DESIGN OF MIXER-SETTLERS TO MAXIMISE PERFORMANCE

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ABSTRACT

The engineering design of conventional mixer-settle r units has been the subject of significant improvements over the last five to ten years. CFD analysis has enabled the visualization of the flow patterns within the units; and the development of internal systems to maximize performance. Specific items have been identified as leading to large macro flow mal-distribution; including the feed spout and the feed in the upper half of the settler depth.

Settler dynamic operation has also been modelled to include the pressure differentials from feed to discharge at various depths in the units. This also contributes to macro flow patterns that are not conducive to good settler operation. The macro flow issues have been addressed by developments of in-settler baffling and coalescing systems of various types.

The detailed design of internal elements has also been progressed to minimise local production of vortices and dead areas. More attention is being paid to the development of smooth transitions and stream flow patterns as tools in achieving good design elements.

With the recent SX fires increased attention is being paid to minimization of: fire ignition risk elements, slowing the propagation of a fire and preservation of other settlers near by in the event of a fire. This involves use of alternate design approaches and materials of construction. Recent fire engineering advances have enabled accurate modeling of the fire event and selection of appropriate systems to either suppress or prevent further fire propagation.
# Table of Contents

1. INTRODUCTION  
2. COMPUTATIONAL FLUID DYNAMICS  
3. SETTLER DYNAMIC FLOW PATTERNS  
4. ENHANCED SETTLER PERFORMANCE  
5. DETAILED DESIGN OF INTERNALS  
6. INCREASED FIRE SAFETY  
7. CONCLUSIONS  
8. ACKNOWLEDGEMENTS  
9. REFERENCES
1.0 INTRODUCTION

The engineering design of conventional mixer-settler units has been the subject of significant improvements over the last five to ten years. The ideal settler is a plug flow device with all depths of the fluids progressing forward at similar space velocities. CFD analysis has enabled a more realistic visualization of the flow patterns within the units and the development of internal systems to maximize performance. Specific items have been identified as leading to large macro flow mal distribution including the feed spout and the feed in the upper half of the settler depth.

The modeling has been taken a step forward with field implementation of the design concepts. Operational results have shown the benefits of including all the possible improvements in the settler design. This paper provides the design concepts and details that have contributed to improved performance of mixer-settlers.
2.0 COMPUTATIONAL FLUID DYNAMICS

A number of CFD analyses of settler flow patterns, of varying complexity, have been undertaken in the last five years (Giralico et al., 1998; Stanbridge and Sullivan, 1999; AMIRA 2005; Kankaanpaa, 2005.) The interpretation of these results has been somewhat limited as applied to the design of settlers.

Giralico (1998) recommended a wedge shaped settler due to the poor performance of the settler feed system. This approach does not really address the problem; which is the difficulty of getting the settler feed to distribute to a very wide settler, when fed with a relatively narrow stream from the mixer. The mixer is conventionally placed at the mid-point of the settler to minimise the distance to be covered in the distribution activity. No special methods were used to help the distribution other than a single ‘boomerang’ angled picket fence. The wedge shape recommended by Giralico was to eliminate the ‘dead zone’ created by the central high velocity feed that created a back eddy on each side of the settler.

Stanbridge and Sullivan (1999) modelled a pressure settler (used in the oil industry) as well as a conventional mineral processing atmospheric settler. In both cases it was shown that feed distribution had a major effect on the settler performance. The key recommendations were that full width and full height distribution was necessary for proper development of the ideal settler plug flow profile. Figure 1.0 Shows the feed end eddy created by a slot feed arrangement.

It is obvious from this model that the settler flow pattern is far from plug flow across the either the width or the depth. With the propagation of the local velocity vectors through the picket fences the macro flow pattern in the settler itself is one of high velocity forward in the organic layer; and reverse flow at the bottom of the settler in the aqueous layer.

Figure 1.0 Settler Feed Eddy (from Stanbridge and Sullivan).

Kankaanpaa (2005) also confirmed that the local velocity vectors are transmitted through at least two picket fences in series; before viscous effects can dampen them out. He also showed that without any picket fences the feed spouting velocity was propagated for long distances in the settler. His modeling also confirmed that a feed arrangement without full depth resulted in a reverse flow of the aqueous from half way down the settler back to the feed end.
The AMIRA P706 Project (2005) did not consider the settler without at least one picket fence. The CFD modeling reflected the pilot scale mixer-settler geometry. As a result it was not geometrically similar to commercial units and some of the CFD results are subject to issues of physical scale. Again confirmation of the propagation of local flow velocities through the picket fences was provided.

The only two phase models were those Kankaanpaa and AMIRA. Both reports confirmed that the presence of picket fences reduced the depth of the emulsion band in the remainder of the settler. The presence of these emulsion bands is essential for ‘filtering’ the fine bubbles (haze) by providing coalescing surfaces (Miller 2001). However as discussed later, deep emulsion bands that exist at the discharge end contribute to major entrainment events and are not desirable.

The major result of the CFD models is the conclusions that:

- Without special attention to the distribution activity any significant flow pattern will be transmitted through the picket fences to adversely affect the flow pattern in the settler. These flow patterns are active in both the vertical and the horizontal planes.
- The feed arrangement to the settler can contribute significant local high velocity profiles that are transmitted through the picket fence(s).
- Feeding the settler in the top (or bottom) half sets up a very large vertical eddy that can severely upset the settler flow pattern.
- Picket fences are essential for providing deep emulsion bands that are kept at the feed end of the settler.
- The depth of the emulsion band is stepped down with two or more picket fences to allow a transition from a deep emulsion band to a thin or non existent emulsion band in the main settler volume.
3.0 SETTLER DYNAMIC FLOW PATTERNS

In recent times it has been shown (Miller 2000a, 2000b, Miller 2001) that the operation of a commercial settler is a dynamic system, with the potential for high circulation flow rates and macro eddies, formed from the phase separation process itself. Figure 2.0 shows the dynamic flow patterns that can be observed in many settlers with one distribution picket fence and without other internal hardware.

These flow patterns are set up by the combination of the phase separation flows and the density gradients inherent in a settler. The feed end is at the average emulsion density while the discharge end has two separated phases. There are density gradients set up: from the feed end to the discharge in the organic layer, and from the discharge end to the feed end in the aqueous layer. These gradients set up pressure differentials and resulting flow patterns as shown in Figures 3.0 and 4.0. These velocities are superimposed on the macro flow patterns set up by the feed system.

Other velocities are also created when the emulsion collapses from a deep band to a shallower band through a picket fence. The collapse velocity profile creates another vertical eddy. This in turn sets up a reverse flow in the top of the organic layer and reinforces the reverse flow at the bottom of the aqueous layer.

As a result of these inherent velocity sets, there is a need to help the settler to dissipate the non-ideal flows. Without some means of eliminating the dynamic flow patterns in the settler, performance will be poor and erratic.
Figure 3.0 Pressure Gradients from Density Differences.

Figure 4.0 Velocity Patterns Resulting from Pressure Gradients.
4.0 ENHANCED SETTLE PERFORMANCE

Enhancement of settler performance is related to a combination of:

- Improved feed distribution
- Elimination of macro eddies induced by the feed and discharge arrangements.
- Improved coalescence with provision of controlled sections that contain deep emulsion bands
- Improved coalescence with in-settler equipment
- Understanding the hydraulic flow patterns to ensure full use of all the available area.

4.1 IMPROVED FEED DISTRIBUTION

Improved feed distribution is the single most effective means of improving settler performance. By ensuring that the feed is distributed evenly across the full settler width, all of the settler area is now potentially used. Improvements in settler feed distribution have been made with the use of the reverse flow settler as shown in Figure 5.0.

Figure 5.0: Reverse Flow Settler with Distribution Vanes

The reverse flow arrangement allows the exit velocity from the mixer to be distributed over the full depth of the settler; and to largely eliminate the vertical eddy that is formed. The addition of the distribution vanes greatly enhances the ability to feed the settler over the full width. However in the settler shown in Figure 5.0 the hydraulic design for the distributors is not correct. The pressure drops were unequal and flow actually went backwards in the longest distribution slot. The slots need to be of varying widths so that the friction losses are equal for the shortest and longest slot. Also evident in this figure are issues with the distribution:

- The longest slot is the narrowest (it should be the widest)
- The shortest slot is the widest (it should be the narrowest)
The high velocity turbulence resulting from the short slot and the eddy behind the feed launder

Another improved distribution system is the “PIP” system pioneered in Chile. This takes the conventional settler central feed and uses a series of concentric picket fences to generate a plug flow in the settler. Figure 6.0 shows one such installation.

Figure 6.0: PIP Settler Feed Distributor.

Long term operation of the PIP System has shown major improvement in settler capacity with up to 75% reduction in entrainment for the same process flows (Polski 2003). The installation of the better feed system has allowed the operation to increase the throughput by 30% over design without reaching critical levels of entrainments in the exit phases.

A more recent development has been the MMS Side-Feed® settler design. This concept re-aligns the mixer and the settler so that the feed stream is directed into the side of the settler behind the first angled picket fence. The arrangement is not new having been installed at the old Cyprus Miami operation. However the concept has been refined with the settler and mixer arrangement now allowing all the piping to be installed on one side of the plant. Figure 7.0 shows a typical MMS Side-Feed® settler.
This arrangement also feeds the settler at the full depth eliminating the major feed slot eddy inherent in many other designs. The feed is split along the width of the settler using staggered and properly spaced straight distribution vanes as shown in Figure 8.0. The straight vanes eliminate the swirling flow associated with curved vanes that are required to turn the flow through ninety degrees in the reverse flow arrangement.

This method of distribution has improved the settler operation with flow now shown to be across the full cross section of the settler.
4.2 ELIMINATION OF MACRO EDDIES

The macro eddies that are inherent in the settler operation can be eliminated by either eliminating the cause of the eddy, or by dissipating the eddy flow pattern by use of baffles and other media. The inclusion of physical systems in the settler can also improve the coalescence as discussed in the next section.

Eliminating the formation of the macro eddies is the most effective method of control. This is possible for those eddies created by physical flow patterns such as at the feed or discharge of the settler. The types of macro eddies seen in settlers include:

- Vertical from the feed slot
- Horizontal from the feed slot (on both sides of the settler. These are the eddies that Giralico tried to address with the tapered settler).
- A single large eddy that takes up the whole settler, from the slot flow of the reverse flow settler.
- Vertical eddies within the organic layer from extraction of an organic recycle from the partially separated phase. This is a particular design used by the Krebs settler.
- Similar eddy formation in the aqueous phase when the recycle is extracted part way down the settler. This design is typical of those from Technicas Reunidas and Outokumpu.
- Horizontal eddies caused by the use of multiple submerged aqueous extraction points across the settler width.
- Vertical eddies in the aqueous phase discharge, inherent in the deep removal geometry used by some of the reverse flow settler designers.

The CFD models show that even with two picket fences some of the macro eddies still propagate into the bulk of the settler. However the provision of a third picket fence eliminates over 95% of the macro flow velocity (AMIRA 2005, Kankaanpaa 2005). The use of random
packed media in-settler systems also assist with the elimination of the macro eddies by dissipating the flow vectors inside the packing (Miller and Readett 2003; Polski 2003). Many of the eddies associated with the phase removal activities are totally eliminated by the use of full length overflow weirs for both aqueous and organic. The recycle stream is then split from the total overflow stream without upsetting the settler flow patterns. The supposed advantages of reduced settler flow rate (with early recycle extraction) are far outweighed by the upsets and eddies induced and the resulting poorer settler performance. However those eddies associated with the separation process itself need to be dissipated or kept within small boundaries within the settler. The recognition of the dynamic processes in the separation activity are essential in understanding why some settlers exhibit ‘unusual’ flow patterns such as reverse organic flow at the feed end. These can only be contained at the feed end by provision of either extra picket fences or in-settler coalescing systems.

4.3 COALESCENCE IN DEEP EMULSION BANDS

The presence of unconstrained deep emulsion bands has been shown (Miller 2001) to provide poor and highly erratic settler performance. The CFD modeling and confirmatory pilot work (AMIRA 2005) has shown that deep emulsion bands are required for good entrainment control. The means by which this is accomplished is via the provision of at least two picket fences to hold back a decreasing thickness of emulsion band; or by in-settler systems that do not allow a thick emulsion band to exist in the remainder of the settler.

The provision of these systems also improves the actual coalescence activity itself by providing extra surface area.

4.4 IMPROVED COALESCENCE EQUIPMENT

Further enhancement of settler operation can be achieved with coalescing systems. These can take various physical forms such as: trays (IMI system), baffles (Lewis 1977), random packed media (Miller, Readett and Dudley 2002) extra picket fences or ordered media (Polski 2003). In all cases the hardware is installed to either increase the settler unit capacity and/or to minimise the entrainment. This is accomplished by the media performing a number of activities, that all help to reduce the entrainment in the exit stream.

- Improves the flow distribution across and in the depth of the settler
- Eliminates eddies and other macro flow patterns induced from the hydraulics or phase separation
- Provides a surface for coalescing of droplets
- Holds back a deep emulsion band layer for filtration of fine haze

As a result of these actions the entrainment is controlled and other operating scenarios can be successfully implemented:

- Allows operation of mixers in any continuity
- Eliminates peak entrainment and shock loads to down stream processes
- Increase the total hydraulic capacity of the settler.

Figure 9.0 shows a typical random packed media installation in a large conventional reverse flow settler.
In many cases the phase separation can be fast and no emulsion band can form as there is no emulsion left after the settler feed system. In these cases the coalescing function of the media becomes an important aspect of the settler enhancements. As a result the large surface area systems perform better than those with low specific surface areas.

Figure 10.0 shows the entrainment of organic in electrolyte from a very large settler where the break times were extremely short. The entrainment is at a very high level compared to the design basis of 50 ppm. The high levels are also extremely erratic and lead to shock loading on the multi media filters. Figure 11.0 shows the immediate effect of installation of a high specific surface random packed media in the settler (Miller 2000a). The entrainment is lowered below the design level and the erratic peaks have been eliminated.
Figure 10.0 Settler Operation with No Emulsion Band

Effect of In-settler Medium on Exit Entrainments with no Dispersion Band

Figure 11.0 In-Settler Coalescing Media with No Emulsion Band Operation
The increase in hydraulic capacity can be quite dramatic. The Girilambone operation (Dudley et al) monitored the settler performance over many years. They found that the settler capacity could be increased and the entrainment decreased when using the random in-settler coalescing media system. Table I illustrates the results that they have obtained.

Further results from the PIP Process also show similar improvements in settler performance.

Table 1 – Typical GCC Settler Entrainment Values

<table>
<thead>
<tr>
<th>Settler Flux (m²/m²/Hr)</th>
<th>Settler</th>
<th>Organic in Aqueous (ppm)</th>
<th>Aqueous in Organic (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td>5-6</td>
<td>E1</td>
<td>110</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>E2</td>
<td>180</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>E3</td>
<td>250</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>S1</td>
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</tr>
<tr>
<td></td>
<td>S1</td>
<td>100</td>
<td>15</td>
</tr>
</tbody>
</table>

The PIP in-settler media is a structured packing that provides both hold up of the emulsion band as well as coalescing surface for entrainment reduction.
5.0 DETAILED DESIGN OF INTERNALS

The detailed design of settler internals is also an important step in increasing the effectiveness of the unit. In many cases the design approach is to minimise the creation of eddies, spouts or jets from sharp edged elements. The creation of a small vortex from a corner can locally upset the settler performance. When a large number of these are included (such as flat pickets in a picket fence) a significant fraction of the settler can be affected.

The Otukumpu VSF settler uses a proprietary ‘non-spouting’ picket fence design. Basic hydraulic calculations show that the shape of this should be an x-y cubic function to ensure adherence of the boundary layer to the surface. However the error between a cubic and a simple quadratic function is less than 5% for over 95% of the shape. The much simpler alternate shape of pickets is a quarter circle. These have been shown in practice to eliminate the vortices associated with flat pickets without any sign of boundary layer separation.

All other sharp edges need to be removed from the settler internals to eliminate the local eddy formation:

- Smooth walls without steps changes.
- Roof supports using round or ogive shaped columns.
- Picket fence supports ditto.
- Smooth shapes to organic launder discharge lip.
- Smooth shapes to organic launder bottom (where the aqueous flows underneath).

These smooth shapes also minimise the adverse effects of scale build up on flow patterns. In plants such as Bulong the scale deposited had a very severe effect of the ability of the settler to operate with controlled entrainments. The flat pickets and local vortex production actually encouraged the growth of scale. By eliminating these the scale can be reduced significantly in extent.

Further entrainment control can be included in the aqueous collection launder. By ensuring that released organic is either preferentially sent back to the mixer with the recycle stream, or retained in the launder for later removal. Baffles work reasonable well for this activity, and some significant reduction in loss to raffinate or electrolyte can be achieved.

Minimisation of air entrainment is also a settler design issue particularly in the discharge launders and nozzles. Air in the feed to the next stage can cause flow pattern upsets if carried through to the next settler, or create air crud that is very difficult to keep in the settler. As discussed in the next section air also has adverse effects in static electricity control.

Air entrainment can be minimised with proper attention to detail in the discharge launder and nozzles. Anti vortex baffles should be used in all nozzles. Organic discharges from settlers to collection launders should have a shaped profile to prevent the flow stream free falling into the launder surface. The launder itself should have the valving and control to operate at high levels (even close to flooding) to minimise the hydraulic drop between settler discharge and launder operating levels. To achieve a surface impingement velocity of <1 m/s requires a drop of <50mm.

A number of detailed design issues are also important in minimising the loss of one stream in another during operating transients. This is especially the case during start up and shut down. In some operations the failure of the raffinate valve to close properly can cause the entire contents of the settler to flow to the raffinate pond or tank, with consequent loss of the organic.
Simple hydrostatic legs can prevent this situation from occurring in pulsed columns but it is not a common feature of their installations. For settlers the situation is easily addressed with full length overflow weirs but can be a significant issue with level control columns or interface level control valves. Simple issues such as this can affect the total organic loss by +200% if not taken. Figure 12.0 shows the layout of a settler that includes all these design elements.

Figure 12.0: MMS Side-Feed® Settler Geometry
6.0 INCREASED FIRE SAFETY

6.1 STATIC ELECTRICITY

The most wide spread ignition issue for the whole of the plant is that of static electricity, coupled with the production of mists and aerosols. The risks that are evident are a result of the combination of:

- Poor design elements
- Excessive energy input to the organic streams. This energy needs to dissipate as either heat or some static electricity
- Lack of appropriately designed drainage pathways for accumulated static charge.

6.1.1 Static Generation

The static electricity issues are significant for plants handling hydrocarbon liquids. There are relevant Australian and international standards for designing process plants to eliminate or minimise the generation of static charge. Mechanisms also need to be included to dissipate (drain or earth) any static charge that is created. Recommendations for grounding are contained in all the standards.

One important factor that is not generally considered is the generation of static in the separation process occurring in a settler. As the particles separate they can form static charge as they slip past each other. The presence of aqueous entrainment in the hydrocarbons is also a high generator of static charge as these droplets can create significant charge through their movement within the non-conducting hydrocarbon. The lower the conductivity of the aqueous the greater is the generation of static electricity. The use of de-mineralised water for washing/scrubbing operations should not be contemplated; unless its conductivity is increased with the addition of acid or electrolyte.

Other charge generation occurs when any relative movement takes place; the higher the velocity and the greater the turbulence; the greater the charge generation. Activities that can generate static include:

- Mixing of droplets
- Mixing or settling of solids
- Disruption of an interface
- Atomisation
- Splashing
- Flow past a fixed boundary eg pipe or vessel wall

The range of liquid conductivities, over which static charge generation is experienced, is $10^{-1}$ to $10^5$ pS/m. The maximum generation occurs with liquid conductivity of the order of 10 pS/m (Hearne and Smithson 2005). The higher the conductivity the faster the generated charge flows to earth. It is unlikely that electrostatic discharge will occur for metal containers or pipes with liquid conductivities greater than 200 pS/m.

Some typical plant results for liquid conductivities are:

- New diluent 1.0 pS/m
• Extractant (copper) 25 – 50 pS/m
• In circuit organic (copper) 80 – 200 pS/m
• In circuit organic (high metal loading) >1 000 pS/m

Simple spark discharge is common from conductive surfaces once an accumulated charge is grounded. However non conductive surfaces can discharge multiple times (brush discharge) as the charges on the non conducting surface have no mobility to the grounding point.

6.1.2 Removal of Static Charge

Conductive surfaces when grounded do not accumulate charge as the conduction allows the charge to be removed. There has been a move recently to provide conductive surfaces on FRP pipes and vessels to allow this charge removal to occur. ODO has led the way in this regard. However where lower grade stainless steel (316/316L) can be utilised for vessel fabrication, there is much greater opportunity for static charge grounding. In chemical environments where metal is not an economic option the use of conductivity enhanced FRP is a viable option adding only 10% to 15% to the overall cost of the FRP.

However ungrounded (isolated) conductors (such as valves or instruments) can cause very high potentials to accumulate (up to tens of kilovolts). This can cause a brush discharge if the pipe or local volume is not full of liquid.

Charge dissipation in tanks is a function of whether the tank bottom can be grounded. If this is achieved then charge relaxation times of less than one second can be achieved (time to reach 1/e = 37% of its starting value).

6.1.3 Minimisation of Static Generation

Poor design elements are departures from the code of practice for control of static electricity. The major issues are:

• High level entries into tanks (loaded and/or stripped organic tanks)
• Free fall of organic from inlets to final levels with fall through surfaces (organic tanks and settler organic launders, coalescer overflow weirs etc)
• Excessive pipe velocities in organic lines from either/or both pipe size too small or excessive available gravity head.
• Entrainment of air into the mixers and subsequent separation in the settlers
• Entrainment of low conductivity aqueous in organic streams from washing and scrubbing settlers

Most of these can be addressed to a greater or lesser extent with alternate equipment design:

• Tank entries at a lower level to keep the entry submerged
• Operation of weirs and discharge launders at high levels to minimise free fall heights.

In order to keep the incident vertical velocity to <1 m/s the free fall height in organic collection launders needs to be less than 50 mm.

• Provision of control valves to dissipate the available head in a controlled manner.
• The excess energy input to the organic has some limited opportunities for redress.
• The free fall into the tank farm area needs to be minimised as illustrated in Figure 13.0

Figure 13.0: Low Head Difference Between SX and Tank-Farm

• Extra energy added from any low hydraulic efficiency pump mixer and axial flow impellers. Modern high efficiency units should be used. This is also an issue with aerosol production.

• Any design feature that may induce energy dissipation needs to be redesigned and removed.

• High pressure cleaning using > 1 MPa should not be used as it constitutes a risk of introducing static electricity via the high velocity nozzles used in the water blaster.

• Drainage of the static charge needs to be integrated into the plant and vessel design.

• Relaxation (dissipation) of the static requires both extended times and large areas of contact to achieve low voltages. This is best achieved with conductive vessels (and vessel internals). In all cases the conductive elements are to be earthed to dissipate the static charge.

• Loaded organic and coalescers tanks:
  o Line coalescers with conductive FRP veils
  o Line loaded organic tank with conductive FRP
  o Pipes to and from coalescers to be conductive FRP
  o Locate the tank feed to the bottom and select appropriate size
  o Add an aqueous entrainment transfer pump to remove de-entrained aqueous from the organic tank
  o Use of graphite conductive valves for flow control and energy dissipation.

• SX intra plant organic pipes – use conductive FRP

• SX settlers:
- Fit feed distributor vanes in conductive FRP
- Use picket fences with non spouting design in conductive FRP
- Organic weir use curved smooth flow weir in conductive FRP
- Line with conductive FRP

- SX mixers:
  - Line with conductive FRP
  - Use high efficiency mixers

All of these elements are simply application of the relevant standards on minimisation and dissipation of static electricity. It is not rocket science and it is easy to do correctly. So often the plant layout is driven by other factors that are perceived to be more important. However the incidents at Olympic Dam have shown that static electricity is probably the most important ignition source that must be addressed by the design engineers.

6.2 FUEL FOR INITIATION

The fuel for initiation needs to be in a form that can be readily ignited, and the flame maintained long enough for the local fire to escalate to involve the large settler pools. The presence of mists and vapours is a major source of potential ignitable fuel that can maintain a fire for the requisite period.

One of the easiest fuel control steps is to eliminate the atmosphere of droplets and aerosols that can form in partially full pipes. By keeping the pipes full there is no opportunity for an explosive atmosphere to form and minimal risk of ignition from any static charge generated.

All points where mists, vapours and aerosols are produced should be eliminated or minimised. Some of these aerosols are produced in prodigious amounts from:

- Stripped and loaded organic tanks if not fed correctly at the bottom
- Organic feed siphon break tanks
- Settler feed systems that induce turbulence
- Settler organic discharge launders
- Entrainment of air into mixers and subsequent release with entrained aerosols

Priority activities need to be directed towards the elimination and minimisation of aerosols in the plant. This will minimise the continuous availability of the ignition fuel sources.

6.3 CONTROL OF FIRE ESCALATION

The fire escalation control is the point at which a great deal of debate is currently occurring in the industry. Whether to include the facility or not; and how intense the facility needs to be for effective escalation management. Some of the points that are included in this debate relate to the design of the mixer-settler and the placement of the plant in relation to other assets.

6.3.1 Plant Placement

One of the most effective and least cost methods of control of fire escalation is to place the entire SX plant so that it can not set alight to a near by asset. This is the same method as enshrined in the local planning rules regarding minimum distance to boundaries and other facilities. The method of determining the separation distance is via a fire plume analysis. This takes into account:

- The area of the fire
- The time of the fire burn
The climatic and wind conditions
The presence of other assets and public access

A typical fire plume analysis for a single tank fire is shown in Figure 14.0

Figure 14.0: Fire Plume Analysis for a Single Tank Fire in an SX Facility

When a number of large tanks (Settlers) are involved the fire can be quite extreme in the radiant energy that can be released. It is not uncommon when modelling a full SX train to have a personnel approach distance of >50 m. Because of this it is necessary to consider either passive or fully automatic systems that minimise the risk of further escalation or to suppress the fire as soon as detected.

6.3.2 Containment within a Settler

In order to contain the fire within a single vessel or plant area it is necessary to first detect it at an early stage. The detection needs to be checked by at least two systems to prevent spurious activation of the fire suppression system.

The only way to extinguish or manage a fire in an SX settler is with the use of overwhelming force (Thomas, 2005). The fire can escalate across the full settler area within a few minutes of initiation and create major radiation immediately. The two main methods of fire extinguishment both try to eliminate the oxygen from the fire equation. The classical method is a foam blanket that tries to separate the fuel and the oxygen. The other is with ultra fine water mist that displaces the air and also cools the fuel below the fire point.
Both systems need a full roof over the settler to be most effective. The foam system can operate without a roof but more foam is required and there are higher risks of escalation to other vessels.

If there is physical barrier between a fire and the fuel load in an adjacent vessel it is quite feasible to prevent the escalation of the fire by cooling that barrier. This is another plank in the argument for having full coverage settler roofs. By cooling the roof with normal pressure water sprays the radiant energy is absorbed and the underlying fuel kept below the flash and fire points. Roofs made of combustible materials such as FRP are suitable for this duty. Non-combusting materials also provide an increased level of resistance to fire escalation but the key is the water spray heat sink.

6.3.3 Containment within the SX Facility

Containment within the SX facility is generally focused on a number of activities that are mutually complimentary:

- Internal separation and / or bunding to localise a fire and prevent spread
- Removal of fuel from vessels and bunds
- Minimisation of fuel in bunds
- Fire breaks to stop transmission via pipes and cables.
- Protection via water sprays for pipe racks and local pipes.

The internal separate bunding can be carried to extremes. This is actually a key point in the storage codes where separate bunds are requested for each tank. This is not feasible for the SX plant as an operating facility. However bunds can be used for control of fire water or failures of containment structures (pipes and vessels).

The removal of the fuel minimises the fire time and the damage that results. Dump systems that take the fuel to a remote storage facility (via one or two fire traps) are an integral part of some plants. Other passive actions are bund overflows that also remove the fluids to a remote storage (pond). The lighter fuel is preferentially removed as it floats on the surface. By including bund overflows for fuel removal it is also possible to utilise the remote pond as the main bunded volume for both spillage and vessel contents. This means that bunds do not have be of high volume and can be only big enough for local spillage issues. The major volumes are removed to the spillage / dump pond for safe handling via the fire traps.

Fire break spools in pipes and fire traps in pipes and drains are also passive and cheap systems that can enhance the inherent safety levels of the plant. These facilities can also be protected from the radiant heat of a fire by water sprays. Even plastic pipes can be preserved by the water sprays if they are applied correctly.

6.3.4 Materials Selection

Materials selection for SX plants is a vexed question due to the high cost of some corrosion resistant materials and the perceived low fire resistance of non metallic materials. Some recent fire modelling has shown that free standing metal tanks of a few millimetres thickness (say settlers) will fail structurally in less than ten minutes without externally applied cooling.

Alternate materials such as FRP (with no additional fire resistance) will also fail structurally a few minutes earlier. It is thus not really a great difference in the performance of the two materials in the event of a fire. Both need external water cooling to be preserved; and both can prevent the spread of a fire if so cooled.

The biggest issue is that of piping for static electricity control. By adhering to the codes for the minimisation of static generation: especially to energy input, line length and static drainage;
there is no particular reason not to use non conductive pipes. They have a slightly elevated rate of static production but are cost effective where corrosion rates of metals are extreme (high chloride solutions). When using non conductive materials such as PE and FRP greater care needs to be taken to ensure good drainage of the charge in the vessels.
7.0 CONCLUSIONS

The operation of mixer-settlers can be improved significantly by better understanding of the settler processes. The design can be altered to take account of the new understandings generated in consideration of the interactions between hardware elements and the settler processes. The main improvements are in the elimination of large and small eddies and circulating flows.

It is now possible to increase settler capacity by 30% to 50% by including better feed distribution and including improved coalescence systems. These systems also increase settler performance when emulsion bands are not present (due to fast breaking emulsions).

The better performing hardware elements also increase the inherent safety of the settler design to minimise the risk of fire initiation and propagation.

A significant number of design elements are easily included in the settler and plant design that increase the passive inherent fire safety.

8.0 ACKNOWLEDGEMENTS

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