Design improvements of activated sludge clarifiers over the past 3 decades reflect an evolving and better understanding of the mechanisms of energy dissipation, flocculation, settling, and thickening principles. However, only recently has attention been focused on the transport characteristics of the sludge conveyors, either for rectangular or circular clarifiers.

Sludge transport problems in large clarifiers are caused by a failure to scale up scrapers and a misunderstanding of sludge transport requirements in large clarifiers where sludge quantities usually exceed the capacity of the scrapers. Accepted procedures for estimating the solids loading and underflow concentration by flux analysis are readily available and are based on a first-in, first-out solids flow, precluding the possibility of short-circuiting, which results in the dilution of the underflow concentration and increased sludge blankets.

Short-circuiting of influent to the underflow in secondary clarifiers has been well documented over the years. Clarifiers with inadequate sludge transport behave in the same manner as clarifiers experiencing increased sludge volume index (SVI), that is, bulking sludge. In short, the response is the same: blankets rise and the underflow is more dilute. Practice, unfortunately, evolved to accept underflow dilution, the resulting higher return rate and solids flux, and lower clarifier capacities (see Box U.S. and European Practices).

Today, the problem of short-circuiting, more pronounced in larger units, can be directly linked to the sludge mechanism transport capacity. An understanding of transport requirements will lead to mechanism designs that will increase transport capacity and eliminate the problems of short-circuiting feed to the underflow and rising sludge blankets that often plague large clarifiers with straight blade or spiral collectors. When short-circuiting is controlled by proper scraper design and operation, secondary clarifiers produce results as predicted by flux analysis.

To define the methodology for transport calculations for two types of sludge conveyors and to provide specific design recommendations for the rake mechanism configuration and tip speeds, the performance of three U.S. facilities was evaluated as well as how the problem of inadequate transport was handled. The plants demonstrated that the circular conveyors could be operated much faster (up to 10 m/min) than the current practice of 2 to 4 m/min, and that, in addition to higher tip speeds, the transport capacity can be substantially increased by deepening and lengthening scraper blades. Specific design procedures were recommended to

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**U.S. and European Practices**

U.S. practice generally favors multiple drawoff or rapid sludge removal clarifiers, especially for units greater than 24 m (80 ft) in diameter. The original rationale was a perceived necessity to recycle the freshest possible sludge to improve 5-day biochemical oxygen demand removal. However, improved treatment performance with anoxic and anaerobic selectors placed ahead of aeration have since proven this concept invalid.

In Europe, the most common mechanism design in circular basins is the spiral collector, either centrally or peripherally driven with central sludge takeoff. The spiral scraper is a simple and effective mechanism and, when short-circuiting is controlled, its resulting performance makes the spiral scraper the clarifier of choice for small and large units. However, U.S. equipment suppliers, unlike their European counterparts, do not scale up the collector scraper size for large clarifiers. As a result, clarifier operators continue to be plagued by short-circuiting caused by lack of transport and dilute return sludge capacity.
A 140-ft Phoenix clarifier modified to spiral scrapers.

Table 1—Determining Rectangular Scraper Depth

<table>
<thead>
<tr>
<th>Scraper velocity, m/min</th>
<th>Sludge depth at hopper, mm</th>
<th>Recommended scraper depth, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Maximum</td>
</tr>
<tr>
<td>0.30</td>
<td>916</td>
<td>1426</td>
</tr>
<tr>
<td>0.61</td>
<td>458</td>
<td>713</td>
</tr>
<tr>
<td>0.92</td>
<td>309</td>
<td>475</td>
</tr>
<tr>
<td>1.22</td>
<td>229</td>
<td>357</td>
</tr>
<tr>
<td>1.53</td>
<td>183</td>
<td>285</td>
</tr>
<tr>
<td>1.83</td>
<td>153</td>
<td>234</td>
</tr>
</tbody>
</table>

*Sludge depth average is 16.1 mm, maximum is 280 mm.

Design Conditions

- Sludge loading rate (SLR) = 88 kg/m²•d (18 lb/ft²•d), average
  = 137 kg/m²•d (28 lb/ft²•d), maximum
- Minimum RAS concentration ≥ 8000 mg/L
- Sludge volume index ≤ 120 mL/g
- Transport distance to hopper = 36 m (120 ft)
Equations

\[ \nu_c = \left( f \right) \left( L \right) \left( d_b \right) \left( v_r \right) \left( 60 \text{ min/h} \right) \]  
(1)

Where

\( \nu_c \) = transport capacity of scrapers, m³/h (ft³/h)

\( f \) = transport efficiency, possibly 0.8 to 1.3, as a function of sludge viscosity, sludge depth and the sludge scrapers’ spacing, depth and velocity.

\( L \) = length of scraper, m (ft)

\( d_b \) = depth of scraper blade, m (ft)

\( v_r \) = velocity of scraper, m/min (ft/min)

\[ d_d = \frac{\left( \text{SLR, kg/m²•d} \right) \times \left( 10^6 \text{ mg/kg} \right) \times \left( 1000 \text{ mm/m} \right)}{\left( 24 \text{ h/d} \right) \times \left( \text{RSS, mg/L} \right) \times \left( 1000 \text{ kg/m}^3 \right)} \]  
(2)

Where

\( \text{SLR} \) = Sludge loading rate

\( \left( 88 \right) \times \left( 10^7 \right) \times \left( 1000 \right) \)

Average \( d_d = \frac{\left( 24 \right) \times \left( 8000 \right) \times \left( 1000 \right)}{458 \text{ mm/h} \left( 18 \text{ in./h} \right) \}

Maximum \( d_d = 713 \text{ mm/h} \left( 28 \text{ in./h} \right) \}

\[ \nu_r = \left( f_1 \right) \left( f_2 \right) \left( \sin \alpha \right) \]  
(3)

Where

\( d_d \) = sludge deposition rate

\( v_r \) = sludge velocity parallel to the scraper blade, m/min,

\( f_1 \) = efficiency of sludge transport allowing for slippage, sludge accumulation and other factors; usually ≤ 0.75, when \( d_d < d_g \),

\( v_s \) = velocity of scraper at radius, \( r \), m/min,

\( \alpha \) = angle between tangent to the spiral scraper and the radius, degrees.

\[ t = \frac{L}{v_c} \quad \text{and} \quad L = \frac{R 

Where

\( L \) = length of the spiral cord, R - R', m (ft)

\( R \) = tank radius, m (ft)

\( R' \) = radius at center of sludge hopper, m (ft)

Design Procedures

In rectangular clarifiers, the scraper velocity limits the forward flow velocity. Adjusting scraper spacing and height can fine-tune scraper performance, but other variables like sludge viscosity and the velocity and direction of the overriding liquid flow will also affect scraper performance. With the proper scraper arrangement, the transport efficiency (f) should be ≥ 1.0, equal to scraper displacement, even when handling low viscosity, bulking sludges. The volumetric displacement capacity (\( \nu_c \)) of the rectangular clarifier scraper (Figure 1) may be simply stated as in Equation 1.

To ensure that the clarifier will not short-circuit influent to the underflow, the mechanism must be able to transport all of the concentrated sludge at the maximum loading to the hopper. Based on the design operating conditions, the requirements for the rectangular scraper can be easily determined (see Box Design Conditions).

The concentrated sludge deposition rate (\( d_d \)) as a function of loading is determined in Equation 2. If the settled sludge were evenly deposited across the tank floor—the assumed prologue to flux failure, then the 458 to 713 mm (18 to 28 in.) of concentrated sludge must be removed and transported to the sludge hopper from the 36-m (120-ft) basin length every hour. The calculated total sludge volume would be 5.1 to 7.9 m³/h (180 to 280 ft³/h) per 0.3 m (1 ft) of tank width. Table 1 shows the required scraper depth as a function of scraper velocity, assuming the transport efficiency is equal to 1.0.

Traditionally, rectangular clarifier mechanisms have been supplied with 152- to 203-mm (6- to 8-in.) flights that move at 0.3 to 0.6 m/min (1 to 2 ft/min). Higher scraper velocities have been considered unnecessary or inoperable by U.S. equipment suppliers who believe flow motivation is derived from hydraulic effects, even with ≤ 1:40 floor slopes. Observations at several plants (Metcalf and Eddy, 1922) revealed that if only gravity and density effects were relied on, the slope must be at least 2° on 1, or 60°, to convey biological sludges hydraulically and by gravity.

The collector mechanism in this example should have at least 381-mm (15-in.) flights and be capable of operating up to 1.5 m/min (5 ft/min). A two-, three-, or variable-speed drive would be flexible enough to handle a wide range of sludge loadings and characteristics.

The slope of the floor should result in at least 0.9 to 1.2 m (3 to 4 ft) of added depth at the sludge withdrawal sump to provide adequate sludge depth over the hopper with minimal sludge retention at the effluent end. Shallow floor slopes should be avoided because they can cause excessive sludge retention, which results in a host of problems including denitrification, solids loss, and rat-holing of a shallow blanket and subsequent short-circuiting.

Sludge hopper placement is important. At higher mixed liquor suspended solids (MLSS), the transport distance should not exceed about 39 m (130 ft). Although a hopper is often placed at the one-third point, transport failure tends to occur at the longer effluent end—longer sludge transport equals greater sludge depth. Such transport failures suggest that, for very long tanks (>60 m), placing the hoppers near midpoint and influent end is best, and both hoppers can be served by a single drive, chains, and scrapers.

Circular clarifiers. Defining the capacity of circular clarifier scrapers is difficult—the sludge to be conveyed is attacked at an angle and flows circumferentially toward the hopper, the floor area shrinks, conveying velocity decreases, and sludge depth increases geometrically as the sludge progresses toward the center of the tank. Although underflow velocity effects in circular tanks are more dominant near the withdrawal point, the resulting deeper blanket near the center dictates that circular units have a steeper floor slope, higher scraper velocity, and deeper blades. To some extent, transporting activated sludge with a conventional circular tank scraper is like “pushing a wet noodle” in that there is ample opportunity for the sludge to flow over the conveyor...
Literature Review

Sludge thickening in secondary clarifiers has been studied extensively by Dick and Ewing (1967), Dick and Young (1972), and Vesilind (1968), and a good understanding of activated sludge rheology is available. Techniques to determine thickening characteristics as a function of the initial solids concentration, clarifier solids loadings, and the sludge volume index (SVI) have been developed by Daigger and Roper (1983) and Keinath (1990). Still, many clarifiers are unable to produce the expected underflow concentrations and have excessive and detrimental blanket depths even with good settling sludges. Kalskof (1972), for example, in his study of German secondary clarifiers, characterized underflow concentrations (percent TSS) to be 1.1 to 1.3 (100/5V), yet larger U.S. clarifiers often return only 40% to 70% of that projected concentration.

Short-circuiting of influent to the clarifier overflow is a well-known characteristic of clarifiers. Retention efficiencies of 25% to 45% are commonly found during dye studies such as those conducted by Lively, et al. (1968), at Cleveland, Ohio. The liquid retention efficiency was about 40%, or 1 hour retention, but the influent short-circuiting to the underflow in less than 10 minutes. Meanwhile, a significant portion of the dye associated with the sludge required more than 1.5 hours to exit the basin. Both the detrimental effects of underflow dilution and excessive solids retention occurred.

In a study at Indianapolis, Myers, et al. (1968), found that the dye reached the underflow in 5 minutes. Based on the dye profile, they concluded that 50% of the return sludge was mixed liquor that had short-circuited, which substantially reduced the return sludge concentration. This observation was consistent with Lively, et al., and other Federal Water Pollution Control Association fullscale retention studies of the 1960s.

Eves (1981) reduced the sludge blankets in a secondary clarifier by modifying the two-arm, six-blade scraper operating at 50 mm/s (9.9 ft/min) to a four-arm spiral collector operating at 68 mm/s (13.5 ft/min). The spiral scraper performed better than the original units except when handling dilute, high SVI sludges. It was not reported whether agitation caused by the higher scraper velocity resulted in the lower clarifier efficiency on the bulking sludges.

Warden (1981), who analyzed the sludge transport characteristics of straight blade and spiral scrapers, gave an interesting analogy of the sludge collector. He stated, "This situation is rather like a nightmare belt conveyor that gets narrower as it approaches the discharge end. It operates at over-capacity at all points along its length and, in fact, overflows continuously as it approaches the discharge end."

He noted that the angle of attack (α), rake speed, and blade height and length were factors the design engineer must consider. He concluded that the capacity of the scrapers must exceed the withdrawal rate to ensure satisfactory operation, that is, eliminate short-circuiting.

Günther (1984) reported on recent design methodology used in Germany and discussed the interrelationship of short-circuiting, scraper blade depth, and scraper velocity. Full-scale results at three facilities with five different clarifier configurations indicate improved sludge collection with higher blade speeds—up to 4.0 m/min (13.1 ft/min)—and deeper blades—up to 0.45 m (1.5 ft). The five clarifiers studied demonstrated that short-circuiting in circular clarifiers increased with higher return sludge flow rates (RAS/Q) and solids loading.

Later, Billmeier (1988) summarized Günther's short-circuiting observations. Billmeier also provided further support for Günther's and Warden's position that the blade angle, length, depth and velocity of the scraper are the primary performance factors in the transport of sludge toward the sludge hopper. He noted that the scraper blades in circular clarifiers are generally too small, but the problem can often be remedied by deepening and lengthening blades and increasing the rotational speed. The new 76-m-dia (220-ft-dia) secondary clarifiers at Stuttgart were to be fitted with inner spiral scrapers that are 1000 mm (39.4 in) in depth to transport the projected deep sludge blankets.

Lumley and Horkey's (1988) data on rectangular tanks showed a higher degree of sludge short-circuiting at higher solids loadings—less than 63 kg/m²·d (13 lb/ft²·d)—when producing a 6500 mg/L return activated sludge concentration than at lower loadings and a RAS of 12,900 mg/L. At the lower sludge loading and lower return activated sludge/flow (RAS/Q) ratio, the sludge retention efficiency improved from 76% to 91%.

The Europeans have been in the forefront of implementing means to control short-circuiting and prevent return sludge dilution. All of the reported studies consider inadequate sludge transport capacity of the collectors because of improper design and operating procedures to be the causative factor of short-circuiting.

European experience indicates that the spiral scraper (Figure 2) is more efficient for rapid sludge transport than the multi-straight blade scraper dominant in U.S. units.

The formula used to predict a spiral scraper's pumping velocity (v) is shown in Equation 3. Time of travel (t) of sludge along a spiral collector length (L) is defined in Equation 4.

The transport factor (f) of circular clarifier scrapers is more complex than rectangular units because it is also a function of the slippage and other factors such as the angle of attack (α), rotational speed, floor slope, sludge viscosity, the diverging spacing between rakes, blade depth relative to the depth of sludge conveyed, and reduced velocity as sludge is transported toward the hopper.

It is difficult to accurately project sludge depths and develop sludge profiles in circular clarifiers. There is no term or experience common to the sanitary engineering field for defining the area or distance of influence ahead of a conveyor or any literature guidance. To determine the conveyed sludge depth profile, the zone of transport and the sludge volume moving ahead of the scraper must be defined. Logically, the transport zone is smaller with high SVI sludge and larger with dense, low SVI sludge. Although not a parallel structure, conventional rectangular scraper placement indicates that a ratio of 10 to 20 times the blade depth ensures an effective transport distance (ETD) zone.

One method to analyze the clarifier sludge profile is to estimate the depth of the sludge transported through a se-
Table 2—Determining Circular Clarifier Scraper Depth

<table>
<thead>
<tr>
<th>Radius, m</th>
<th>Rake velocity, (v_r), m/min</th>
<th>Scrapped area, m²</th>
<th>Sludge deposition, kg/d</th>
<th>Sludge volume, m³/min</th>
<th>Effective transport perimeter, m</th>
<th>Sludge depth, mm</th>
<th>Sludge depth, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.3</td>
<td>6.40</td>
<td>379</td>
<td>35,201</td>
<td>0</td>
<td>40</td>
<td>76</td>
<td></td>
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<tr>
<td>15.3</td>
<td>5.5</td>
<td>321</td>
<td>29,786</td>
<td>2.80</td>
<td>11.7</td>
<td>122</td>
<td>248</td>
</tr>
<tr>
<td>15.2</td>
<td>4.5</td>
<td>263</td>
<td>24,370</td>
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<td>14.3</td>
<td>220</td>
<td>439</td>
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<tr>
<td>12.2</td>
<td>3.7</td>
<td>204</td>
<td>18,954</td>
<td>7.08</td>
<td>16.9</td>
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<td>625</td>
</tr>
<tr>
<td>9.1</td>
<td>2.7</td>
<td>146</td>
<td>13,539</td>
<td>8.58</td>
<td>19.5</td>
<td>424</td>
<td>845</td>
</tr>
<tr>
<td>6.1</td>
<td>1.8</td>
<td>88</td>
<td>8,123</td>
<td>9.66</td>
<td>22.1</td>
<td>653</td>
<td>1305</td>
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<tr>
<td>3.0</td>
<td>0.91</td>
<td>19</td>
<td>1,733</td>
<td>10.0</td>
<td>19.1</td>
<td>1452</td>
<td>2902</td>
</tr>
<tr>
<td>1.8</td>
<td>0.55</td>
<td></td>
<td></td>
<td>10.5</td>
<td>11.4</td>
<td>3843</td>
<td>7656</td>
</tr>
</tbody>
</table>

\(\text{SLR is } 93 \text{ kg/m}^2\cdot\text{d at } \text{RSS of } 8000 \text{ mg/L}\)

\(\text{Sludge depth at } 6.4 \text{ m/min tip speed.}\)

\(\text{Sludge depth at } 3.2 \text{ m/min tip speed.}\)

\(\text{Invalid, within zone of hydraulic drawdown by return sludge flow.}\)

---

**Figure 1—Rectangular Clarifier Displacement Capacity**

\[
V_{sc} = |\bar{f}| (\bar{1})(d_s)(v)
\]

\(f = 0.8 \text{ to } 1.3\)

---

ries of decreasing circles until the sludge reaches the hopper. It cannot be assumed that the sludge flows evenly across the entire floor at a velocity dictated by the scraper depth. In the outer area, the sludge may move through only 15% to 20% of the circumference (effective transport perimeter), while in the inner reach it may flow through the en-
U.S. Experiences

The discovery in the 1980s of short-circuiting in several Federal Water Pollution Control Association studies did not result in any corrective action in the U.S. Perhaps this was because of the prevailing U.S. equipment manufacturers’ opinion that hydraulic and sludge density effects were the primary forces moving sludge toward the hopper. This opinion is in stark contrast to European reported studies and recent, successful U.S. experiences with collector analysis and modifications to control short-circuiting.

Columbus, Ohio. The six 60-m-dia (200-ft-dia) clarifiers at the Southerly Wastewater Treatment Plant (WWTP) have dual floor slopes—0.5 m/12 m and 1.5 m/12 m (0.5 in./12 in. and 1.5 in./12 in.)—and spiral scrapers, two arms at 100% radius, and two arms at 50% radius. The scraper depth, including squeegee, is 279 mm (11 in.).

During the startup period, the sludge volume index (SVI) was about 130 to 150 mL/g and the sludge blanket often exceeded 3 m (10 ft) with a solids loading rate (SLR) of 97 to 117 kg/m²-d (20 to 24 lb/ft²-d). Sludge profiles and tracer studies of the basins consistently indicated that the dense sludge at the floor was being diluted by influent at the point of withdrawal. While the Daggert-Roper flux analysis indicated that the clarifier shall be capable of handling a SVI of 150 to 170 mL/g, the inadequate scraper capacity allowed short-circuiting and a SVI < 100 mL/g was required to control blankets.

Further, several controlled recycle/feed tests demonstrated that increasing RAS/Q ratios resulted in a decreased RAS concentration and a deeper blanket as projected by European investigators. Because the scraper capacity is fixed, increasing the RAS/Q ratio increases the flux and further overloads the scraper. The end result is pronounced short-circuiting and RAS dilution.

The calculated sludge retention, assuming a low transport efficiency (F) of 0.2 (high slippage), yielded a wall-to-hopper retention of 4.6 hours. Tracer tests proved the sludge retention times to be 4 to 5 hours from the outside wall to the hopper. Thus, high slippage because of a sludge depth much greater than the flights caused excessive circumferential movement and long transport times. The two new units to be installed at Southerly incorporated tapered scraper depths (250 to 900 mm) and dual-speed drivers at 3.0 and 4.6 m/min (10 and 15 ft/min).

The new anoxic selectors decreased the SVI and, at a SVI of 70 to 90 mL/g, the RAS/Q was reduced to less than 0.4. The compacted, more transportable 12,000 to 20,000 mg/L RAS produced only nominal blankets at the wall. Recent operating experience has shown that a higher SVI of 105 to 110 mL/g results in an intermediate blanket depth with the original shallow scrapers.

South Valley, Utah. The South Valley plant has four 46-m-dia x 4-m (150-ft-dia x 13-ft) side wall depth (SWD) clarifiers with conventional multiple-bladed scrapers. The mixed liquor suspended solids (MLSS) is generally 4000 mg/L and the unstrirred and undiluted SVIs are 120 to 140 mL/g. When the SLR was about 98 kg/m²-d (20 lb/ft²-d), the blanket expanded rapidly and overflowed the walls.

The plant management initially increased the rake speed from about 3.0 to 5.2 m/min (12 to 17 ft/min) and then, based on improved performance at 5.2 m/min (17 ft/min), increased the speed to 6.7 m/min (33 ft/min). The blankets were reduced and the effluent has averaged single-digit total suspended solids (TSS) values since 1989.

Tests showed that the dense sludge profile sloped downward toward the sludge hopper at the 10.0 m/min (33 ft/min) rotational speed. This firm evidence that the conveyor transport rate was higher than the RAS rate because inadequate transport produces the typical horizontal dense-phase profile. Further, the bottom sludge concentration increased as the sludge approached the hopper. Simultaneous tests conducted at 5.2 m/min (17 ft/min) and 10.0 m/min (33 ft/min) showed that the higher speed caused turbulence in the lower tank area, but no solids loss. The slower 86-m/min (17-ft/min) scraper speed caused the blanket to expand because of lowered transport capacity, hence longer transport time.

Phoenix, Ariz. The 23rd Avenue WWTP has one 48-m-dia x 2-m (160-ft-dia x 8.75-ft) SWD and three 42-m-dia x 2.7-m (140-ft-dia x 9-ft) SWD conventional, center drawoff clarifiers. Because of bulking sludge, blanket depths approached the weir even at a SLR of 19 to 24 kg/m²-d (4 to 5 lb/ft²-d). The rake speeds were increased to 6.4 to 7.9 m/min (21 to 26 ft/min) at the same time that a new selector operation to control SVIs was initiated.

The inner scrapers of the 49-m-dia (160-ft-dia) unit were increased to 610 mm (24 in.) deep by adding steel plates within the rake structure. An energy dissipating inlet was also added and the feedwell was shortened to reduce the scour of the sludge blanket. The higher rake speed reduced the blanket depth before scraper and inlet modification.

The three 42-m-dia (140-ft-dia) units have since been retrofitted with double spiral blades 254 to 762 mm (10 to 30 in.) deep. The combination of higher scraper speeds, reduced SVIs of 80 to 100 mL/g, and deeper blades increased the SLR capacity to 98 kg/m²-d (20 lb/ft²-d) with negligible blankets in the outer 33% of the tanks. The MLSS—in excess of 3000 mg/L—can now be processed in these shallow basins at flows up to 1.8 m³/s (42 mgd) while producing low single-digit TSS and BOD₅ values.
speed of 3.2 m/min (10.5 ft/min) is too slow. The solution is a two- or variable-speed drive for a range of 4.3 to 6.4 m/min (14 to 21 ft/min) to handle the varying loading and SVIs normally experienced.

**DISCUSSION**

While short-circuiting or solids transport problems are discussed in European studies, investigators have not considered unassisted hydraulic flow to be a significant factor in sludge transportation in large circular and rectangular clarifiers. In fact, they have considered influent short-circuiting to the underflow to result from deficiencies in the conveyor transport design or overloading of the scraper. Simply put, if the RAS rate exceeds the scraper capacity, short-circuiting will occur.

In contrast to the overseas investigators, U.S. clarifier suppliers and evaluators have considered hydraulic and density effects to be the primary motivating forces to transport secondary sludges. There is ample evidence to demonstrate that this is not the case and collectors must be scaled up in larger clarifiers consistent with the quantity of sludge to be transported.

Scraper modifications are usually easy to complete and are not costly. Many facilities can simply increase scraper speed to 5 to 8 m/min. In other situations, the scraper arrangement must be modified or replaced to improve performance. Significant increases in hydraulic capacity, a lower RAS/Q, and reduced sludge retention are the beneficial results from such scale up.

Increasing RAS/Q causes deeper blankets; once the scraper capacity is exceeded, increased flux from higher RAS rates causes more short-circuiting and deeper sludge blankets. Pacing the RAS to Q will decrease clarifier capacity and performance.

The primary means of blanket control should be the modification of the scraper speed. The scraper speed, not the RAS rate, should be initially adjusted to maintain the blanket at the desired depth. Increasing the RAS rate is a secondary choice, which accepts the fact that the underflow concentration cannot be maintained because of excessive solids loading, increased SVI, or both.

In large clarifiers, four-arm mechanisms are more efficient. The need for secondary stub arms can be determined from the sludge depth projections of scraper designs. The dual slope in the floor—38 mm/305 mm (1.5 in./12 in.) from 0- to 15-m (0- to 50-ft) radius and 38 mm/305 mm (0.5 in./12 in.) from 15- to 30-m (50- to 100-ft) radius—may provide adequate sludge depth over the hopper, minimized sludge inventory, and improved transport in the inner critical area and control denitrification.

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**REFERENCE**