_u is normalized streamwise turbulence of the free falling jet, and V_{imp} is the plunge jet's impinging velocity as found using Equation (3.3). Equation (3.4) can be used to find the diameter of the center column of the plunging jet ($d_{imp,a}$) by assuming that half of the volumetric flow rate is used in the calculation. The velocity of this intact center column ($V_{imp,a}$) is assumed to remain at the plunge jet velocity found using Equation (3.3). The effective velocity outside of the center column ($V_{imp,b}$) is found by averaging the other half of the flow rate across the plunge jet area outside of the center column.

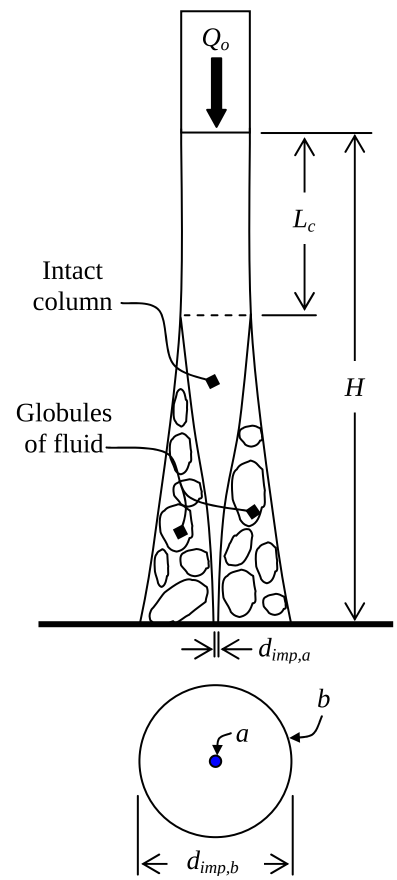

Figure 3.2. Plunging jet schematic.

In the present work, the weight percentage of sludge solids will be predicted from the ratio of the volume of sludge (Vol_{scour}) to the volume of supernate (Vol_{tank}) for a conservative evaluation of the sludge carryover during the operation of the EFP and the downcomer. The volume of sludge is calculated as the scour area at the bottom of the tank times the depth of loosely-packed sludge solids, as will be shown in the following section. The scour area for a given particle size is defined as the area at the sludge layer where the velocity is higher than the V_{min} for that particle and, thus, would scour that particle size.

4.0 CALCULATIONS AND RESULTS

The results for this work can be broken into two sections, which represent the minimum and maximum supernate levels within Tank 26. Section 4.1 presents results for case 1 with the supernate level at the maximum height of 341.5 inches above the bottom of the tank. Results from case 2 where the supernate level is at the minimum height of 161 inches above the tank floor are described in Section 4.2. Note, the aforementioned analysis was done for the limiting cases with the eductor and bypass flows set at 50 and 30 gpm, respectively. Section 4.3 presents two additional cases where the volumetric flow rates for the evaporator feed pump eductor and bypass were set to their minimums (20 gpm and 5 gpm, respectively).

4.1 CASE 1 – HIGH SUPERNATE LEVEL

Figures 4.1 and 4.2 show a sketch of the flow patterns created by the downcomer and the evaporator feed pump for the high supernate level model (case 1). The sketch is not drawn to scale to highlight the affected regions within the tank, which are too small to represent in full scale. The downward flow from the downcomer dissipates as it impinges upon the sludge layer at the bottom of the tank. At the sludge layer, the fluid scours UDS (from the sludge layer where the fluid velocity is greater than V_{min}) as it flows outward in all directions until it reaches the tank walls. The fluid then flows up the wall and along the supernate surface until it is entrained back downward toward the bottom of the tank. In this manner, large recirculation regions are formed that essentially mix the tank, spreading any scoured sludge particles throughout the tank. The EFP bypass creates similar flow patterns, although to a smaller extent due to the lower momentum (1.36 kg-m/s vs. 4.46 kg-m/s for the EFP bypass and downcomer, respectively).

Figure 4.2 shows the steady-state flow patterns near the EFP corresponding to the red dashed box within Figure 4.1. Here the color of the velocity vector corresponds to the total velocity magnitude (V_{total}). Note that arrows have been included throughout Figure 4.2 to show its similarity to Figure 4.1. The velocity vectors more than twelve eductor diameters downstream of the eductor orifice are not being turned toward the eductor. In addition, all of the fluid traveling into the eductor can be traced back toward the supernate surface.

There are two important points to make from Figures 4.1 and 4.2:

1. The recirculation regions will mix the tank fairly well so that most solids that are picked up from the sludge layer will be spread throughout the tank.
2. Undissolved solids entering the EFP eductor do not follow a straight path from the sludge layer to eductor. Instead, the UDS travel throughout the tank because of the recirculation regions before entering the EFP eductor via the supernate surface.

Total velocity contours at the sludge layer (1 mm above the sludge layer, or 89.04” above the tank bottom) for the high supernate model are presented in Figure 4.3. Note that the EFP (representing the bypass and eductor) and downcomer are marked by white circles within the contours. The highest velocity achieved at the sludge layer is 0.190 ft/s (0.058 m/s), which is much less than the minimum scour velocity of 2.27 ft/s (0.7 m/s), see Table 3.2, necessary to scour cohesive, densely-packed particles. However, above the densely packed sludge layer is a turbid layer of loosely-packed particles. Based on past experience and laboratory turbidity measurements [3, 9], this layer is estimated to be approximately 6 inches deep and have a solids weight-percentage on the order of 1%. By using the minimum scour velocities provided in Table 3.2, an area of scour (A_{scour}) can be found. The area of scour represents the area along the sludge surface with the minimum scour velocity (V_{min}) necessary to entrain particles of a given size.

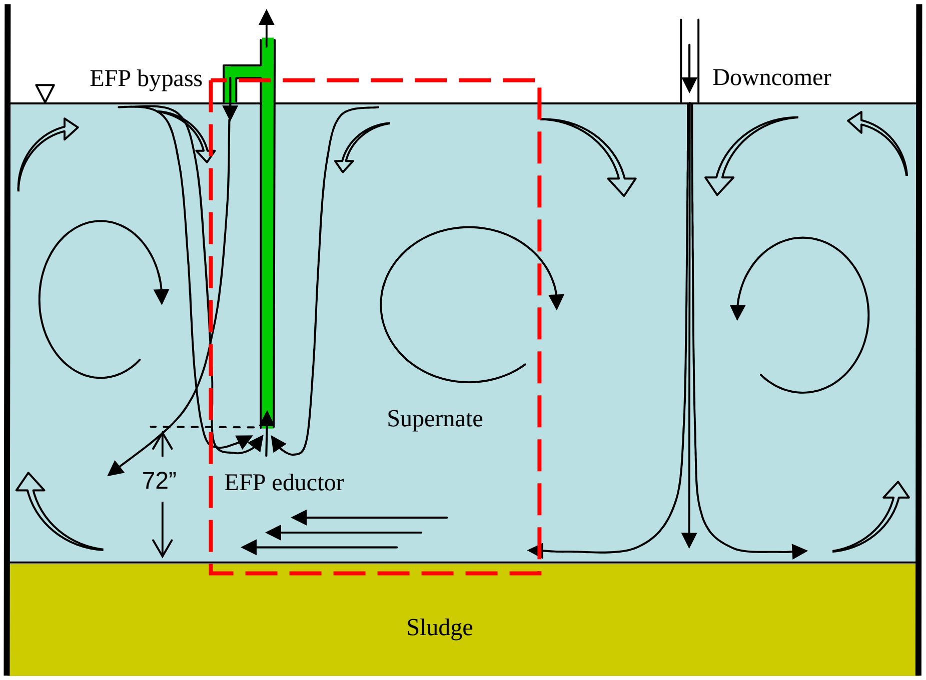

Figure 4.1. Two-dimensional sketch of the flow patterns produced by the downcomer and evaporator feed pump eductor and bypass for the high supernate level model. Not to scale.

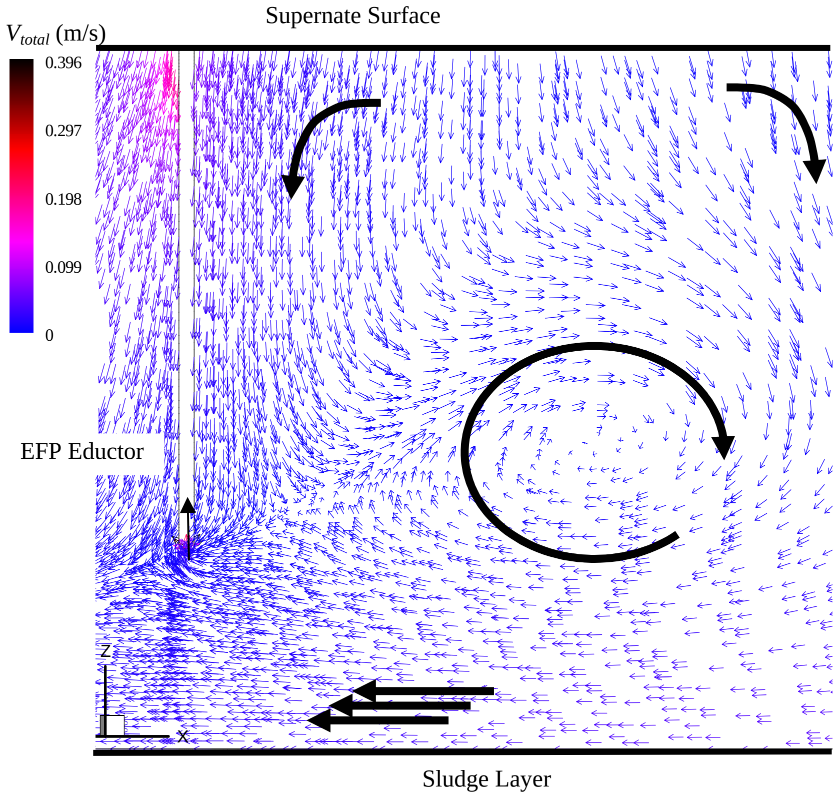

Figure 4.2. Three-dimensional velocity vector field showing the flow patterns for a selected region (corresponding to the red dashed box in Figure 4.1) within the high supernate model.

Figure 4.4a shows the area of scour for 1 µm particles (V_{min} = 19.4 mm/s). The volume of scour (Vol_{scour}) is then calculated by multiplying the area of scour by the thickness of the turbid region (t_{turbid}), as shown in Figure 4.4b. For a well mixed tank, the volume fraction of sludge entrained from the turbid region can be estimated by dividing the scour volume by the tank volume (Vol_{scour}/Vol_{tank}) and multiplying the result by the assumed weight fraction of sludge particles within the turbid region. Using the characteristic particle size of 1 µm and the assumed 1 wt% of sludge particles within the turbid region, the evaporator feed transfer into the eductor will contain approximately 0.0184 vol%, or 0.0307 wt%, sludge solids. Table 4.1 provides additional values based on several characteristic particle diameters within the turbid region.

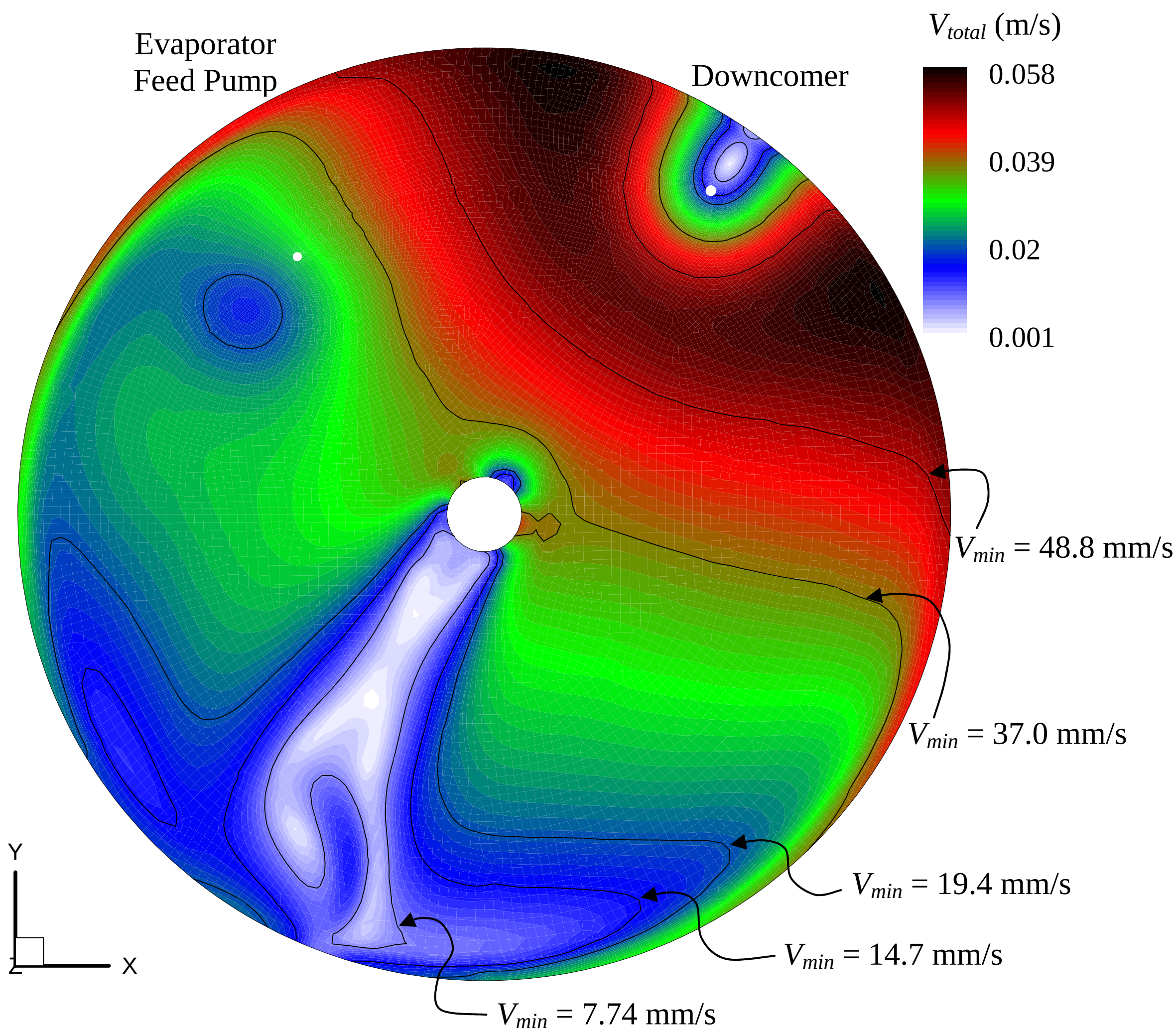

Figure 4.3. Total velocity contours at the sludge layer for the high supernate level model.

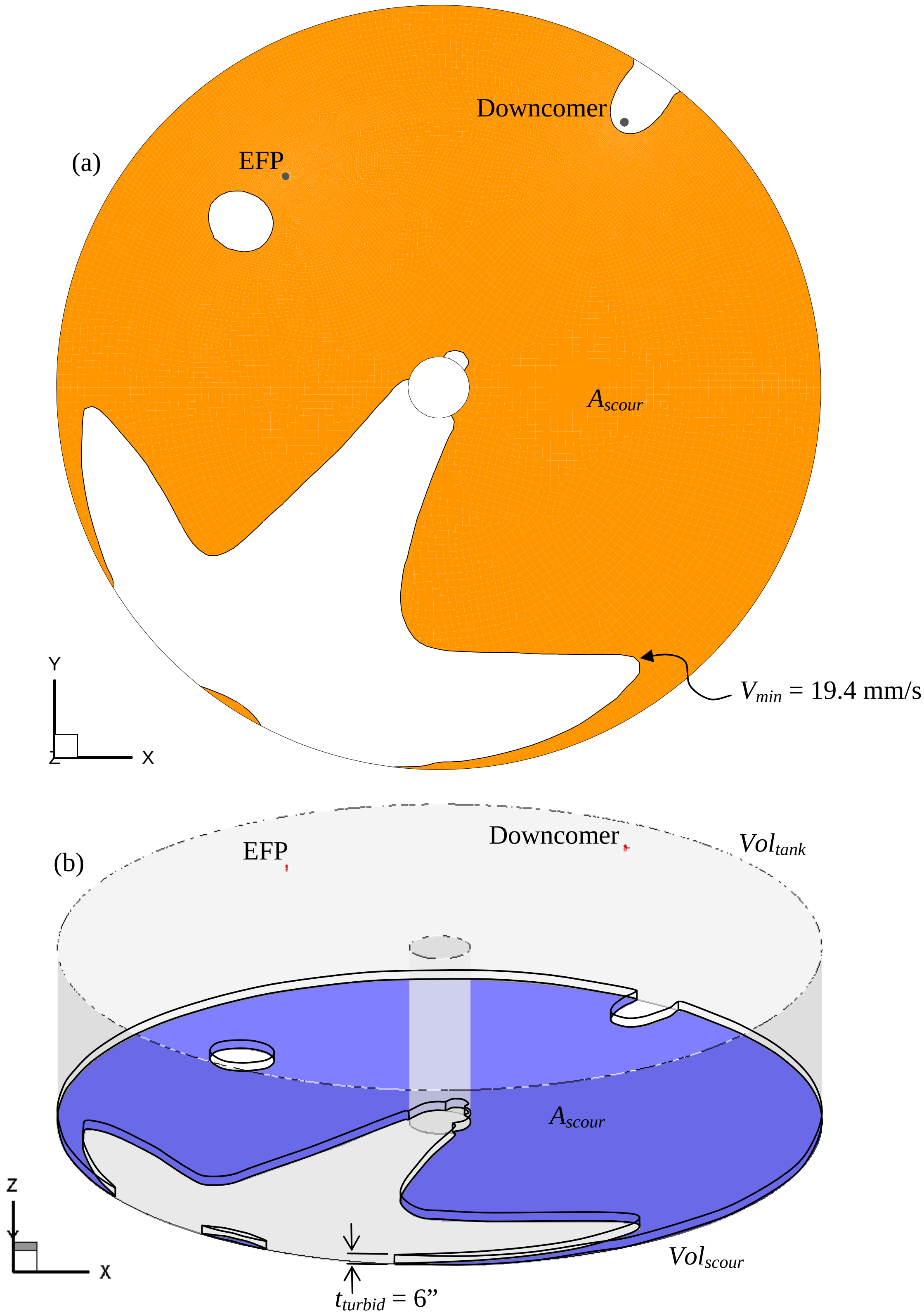

Figure 4.4. Schematic showing the area of scour (a) within the turbid region assuming 1 µm particles and the resulting volume (b) created using the turbid region thickness.

Table 4.1. Volume- and weight-percentage of UDS drawn into the eductor by the evaporator feed pump based on 1 wt% sludge particles within the turbid region for the high supernate case.

Characteristic Particle Size	V_{min}	A_{scour}	Vol_{scour}	Vol% sludge	Wt% sludge
0.1 μm	0.305 in/s (7.74 mm/s)	5,370 ft^2 (499 m^2)	2,690 ft^3 (76.0 m^3)	0.0226%	0.0378%
0.5 μm	0.579 in/s (14.7 mm/s)	4,930 ft^2 (458 m^2)	2,470 ft^3 (69.8 m^3)	0.0208%	0.0347%
1.0 μm	0.764 in/s (19.4 mm/s)	4,370 ft^2 (406 m^2)	2,180 ft^3 (61.8 m^3)	0.0184%	0.0307%
5.0 μm	1.46 in/s (37.0 mm/s)	1,900 ft^2 (177 m^2)	950 ft^3 (27.0 m^3)	0.0080%	0.0134%
10.0 μm	1.92 in/s (48.8 mm/s)	861 ft^2 (80.0 m^2)	430 ft^3 (12.2 m^3)	0.0036%	0.0061%

4.2 CASE 2 – LOW SUPERNATE LEVEL

Figure 4.5 presents a sketch (not to scale) of the flow patterns created in Tank 26 when the supernate level is at its minimum of 161 inches above the bottom of the tank (case 2). At this height, the downcomer and EFP bypass are both plunging jets that fall 180.5 in (4.58 m) before impacting the supernate surface at approximately 31.5 ft/s (9.6 m/s). At this impact velocity, the downcomer plunging jet will maintain much of its strength throughout the 72 inches of supernate above the sludge layer. The EFP bypass plunging jet will still penetrate the supernate with an appreciable amount of force, but to a lesser effect compared to the downcomer due to its break-up length after approximately 100 inches. The recirculation regions seen for the high supernate model are still present here, but with larger velocities and smaller sizes. Thus, their scouring ability is much higher than that seen in Section 4.1.

Again, the two main points from the high supernate model are valid for the low supernate level model:

1. The recirculation regions mix the tank fairly well so that most solids scoured from the sludge layer will be spread throughout the tank.
2. Undissolved solids entering the EFP eductor travel throughout the tank via recirculation regions rather than following a straight path from the sludge layer to the eductor.

Unlike the high supernate level case, the velocity at the sludge layer is an order of magnitude higher with a maximum total velocity of 1.87 ft/s (0.571 m/s) below the downcomer. While this is not higher than the 2.27 ft/s (0.692 m/s) necessary to scour cohesive sludge, it is rather close. However, the velocity across the sludge layer drops off quickly with increasing distance from the downcomer, as seen in the velocity contour plot in Figure 4.6 (1 mm above the sludge layer, or 89.04” above the tank bottom). Note that the EFP and downcomer are marked by white circles within the contours.

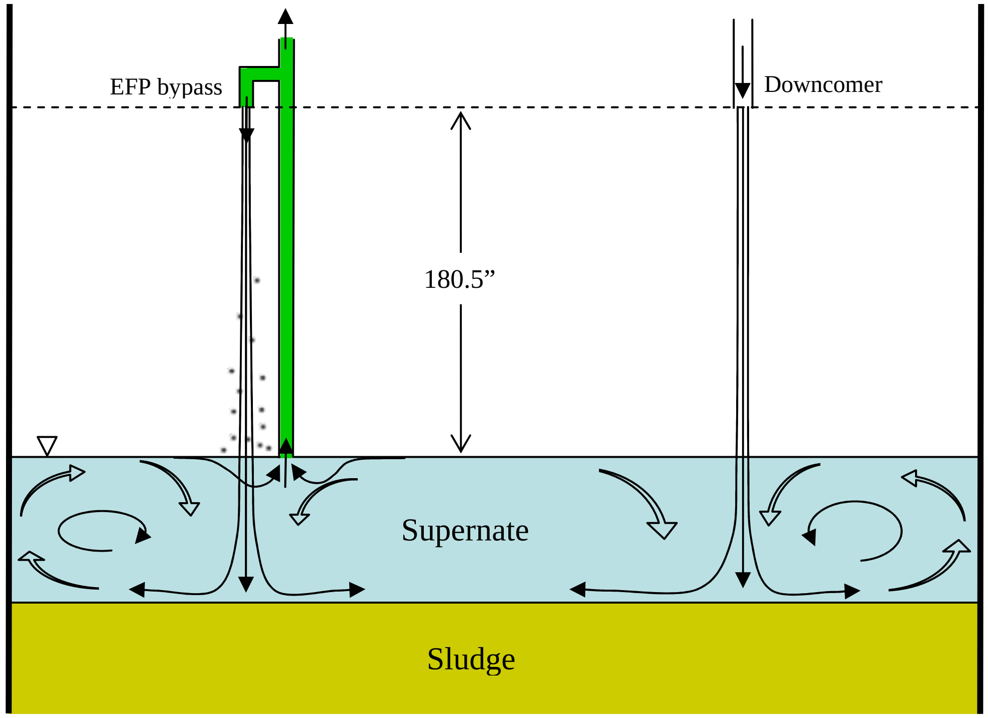

Figure 4.5. Two-dimensional sketch of the flow patterns produced by the downcomer and evaporator feed pump eductor and bypass for the low supernate level model. Not to scale.

While the downcomer and EFP bypass have the same freefall distance, their velocities at the sludge layer as well as their affected regions within the turbid layer are not equal. This can be attributed to the difference in momentum (1.36 kg-m/s vs. 4.46 kg-m/s for the EFP bypass and downcomer, respectively) as well as the condition of the plunging jets at the supernate surface. The downcomer remains coherent, which allows its impulse to cut through the liquid down to the sludge layer while keeping a high velocity. In contrast, the EFP bypass does not remain coherent and, thus, much of its momentum is spread throughout a large area of the surface in the form of globules of liquid. The remaining intact column of fluid (approximately half) dissipates more quickly as it plunges through the supernate, resulting in smaller velocities. Even with the lower velocities, the EFP bypass does entrain some sludge from the turbid region as shown in Figure 4.6. This is a significant change compared to the high supernate level case where the EFP bypass impedes the downcomer’s ability to scour, as shown by comparing the area below the EFP in Figures 4.3 and 4.6 for the low and high supernate levels, respectively.

At the minimum supernate level, the velocity magnitude is too low to scour the densely-packed, cohesive particles. Thus, only the loosely-packed particles within the turbid layer will be affected. Using the procedure described in Section 4.1 (see Figure 4.4) and assuming a characteristic particle size of 1 μm with 1 wt% sludge particles in the turbid region, the evaporator feed transfer into the eductor will contain approximately 0.0560 vol%, or 0.0935 wt%, sludge solids. Table 4.2 provides additional values based on several characteristic particle diameters within the turbid region.

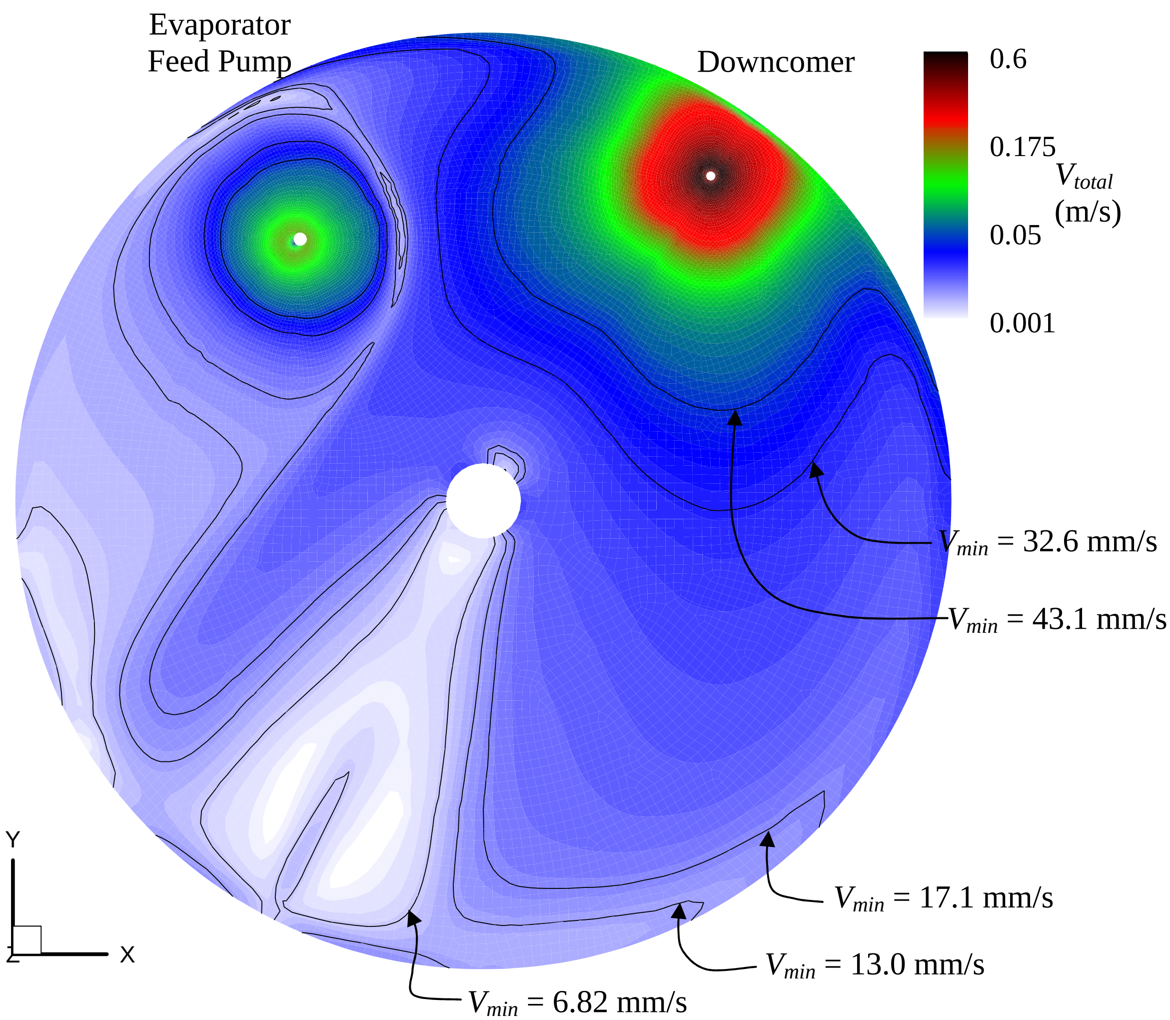

Figure 4.6. Total velocity contours at the sludge layer for the low supernate level model.

Table 4.2. Volume- and weight-percentage of UDS drawn into the eductor by the evaporator feed pump based on 1 wt% sludge particles within the turbid region for the low supernate case.

Characteristic Particle Size	V_{min}	A_{scour}	Vol_{scour}	Vol% sludge	Wt% sludge
0.1 µm	0.269 in/s (6.82 mm/s)	5,100 ft^2 (474 m^2)	2,550 ft^3 (72.3 m^3)	0.0755%	0.126%
0.5 µm	0.512 in/s (13.0 mm/s)	4,250 ft^2 (395 m^2)	2,130 ft^3 (60.2 m^3)	0.0629%	0.105%
1.0 µm	0.673 in/s (17.1 mm/s)	3,790 ft^2 (352 m^2)	1,890 ft^3 (53.6 m^3)	0.0560%	0.0935%
5.0 µm	1.28 in/s (32.6 mm/s)	1,470 ft^2 (136 m^2)	734 ft^3 (20.8 m^3)	0.0217%	0.0362%
10.0 µm	1.70 in/s (43.1 mm/s)	906 ft^2 (84.1 m^2)	453 ft^3 (12.8 m^3)	0.0134%	0.0224%

4.3 ADDITIONAL CASES

Additional cases for both the high and low supernate levels were evaluated with the EFP bypass and eductor activated with the minimum volumetric flow rates of 5 gpm and 20 gpm, respectively. Figure 4.7 presents the total velocity contours for these additional cases with

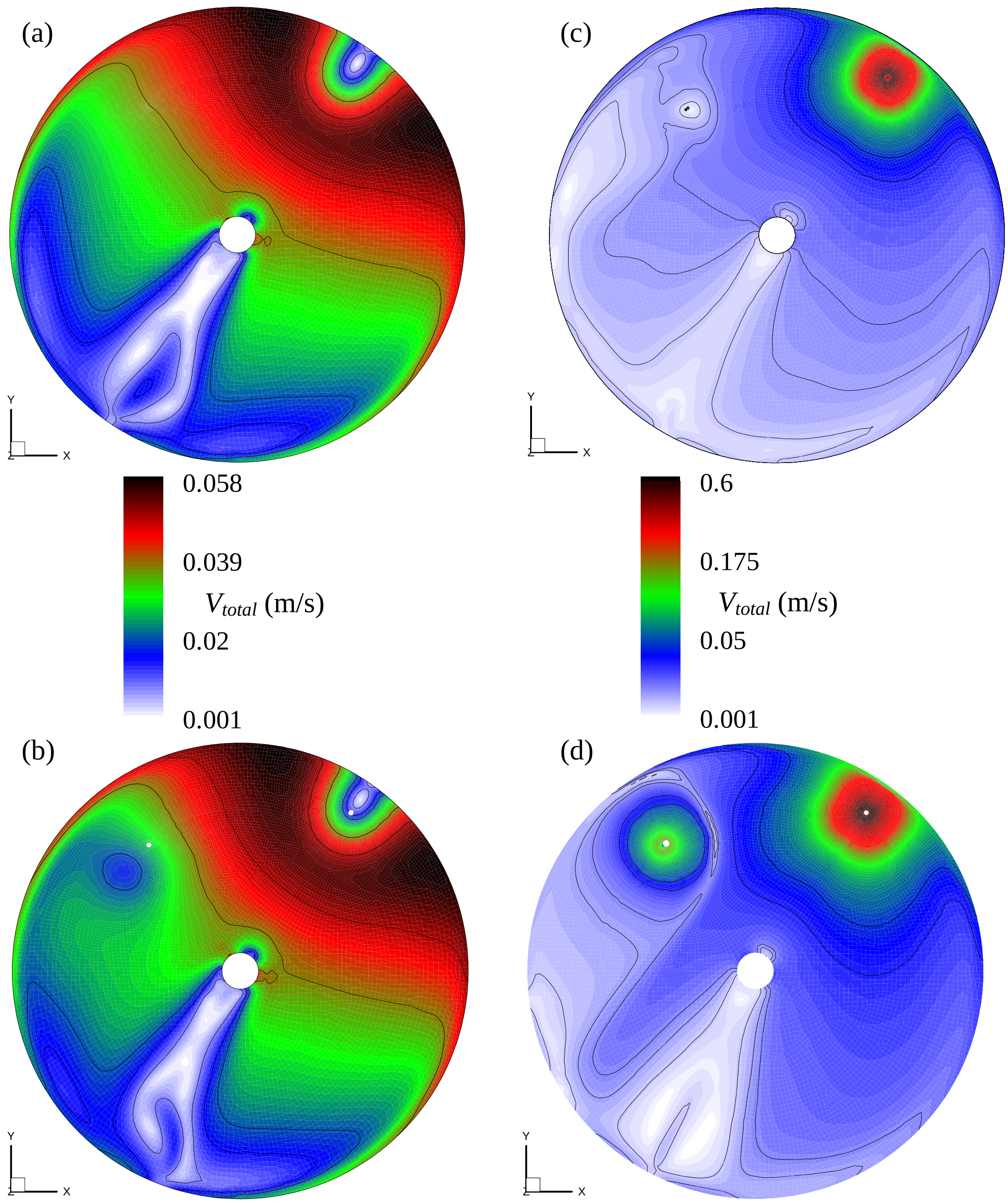

Figure 4.7. Total velocity contours for the high (a, b) and low (c, d) supernate level models with the EFP bypass activated at 5 gpm (a, c) and 30 gpm (b, d).

the EFP bypass discharging at 5 gpm (Figures 4.7a and c) compared to the results with the EFP bypass discharging at 30 gpm (Figures 4.7b and d, respectively). Note that the downcomer remains constant with a flow rate of 110 gpm. For the high supernate cases (Figures 4.7a and b, 5 gpm and 30 gpm, respectively), the flow patterns are very similar with maximum velocities that are comparable, with the 30 gpm case (discussed in Section 4.1) having the higher velocity magnitudes and larger areas of scour for the range of particle sizes examined. Thus, the 30 gpm model (as discussed in Section 4.1) is the bounding case.

Similarly, when comparing the low supernate level models with the EFP bypass at 5 gpm and 30 gpm (Figures 4.7c and d, respectively), the 30 gpm case as discussed in Section 4.2 has the higher velocities and is the bounding case. In addition, the resulting flow patterns are still similar throughout the bulk of the tank, which suggested that the plunging jet height of the EFP bypass is more significant with regards to sludge scour.

5.0 CONCLUSIONS

The preceding analysis of Tank 26 was based on the following conditions, in coordination with Table 3.1:

- Only the liquid within Tank 26 is modeled. Particle motions are inferred based on the velocity field and the interactions (entrainment, settling, etc.) that would occur because of those velocities.
- Flow rates are set to the highest values for the evaporator feed pump eductor and bypass, which have ranges of 20 – 50 gpm and 5 – 30 gpm, respectively [4].
- When the supernate liquid level is below the downcomer orifice, the downcomer flow and EFP bypass are treated as plunging jets.
- Tank 26 contains primarily cohesive, densely-packed sludge, with a turbid layer approximately 6 inches deep of loosely-packed solids above the sludge layer [3].
- Based on sampling test results for Tank 40 sludge Batch 3 [2], the typical range of particulate diameters is between 0.1 and 25 μm, with approximately 20 vol.% of the sludge distribution consisting of particles less than 1 μm in diameter.

The preceding analysis was also based on the following assumptions:

- Internal tank structures (piping, etc.) are not included for simplification [5].
- The surface waves and instabilities at the supernate surface were neglected, with a pressure outlet boundary condition of atmospheric pressure at the free surface.
- The liquid volume in Tank 26 is assumed to stay relatively constant during the transfer process because the downcomer, which adds liquid at 110 gpm, will increase the fluid height by a maximum of 0.031 inches per minute.
- The fluid properties over the entire region of the tank are the same, with the supernate treated as water at 20^oC in the calculation. Previous calculations [6] have shown very little sensitivity to fluid temperature in the resulting flow patterns.
- The sludge layer is modeled as a solid, level surface with a free slip condition.

- Loosely-packed sludge solids in the turbid region are assumed to contain approximately 99 wt% supernate and 1 wt% sludge particles.
- Sample results from the sludge in Tank 40 [2] provide the best representation of the sludge in Tank 26 as no sample data is available at this time.
- The turbid region is treated as supernate during the analysis and modeled as water.
- Solids in the sludge layer are homogeneously distributed and are picked up into the flow when the local velocity at the sludge layer surface (at the solid boundary) exceeds the minimum scour velocity required to transport sludge solids.
- The plunging jet created by the EFP bypass retains 50% of its fluid flow within the intact center column with the remaining 50% striking the supernate surface as fluid globules in random patterns within the impinging area ($d_{imp,b}$).
- The liquid in Tank 26 is homogeneously mixed based on previous results [1] and the resulting flow patterns.

From these conditions and assumptions, the evaporator feed pump will draw between 0.03 and 0.1 wt% sludge solids into the eductor depending upon the tank liquid level (252.5 and 72 inches above the sludge layer, respectively). Lower tank liquid levels, with respect to the sludge layer, result in higher amounts of sludge entrainment due to the increased plunging jet velocities as well as decreased dissipation depth.

The preceding work has helped to quantify the behavior of plunging jets for future work.

6.0 REFERENCES

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APPENDIX A. ADDITIONAL TURBIDITY CALCULATIONS

Because very little is known about the turbid region, additional calculations were performed for both the low and high supernate level models. In these calculations, the wt% particulate within the turbid region was varied between 0.1 and 10.0 wt%. The results of these calculations are found in Tables A.1 – A.8.

Table A.1. Volume- and weight-percentage of UDS drawn into the eductor by the evaporator feed pump based on 0.1 wt% sludge particles within the turbid region for the high supernate case.

Characteristic Particle Size	V_{min}	A_{scour}	Vol_{scour}	Vol% sludge	Wt% sludge
0.1 μm	0.305 in/s (7.74 mm/s)	5,370 ft^2 (499 m^2)	2,690 ft^3 (76.0 m^3)	0.0023%	0.0038%
0.5 μm	0.579 in/s (14.7 mm/s)	4,930 ft^2 (458 m^2)	2,470 ft^3 (69.8 m^3)	0.0021%	0.0035%
1.0 μm	0.764 in/s (19.4 mm/s)	4,370 ft^2 (406 m^2)	2,180 ft^3 (61.8 m^3)	0.0018%	0.0031%
5.0 μm	1.46 in/s (37.0 mm/s)	1,900 ft^2 (177 m^2)	950 ft^3 (27.0 m^3)	0.0008%	0.0013%
10.0 μm	1.92 in/s (48.8 mm/s)	861 ft^2 (80.0 m^2)	430 ft^3 (12.2 m^3)	0.0004%	0.0006%

Table A.2. Volume- and weight-percentage of UDS drawn into the eductor by the evaporator feed pump based on 0.5 wt% sludge particles within the turbid region for the high supernate case.

Characteristic Particle Size	V_{min}	A_{scour}	Vol_{scour}	Vol% sludge	Wt% sludge
0.1 μm	0.305 in/s (7.74 mm/s)	5,370 ft^2 (499 m^2)	2,690 ft^3 (76.0 m^3)	0.0113%	0.0189%
0.5 μm	0.579 in/s (14.7 mm/s)	4,930 ft^2 (458 m^2)	2,470 ft^3 (69.8 m^3)	0.0104%	0.0174%
1.0 μm	0.764 in/s (19.4 mm/s)	4,370 ft^2 (406 m^2)	2,180 ft^3 (61.8 m^3)	0.0092%	0.0154%
5.0 μm	1.46 in/s (37.0 mm/s)	1,900 ft^2 (177 m^2)	950 ft^3 (27.0 m^3)	0.0040%	0.0067%
10.0 μm	1.92 in/s (48.8 mm/s)	861 ft^2 (80.0 m^2)	430 ft^3 (12.2 m^3)	0.0018%	0.0030%

Table A.3. Volume- and weight-percentage of UDS drawn into the eductor by the evaporator feed pump based on 5.0 wt% sludge particles within the turbid region for the high supernate case.

Characteristic Particle Size	V_{min}	A_{scour}	Vol_{scour}	Vol% sludge	Wt% sludge
0.1 μm	0.305 in/s (7.74 mm/s)	5,370 ft^2 (499 m^2)	2,690 ft^3 (76.0 m^3)	0.113%	0.189%
0.5 μm	0.579 in/s (14.7 mm/s)	4,930 ft^2 (458 m^2)	2,470 ft^3 (69.8 m^3)	0.104%	0.174%
1.0 μm	0.764 in/s (19.4 mm/s)	4,370 ft^2 (406 m^2)	2,180 ft^3 (61.8 m^3)	0.0920%	0.154%
5.0 μm	1.46 in/s (37.0 mm/s)	1,900 ft^2 (177 m^2)	950 ft^3 (27.0 m^3)	0.0401%	0.0669%
10.0 μm	1.92 in/s (48.8 mm/s)	861 ft^2 (80.0 m^2)	430 ft^3 (12.2 m^3)	0.0181%	0.0303%

Table A.4. Volume- and weight-percentage of UDS drawn into the eductor by the evaporator feed pump based on 10.0 wt% sludge particles within the turbid region for the high supernate case.

Characteristic Particle Size	V_{min}	A_{scour}	Vol_{scour}	Vol% sludge	Wt% sludge
0.1 μm	0.305 in/s (7.74 mm/s)	5,370 ft^2 (499 m^2)	2,690 ft^3 (76.0 m^3)	0.226%	0.378%
0.5 μm	0.579 in/s (14.7 mm/s)	4,930 ft^2 (458 m^2)	2,470 ft^3 (69.8 m^3)	0.208%	0.347%
1.0 μm	0.764 in/s (19.4 mm/s)	4,370 ft^2 (406 m^2)	2,180 ft^3 (61.8 m^3)	0.184%	0.307%
5.0 μm	1.46 in/s (37.0 mm/s)	1,900 ft^2 (177 m^2)	950 ft^3 (27.0 m^3)	0.0801%	0.134%
10.0 μm	1.92 in/s (48.8 mm/s)	861 ft^2 (80.0 m^2)	430 ft^3 (12.2 m^3)	0.0363%	0.0606%

Table A.5. Volume- and weight-percentage of UDS drawn into the eductor by the evaporator feed pump based on 0.1 wt% sludge particles within the turbid region for the low supernate case.

Characteristic Particle Size	V_{min}	A_{scour}	Vol_{scour}	Vol% sludge	Wt% sludge
0.1 μm	0.269 in/s (6.82 mm/s)	5,100 ft^2 (474 m^2)	2,550 ft^3 (72.3 m^3)	0.0075%	0.0126%
0.5 μm	0.512 in/s (13.0 mm/s)	4,250 ft^2 (395 m^2)	2,130 ft^3 (60.2 m^3)	0.0063%	0.0105%
1.0 μm	0.673 in/s (17.1 mm/s)	3,790 ft^2 (352 m^2)	1,890 ft^3 (53.6 m^3)	0.0056%	0.0094%
5.0 μm	1.28 in/s (32.6 mm/s)	1,470 ft^2 (136 m^2)	734 ft^3 (20.8 m^3)	0.0022%	0.0036%
10.0 μm	1.70 in/s (43.1 mm/s)	906 ft^2 (84.1 m^2)	453 ft^3 (12.8 m^3)	0.0013%	0.0022%

Table A.6. Volume- and weight-percentage of UDS drawn into the eductor by the evaporator feed pump based on 0.5 wt% sludge particles within the turbid region for the low supernate case.

Characteristic Particle Size	V_{min}	A_{scour}	Vol_{scour}	Vol% sludge	Wt% sludge
0.1 μm	0.269 in/s (6.82 mm/s)	5,100 ft^2 (474 m^2)	2,550 ft^3 (72.3 m^3)	0.0377%	0.0630%
0.5 μm	0.512 in/s (13.0 mm/s)	4,250 ft^2 (395 m^2)	2,130 ft^3 (60.2 m^3)	0.0314%	0.0525%
1.0 μm	0.673 in/s (17.1 mm/s)	3,790 ft^2 (352 m^2)	1,890 ft^3 (53.6 m^3)	0.0280%	0.0468%
5.0 μm	1.28 in/s (32.6 mm/s)	1,470 ft^2 (136 m^2)	734 ft^3 (20.8 m^3)	0.0108%	0.0181%
10.0 μm	1.70 in/s (43.1 mm/s)	906 ft^2 (84.1 m^2)	453 ft^3 (12.8 m^3)	0.0067%	0.0112%

Table A.7. Volume- and weight-percentage of UDS drawn into the eductor by the evaporator feed pump based on 5.0 wt% sludge particles within the turbid region for the low supernate case.

Characteristic Particle Size	V_{min}	A_{scour}	Vol_{scour}	Vol% sludge	Wt% sludge
0.1 μm	0.269 in/s (6.82 mm/s)	5,100 ft^2 (474 m^2)	2,550 ft^3 (72.3 m^3)	0.377%	0.630%
0.5 μm	0.512 in/s (13.0 mm/s)	4,250 ft^2 (395 m^2)	2,130 ft^3 (60.2 m^3)	0.314%	0.525%
1.0 μm	0.673 in/s (17.1 mm/s)	3,790 ft^2 (352 m^2)	1,890 ft^3 (53.6 m^3)	0.280%	0.468%
5.0 μm	1.28 in/s (32.6 mm/s)	1,470 ft^2 (136 m^2)	734 ft^3 (20.8 m^3)	0.108%	0.181%
10.0 μm	1.70 in/s (43.1 mm/s)	906 ft^2 (84.1 m^2)	453 ft^3 (12.8 m^3)	0.0669%	0.112%

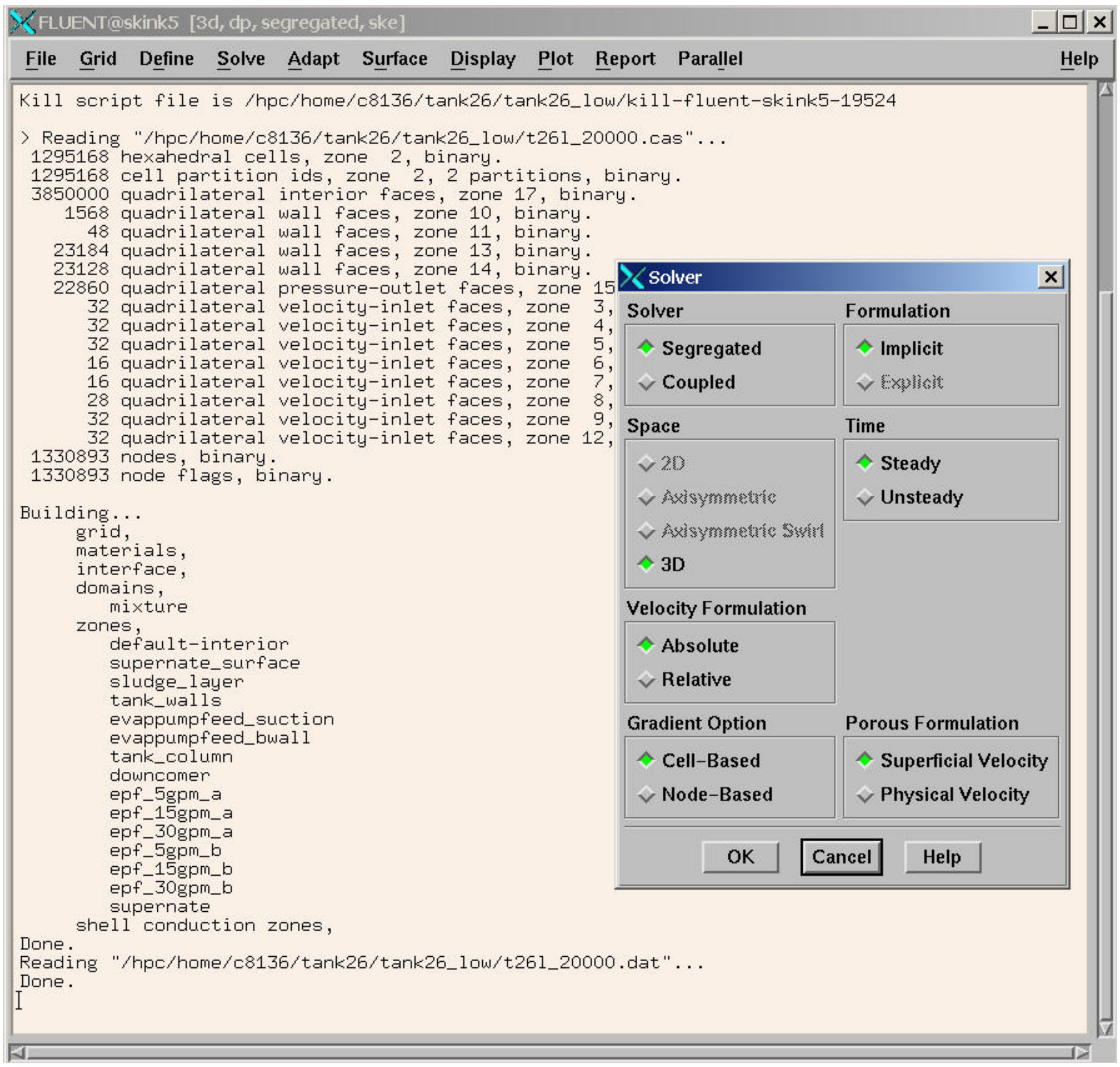
Table A.8. Volume- and weight-percentage of UDS drawn into the eductor by the evaporator feed pump based on 10.0 wt% sludge particles within the turbid region for the low supernate case.

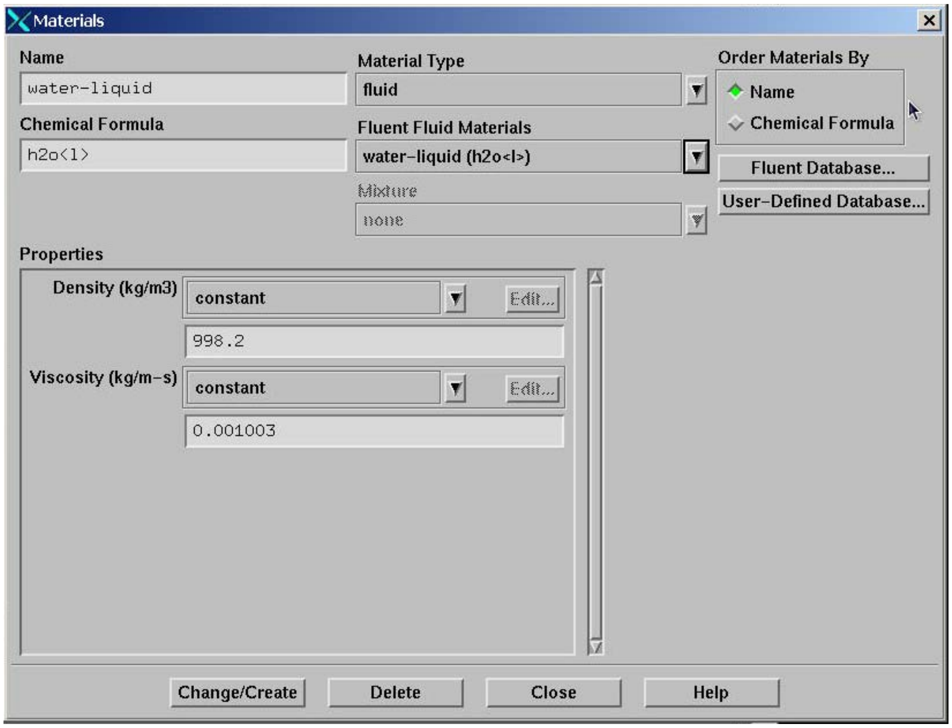
Characteristic Particle Size	V_{min}	A_{scour}	Vol_{scour}	Vol% sludge	Wt% sludge
0.1 μm	0.269 in/s (6.82 mm/s)	5,100 ft^2 (474 m^2)	2,550 ft^3 (72.3 m^3)	0.755%	1.26%
0.5 μm	0.512 in/s (13.0 mm/s)	4,250 ft^2 (395 m^2)	2,130 ft^3 (60.2 m^3)	0.629%	1.05%
1.0 μm	0.673 in/s (17.1 mm/s)	3,790 ft^2 (352 m^2)	1,890 ft^3 (53.6 m^3)	0.560%	0.935%
5.0 μm	1.28 in/s (32.6 mm/s)	1,470 ft^2 (136 m^2)	734 ft^3 (20.8 m^3)	0.217%	0.362%
10.0 μm	1.70 in/s (43.1 mm/s)	906 ft^2 (84.1 m^2)	453 ft^3 (12.8 m^3)	0.134%	0.224%

APPENDIX B. FLUENT SETTINGS

All FLUENT files pertinent to this analysis can be found at the following address: \\Hpcfs\c8136\tank26. Because of computer security issues, access to these files can only be obtained by calling one of the authors of this report.

Within this folder, there are additional folders for the low and high supernate models. The following screen-shots provide the important parameters used in the above analyses.

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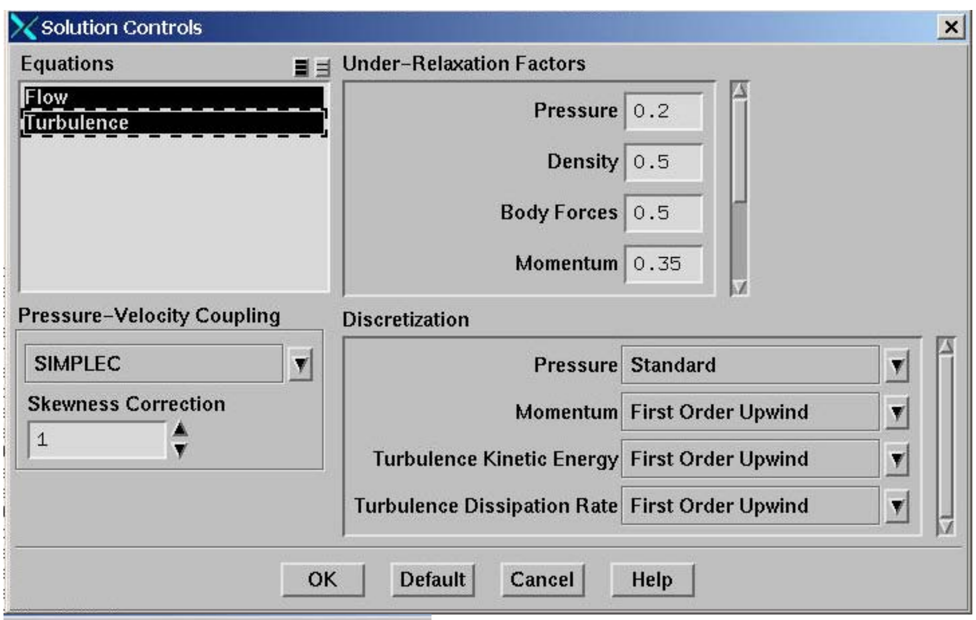
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SIMPLEC
Skewness Correction
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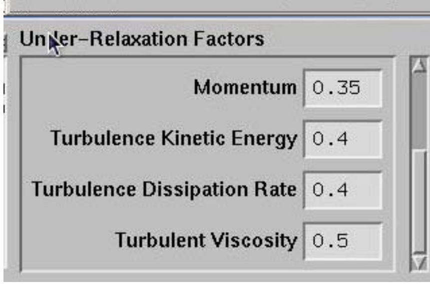
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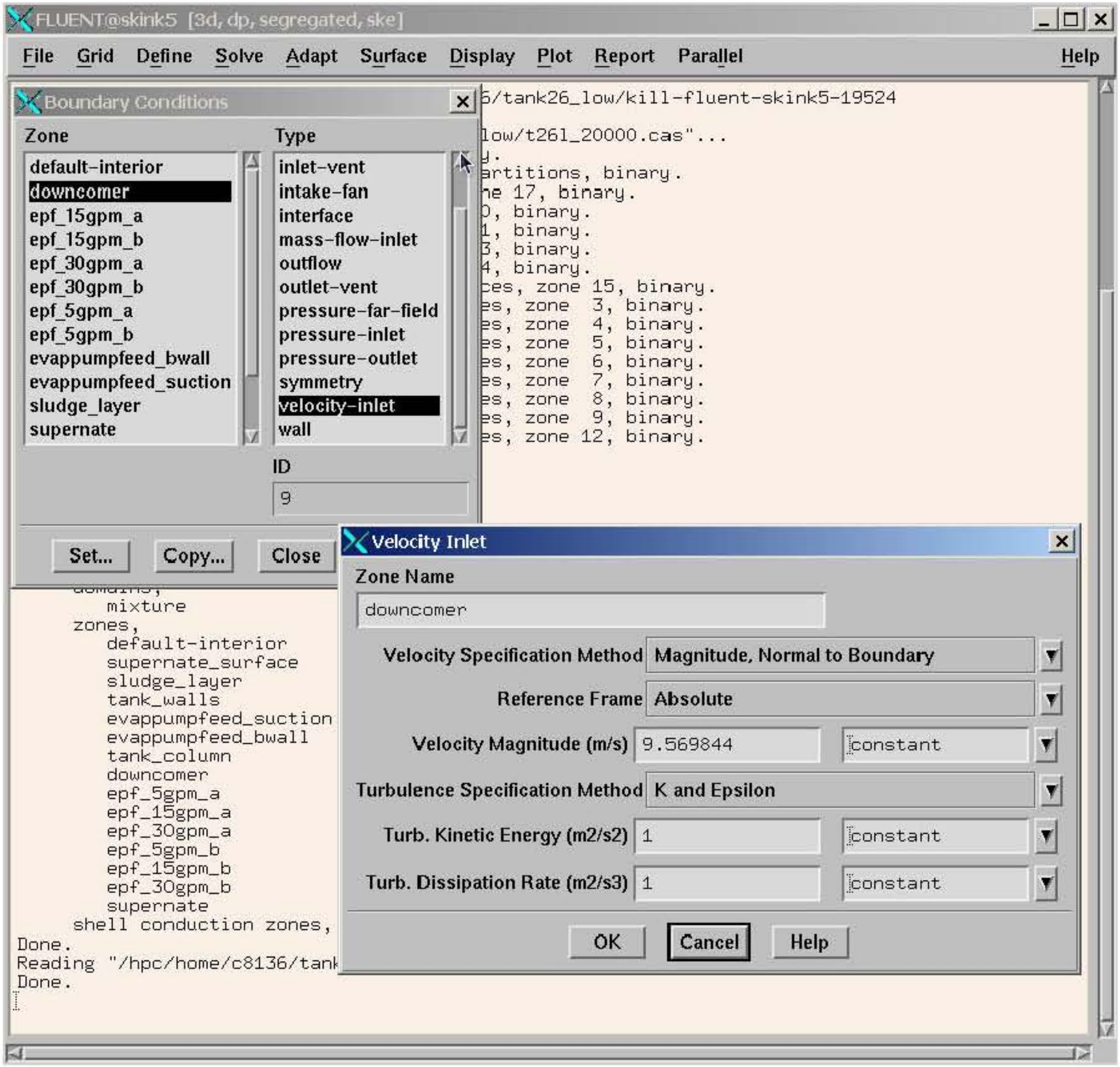
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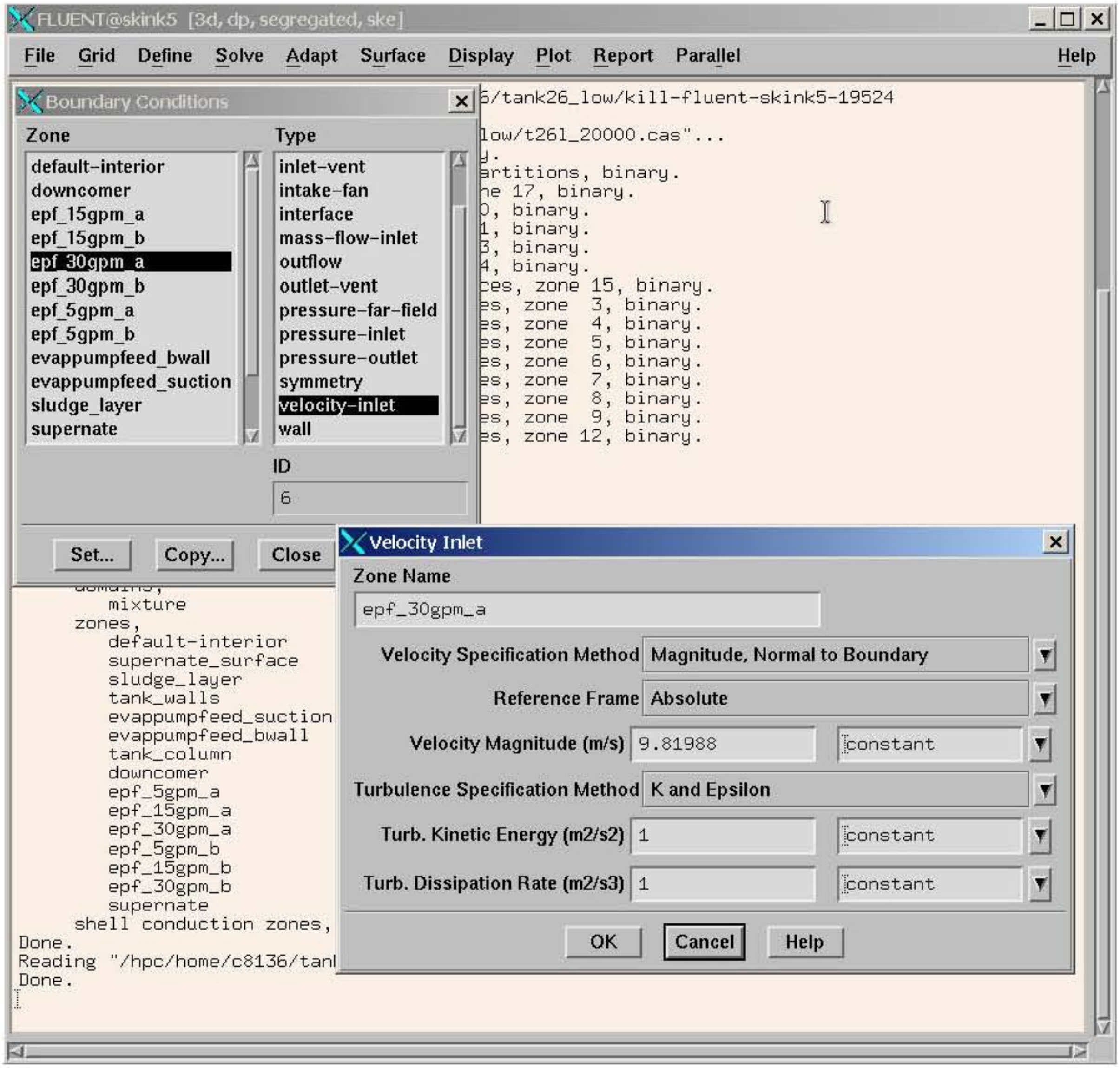
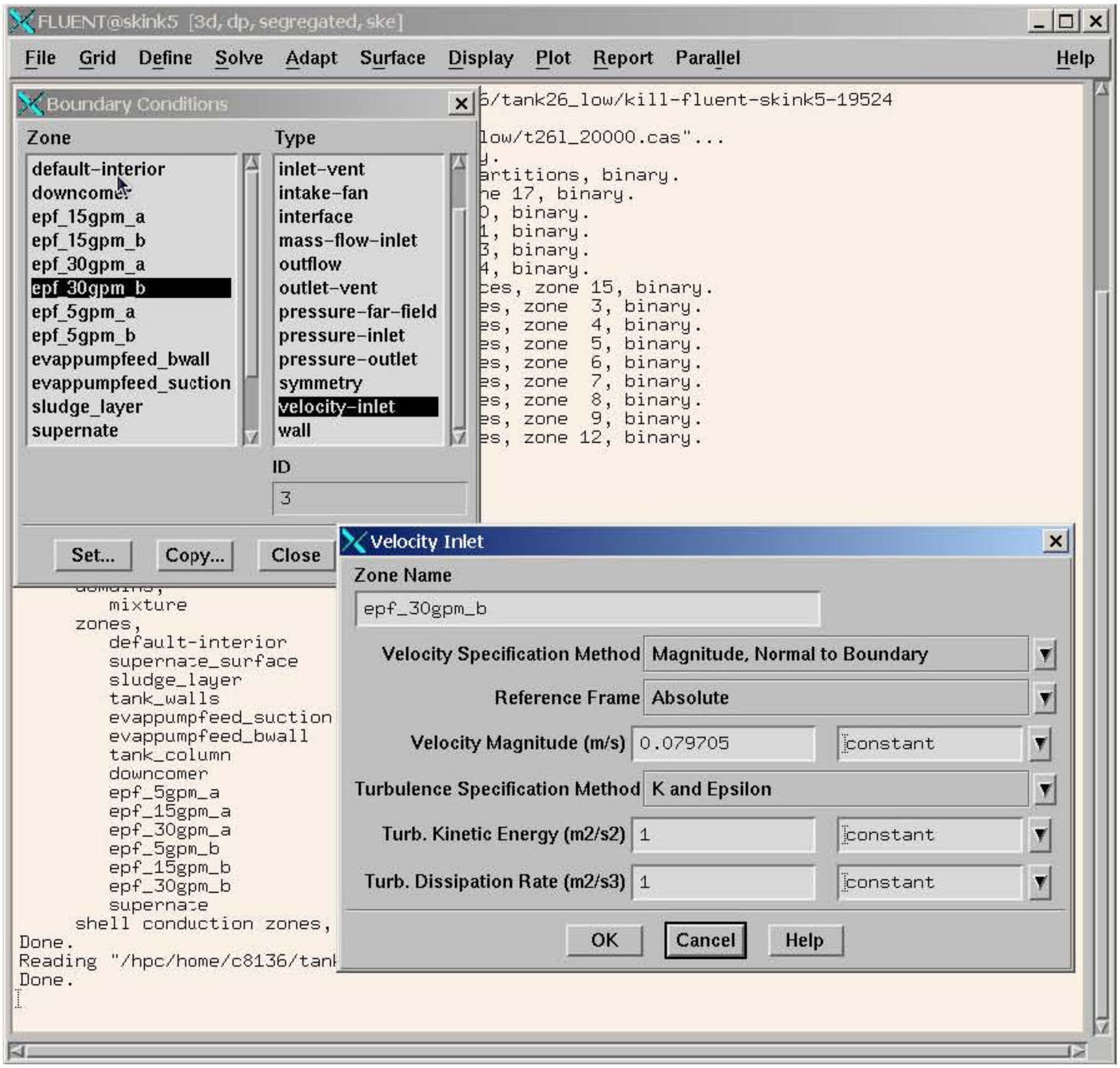
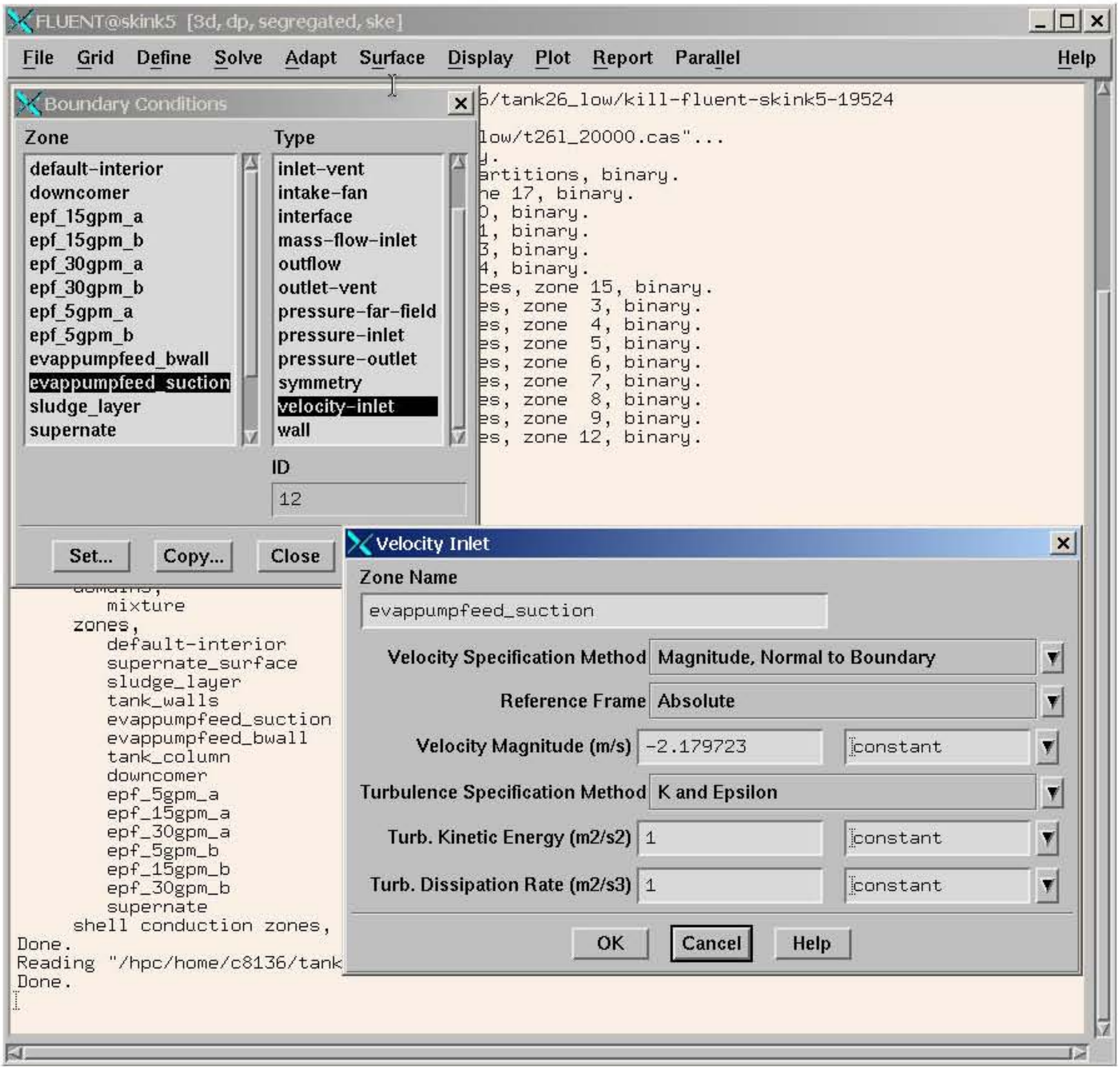
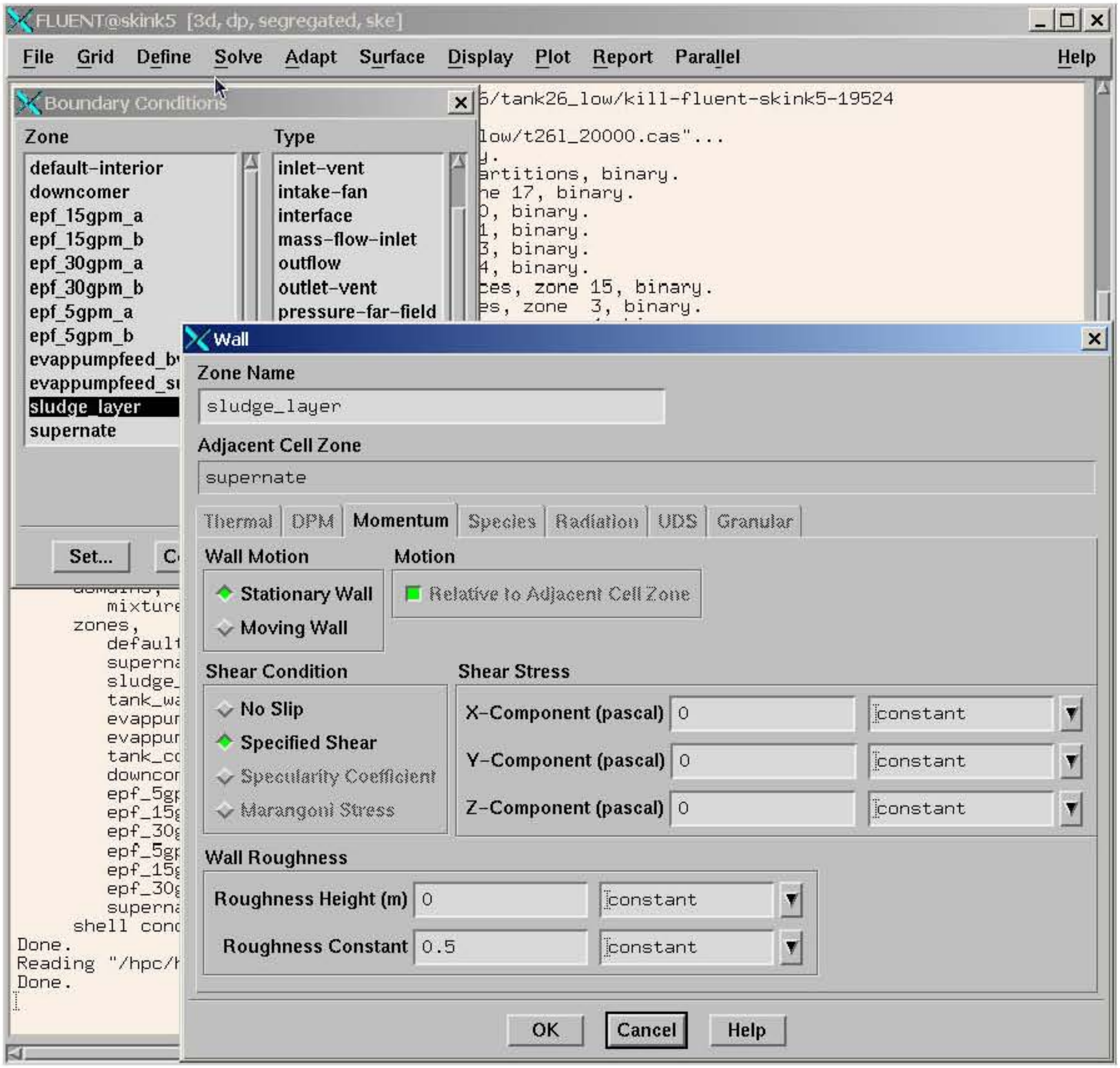
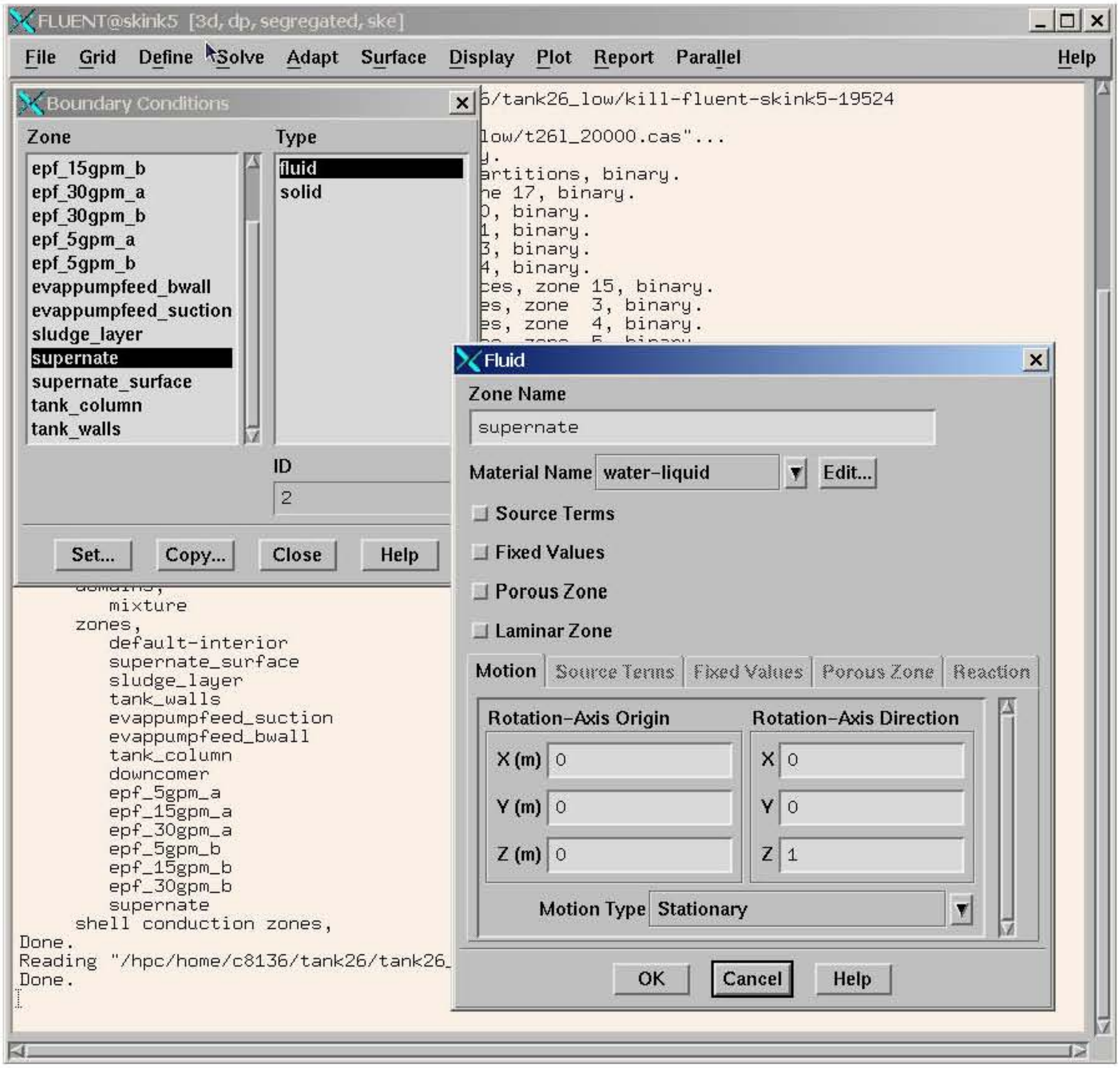
sludge_layer
tank_walls
evappumpfeed_suction
evappumpfeed_bwall
tank_column
downcomer
epf_5gpm_a
epf_15gpm_a
epf_30gpm_a
epf_5gpm_b
epf_15gpm_b
epf_30gpm_b
supernate
shell conduction zones,
Done.
Reading "/hpc/home/c8136/tank
Done.

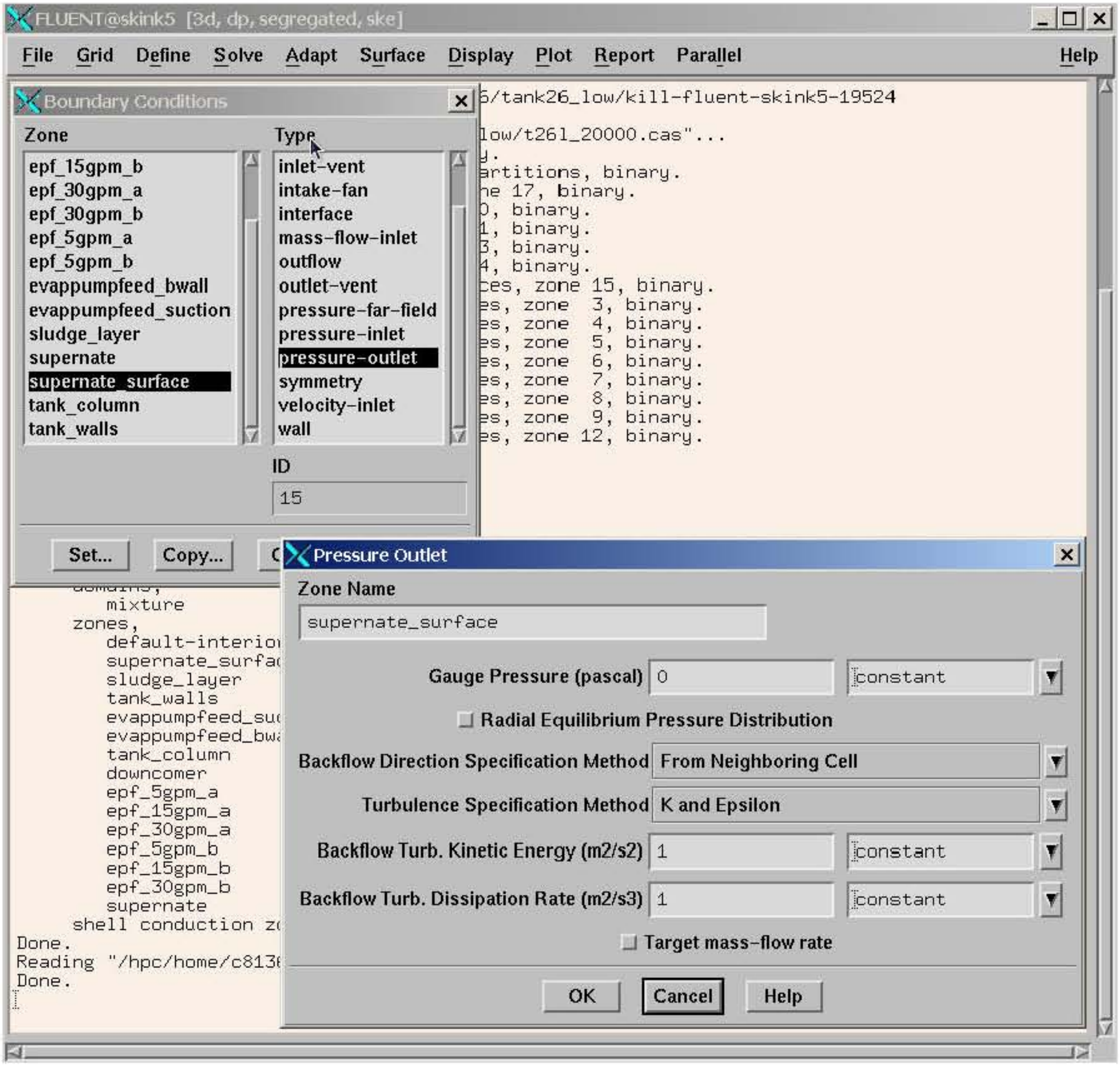

FLUENT@skink5 [3d, dp, segregated, ske]
File Grid Define Solve Adapt Surface Display Plot Report Parallel Help
Boundary Conditions
Zone
default-interior
downcomer
epf_15gpm_a
epf_15gpm_b
epf_30gpm_a
epf_30gpm_b
epf_5gpm_a
epf_5gpm_b
evappumpfeed_bwall
evappumpfeed_suction
sludge_layer
supernate
Type
inlet-vent
intake-fan
interface
mass-flow-inlet
outflow
outlet-vent
pressure-far-field
pressure-inlet
pressure-outlet
symmetry
velocity-inlet
wall
ID
6
Set...
Copy...
Close
Velocity Inlet
Zone Name
epf_30gpm_a
Velocity Specification Method
Magnitude, Normal to Boundary
Reference Frame
Absolute
Velocity Magnitude (m/s)
9.81988
constant
Turbulence Specification Method
K and Epsilon
Turb. Kinetic Energy (m2/s2)
1
constant
Turb. Dissipation Rate (m2/s3)
1
constant
OK
Cancel
Help


FLUENT@skink5 [3d, dp, segregated, ske]
File Grid Define Solve Adapt Surface Display Plot Report Parallel Help
Boundary Conditions
Zone
default-interior
downcomer
epf_15gpm_a
epf_15gpm_b
epf_30gpm_a
epf_30gpm_b
epf_5gpm_a
epf_5gpm_b
evappumpfeed_bwall
evappumpfeed_suction
sludge_layer
supernate
Type
inlet-vent
intake-fan
interface
mass-flow-inlet
outflow
outlet-vent
pressure-far-field
pressure-inlet
pressure-outlet
symmetry
velocity-inlet
wall
ID
3
Set... Copy... Close
Velocity Inlet
Zone Name
epf_30gpm_b
Velocity Specification Method Magnitude, Normal to Boundary
Reference Frame Absolute
Velocity Magnitude (m/s) 0.079705 constant
Turbulence Specification Method K and Epsilon
Turb. Kinetic Energy (m2/s2) 1 constant
Turb. Dissipation Rate (m2/s3) 1 constant
OK Cancel Help
mixture
zones,
default-interior
supernate_surface
sludge_layer
tank_walls
evappumpfeed_suction
evappumpfeed_bwall
tank_column
downcomer
epf_5gpm_a
epf_15gpm_a
epf_30gpm_a
epf_5gpm_b
epf_15gpm_b
epf_30gpm_b
supernate
shell conduction zones,
Done.
Reading "/hpc/home/c8136/tank
Done.


FLUENT@skink5 [3d, dp, segregated, ske]
File Grid Define Solve Adapt Surface Display Plot Report Parallel Help
Boundary Conditions
Zone
default-interior
downcomer
epf_15gpm_a
epf_15gpm_b
epf_30gpm_a
epf_30gpm_b
epf_5gpm_a
epf_5gpm_b
evappumpfeed_bwall
evappumpfeed_suction
sludge_layer
supernate
Type
inlet-vent
intake-fan
interface
mass-flow-inlet
outflow
outlet-vent
pressure-far-field
pressure-inlet
pressure-outlet
symmetry
velocity-inlet
wall
ID
12
Set...
Copy...
Close
Velocity Inlet
Zone Name
evappumpfeed_suction
Velocity Specification Method Magnitude, Normal to Boundary
Reference Frame Absolute
Velocity Magnitude (m/s) -2.179723 constant
Turbulence Specification Method K and Epsilon
Turb. Kinetic Energy (m2/s2) 1 constant
Turb. Dissipation Rate (m2/s3) 1 constant
OK
Cancel
Help
mixture
zones,
default-interior
supernate_surface
sludge_layer
tank_walls
evappumpfeed_suction
evappumpfeed_bwall
tank_column
downcomer
epf_5gpm_a
epf_15gpm_a
epf_30gpm_a
epf_5gpm_b
epf_15gpm_b
epf_30gpm_b
supernate
shell conduction zones,
Done.
Reading "/hpc/home/c8136/tank
Done.


FLUENT@skink5 [3d, dp, segregated, ske]
File Grid Define Solve Adapt Surface Display Plot Report Parallel Help
Boundary Conditions
Zone
default-interior
downcomer
epf_15gpm_a
epf_15gpm_b
epf_30gpm_a
epf_30gpm_b
epf_5gpm_a
epf_5gpm_b
sludge_layer
supernate
Type
inlet-vent
intake-fan
interface
mass-flow-inlet
outflow
outlet-vent
pressure-far-field
Set...
Wall
Zone Name
sludge_layer
Adjacent Cell Zone
supernate
Thermal DPM Momentum Species Radiation UDS Granular
Wall Motion
Motion
Stationary Wall
Moving Wall
Relative to Adjacent Cell Zone
Shear Condition
Shear Stress
No Slip
Specified Shear
Specularity Coefficient
Marangoni Stress
X-Component (pascal) 0 constant
Y-Component (pascal) 0 constant
Z-Component (pascal) 0 constant
Wall Roughness
Roughness Height (m) 0 constant
Roughness Constant 0.5 constant
OK Cancel Help
Done.
Done.


FLUENT@skink5 [3d, dp, segregated, ske]
File Grid Define Solve Adapt Surface Display Plot Report Parallel Help
Boundary Conditions
Zone
epf_15gpm_b
epf_30gpm_a
epf_30gpm_b
epf_5gpm_a
epf_5gpm_b
evappumpfeed_bwall
evappumpfeed_suction
sludge_layer
supernate
supernate_surface
tank_column
tank_walls
Type
fluid
solid
ID
2
Set... Copy... Close Help
Fluid
Zone Name
supernate
Material Name water-liquid Edit...
Source Terms
Fixed Values
Porous Zone
Laminar Zone
Motion Source Terms Fixed Values Porous Zone Reaction
Rotation-Axis Origin
X (m) 0
Y (m) 0
Z (m) 0
Rotation-Axis Direction
X 0
Y 0
Z 1
Motion Type Stationary
OK Cancel Help
mixture
zones,
default-interior
supernate_surface
sludge_layer
tank_walls
evappumpfeed_suction
evappumpfeed_bwall
tank_column
downcomer
epf_5gpm_a
epf_15gpm_a
epf_30gpm_a
epf_5gpm_b
epf_15gpm_b
epf_30gpm_b
supernate
shell conduction zones,
Done.
Reading "/hpc/home/c8136/tank26/tank26_
Done.


FLUENT@skink5 [3d, dp, segregated, ske]
File Grid Define Solve Adapt Surface Display Plot Report Parallel Help
Boundary Conditions
Zone
epf_15gpm_b
epf_30gpm_a
epf_30gpm_b
epf_5gpm_a
epf_5gpm_b
evappumpfeed_bwall
evappumpfeed_suction
sludge_layer
supernate
supernate_surface
tank_column
tank_walls
Type
inlet-vent
intake-fan
interface
mass-flow-inlet
outflow
outlet-vent
pressure-far-field
pressure-inlet
pressure-outlet
symmetry
velocity-inlet
wall
ID
15
Set...
Copy...
Pressure Outlet
Zone Name
supernate_surface
Gauge Pressure (pascal)
0
constant
Radial Equilibrium Pressure Distribution
Backflow Direction Specification Method
From Neighboring Cell
Turbulence Specification Method
K and Epsilon
Backflow Turb. Kinetic Energy (m2/s2)
1
constant
Backflow Turb. Dissipation Rate (m2/s3)
1
constant
Target mass-flow rate
OK
Cancel
Help