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Evaluation of Flygt Propeller Mixers for Double-Shell Tank High-Level Waste Auxiliary Solids Mobilization

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Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

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COGEMA
ENGINEERING CORP.

EVALUATION OF FLYGT PROPELLER MIXERS FOR DOUBLE-SHELL TANK HIGH-LEVEL WASTE AUXILIARY SOLIDS MOBILIZATION

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EXECUTIVE SUMMARY

The Waste Feed Delivery Program has a commitment to deliver high-level waste feed to a treatment facility for eventual conversion into an immobilized form (glass) appropriate for disposal. The high-level waste feed, consisting of sludge and supernatant liquid, is stored underground in double-shell tanks. Before retrieval for delivery to the treatment facility, the waste in the tanks will be mixed using jet mixer pumps to mobilize the sludge and form a uniform slurry suitable for pumping. Limitations of the jet mixer pumps may result in large potential areas in the tanks that will still need solids mobilization, even with two or more mixer pumps deployed. The Waste Feed Delivery Program has included sources of additional feed (contingency feed) in the baseline retrieval plans to mitigate this risk. To further increase confidence in meeting waste feed delivery commitments, another risk-handling action under consideration is the use of auxiliary mixing systems. One technology being assessed for this purpose is the submersible propeller mixer.

This study is a preliminary technology and engineering evaluation of the Flygt* propeller mixer as a potential tool for high-level waste auxiliary solids mobilization (i.e., extended sludge retrieval by suspending waste in potential "dead areas" left by mixer pumps). A more general evaluation of the technology from a broader perspective of waste retrieval applications at the Hanford Site is also provided.

The Flygt™ mixer is an axial flow device consisting of a propeller driven by a compact, direct-drive submersible motor. The Flygt™ mixer has been successfully deployed for waste retrieval at Oak Ridge National Laboratory in 1998, and is currently being developed by Savannah River Site, Pacific Northwest National Laboratory, and ITT Flygt Corporation for a deployment planned later this year.

* Flygt is a trademark of the ITT Flygt Corporation, Svetsarvagen 12 Solna, Sweden Corporation, Sweden.

The Flygt™ mixer is characterized by a number of notable features for waste retrieval applications in general:

- A simple and compact submersible design deployed through 34- or 42-in. tank risers. The mixer appears deployable with minimal infrastructure upgrades.
- A low initial procurement cost of the commercially available mixers, typically on the order of $35,000.
- Produces a high, unidirectional, and low-pressure flow (>20,000 gal/min) that can produce bulk flow patterns within a tank. If multiple mixers are used and oriented properly, the additive effects of the bulk flow circulation can increase waste retrieval rates beyond what would be expected for the total mixer power applied. As a basis for comparison, a 300-hp mixer pump produces a smaller 10,000-gal/min flow at higher pressure.
- Directional flexibility if used with an adequate deployment mast. The compact submersible design and unidirectional discharge allow the mixer to be aimed in almost any direction, vertically or horizontally. For example, the unit initially could be pointed vertically downward to mobilize solids directly underneath and burrow a hole where the mixer could then be lowered and operated horizontally to mobilize waste in the surrounding area. This is a key advantage over fixed-depth retrieval equipment.
- Has a substantial track record of effectiveness in industrial solids or sludge suspension and blending applications. Many of these applications are characterized by waste with difficult rheology and/or hostile environments.
- Electrically powered and is not dependent on fresh water supply or recycle of supernatant from another facility. From this standpoint, utility needs and upgrades are minimal.
- The power input ($\leq$50 hp) to the tank results in a slower heat-up of the waste in comparison to jet mixer pumps.
- The simplicity of the concept seems to indicate that the mixer can be deployed with minimal instrumentation and control.

- The compact submersible unit and propeller have no liquid-retaining cavities and appear relatively easy to decontaminate.
- The technology appears compatible with flammable gas requirements.

The conclusions regarding the potential use of the Flygt™ mixer for risk mitigation (i.e., specifically for auxiliary high-level waste solids mobilization) are as follows.

- Under current assumptions for mixer pump configurations, the deployment for this specific application is partially limited by riser size and availability. The double-shell tank farms with available large risers in satisfactory locations are the AY and AZ Farms, and the SY Farm if the existing construction risers are brought up to grade. This would apply to five Phase 1 high-level waste double-shell tanks.
- Existing experimental data are too limited to make an accurate full-scale prediction of mobilization performance. Preliminary predictions contributed by the vendor, claiming greater cleaning radii than the jet mixer pump, clearly bear uncertainty. It appears likely however that the Flygt™ mixer can meet the minimum mobilization effectiveness requirement based on the similarity in predicted far-field velocities to that of a jet mixer pump.
- The long-term functionality of the Flygt™ motor under high temperatures (>100 °F) and high radiation dose (peak dose to 1100 Rad/h) is unknown. The motor temperature limitation of the mixer when heavily loaded has the potential to restrict its usage. It is anticipated, however, that these issues can be overcome by design modifications to radiation harden the equipment and increase its operating temperature capability.
- The estimated rough-order-of-magnitude cost for a first deployment of two mixers in a tank is expected to be on the order of $8.9 M. This cost covers initial development and is expected to be significantly reduced for additional units. A "fast-track" schedule for this initial deployment is estimated to take 18 months.

It is recommended that the Flygt™ mixer concept be evaluated further and developed for potential cost reduction and/or enhanced performance of waste retrieval applications. More specifically, the following actions are recommended:

- Investigate the Flygt™ mixer as an auxiliary or complementary sludge mobilization technology. It is recommended that scaled testing, using the principles of similarity, be performed with high shear-strength simulants to increase the accuracy of mobilization effectiveness predictions and that tests be performed comparing the mobilization performance of submersible propeller mixers to that of jet nozzles.
- Closely monitor the deployment of Flygt™ mixers in Tank 19 at the Savannah River Site from the standpoint of equipment modification and reliability.

The use of the Flygt™ mixer for other applications, such as the retrieval of low-activity waste, may be a more lucrative application than its proposed use for auxiliary high-level waste solids mobilization. Therefore, the following additional action is recommended:

- Investigate the Flygt™ mixer for low-cost mixing, blending, and solids-suspension applications such as retrieval of low-activity waste (e.g., salt dissolution of double-shell slurry/double-shell slurry feed waste). The high volume exchange rate per power input of the propeller mixer technology is optimized for such applications.

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TERMS

CWSS	constant wall shear stress
DOE	U.S. Department of Energy
DST	double-shell tank
ECR	effective cleaning radius
FGEAB	Flammable Gas Equipment Advisory Board
HLW	high-level waste
ISCS	Ignition Source Control Set
NFPA	National Fire Protection Association
ORNL	Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
ROM	rough order of magnitude
RPP	River Protection Project
SRS	Savannah River Site
SST	single-shell tank
τ_c	critical shear stress
τ_s	sludge shear strength

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1.0 INTRODUCTION

The River Protection Project (RPP) is planning to retrieve radioactive waste from the single-shell tanks (SST) and double-shell tanks (DST) underground at the Hanford Site. This waste will then be transferred to a waste treatment plant to be immobilized (vitrified) in a stable glass form. Over the years, the waste solids in many of the tanks have settled to form a layer of sludge at the bottom. The thickness of the sludge layer varies from tank to tank, from no sludge or a few inches of sludge to about 15 ft of sludge.

The baseline waste retrieval strategy for DSTs (Kirkbride et al. 1999) uses jet mixer pumps to stir up (mobilize) the sludge and form a uniform slurry suitable for pumping to the vitrification facility. These mixer pumps expel powerful submerged jets of tank fluid horizontally out of two diametrically opposed nozzles (180° apart). The entire jet mixer pump assembly can be rotated to allow a full sweeping of the tank circumference. The fluid jets impinge upon the sludge and suspend the solid particles. The amount of sludge mobilized by the mixer pump jets depends not only on the jet properties, but on the capability of the sludge to resist the stresses imposed by the jets and the location of the jets relative to the sludge. The actual sweeping capability of the mixer pump and its efficiency in mobilizing material in the discharge path is termed the effective cleaning radius (ECR) and represents the effective radial distance for solids mobilization. In mixer pump performance evaluations, ECR is defined as "the distance between the mixer pump nozzle exit and the base of the distant sludge bank...thus a mixer pump mobilizes the sludge within a circular area with a radius equal to the ECR plus the distance between the nozzle tip and the pump column centerline." (Powell et al. 1997, page 2.3).

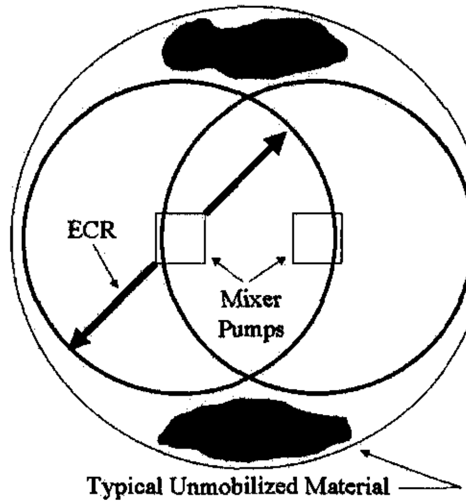
Predicting jet mixer performance has been the subject of computer modeling and simulant testing at the Hanford Site and other U.S. Department of Energy (DOE) waste sites for the past 20 yr (Powell et al. 1997). Unfortunately, the accuracy of waste shear strength measurements, τ_s, is not known; this constrains the confidence level of ECR predictions. The best empirical equation obtained thus far for estimating the ECR of jet mixers in cohesive tank sludge is based on limited data for a few fixed geometries. This equation was created from curve fits of data:

$$\mathbf{ECR = K \cdot U_0 D \cdot \tau_s^n} \qquad (1)$$

where:
- ECR = effective cleaning radius
- K = constant (a function of the relative height of the nozzle centerline)
- U_0D = jet velocity times jet diameter
- τ_s = sludge shear strength
- n = experimental constant.

Predicted tank retrieval efficiencies from the empirical ECR equation vary from 12 ft to 42 ft (Crawford 1999). For example, in Grams (1995) an ECR of only 12 ft to 13 ft was calculated for Tank 241-AW-103. Other studies such as Akins (1999) list values to approximately 30 ft with only 20% solids mobilized. This ECR performance would thus leave a large potential open area needing solids mobilization in the 75-ft-diameter DST, even with two or more mixer pumps deployed. In addition, all material that is mobilized may not be available for recovery, as it may just be swept into the unmobilized areas. Once material is transported to the "dead" area it has been eliminated from the retrieval process. The magnitude of this material buildup or layer will not be known until confirmed during actual mixing with sampling (Rasmussen 2000) or by inference from tank instrumentation. Figure 1-1 depicts dual mixer pump coverage in a storage tank and the potential material not mobilized.

Figure 1-1. Tank Plan of Mixer Coverage.



Current-design mixer pumps are costly, require a large-diameter tank riser, are difficult to deploy, and require significant lead time for construction. To increase confidence in meeting waste feed delivery commitments, a mitigation action under consideration is the use of auxiliary mixing systems to either mobilize the dead-zone material into the liquid layers or translocate the waste to the ECR area swept by the mixer pumps. Another risk-handling action (currently included in baseline retrieval planning) is to provide a source of contingency feed.

A range of technologies are being assessed (Bamberger 1999) that could be deployed as auxiliary mixers including pulsed air mixers, fluidic pulse-jet mixers, sluicers, borehole miner extendible nozzle sluicer, robotic end effector, and high-pressure scarifier. One such technology, the free jet flow agitator (henceforth, referred to as the submersible propeller mixer) is the subject of this case study.

The Flygt[1] Model 4600 submersible propeller mixer is being investigated because of its apparent simplicity and cost; experience on other DOE sites for waste retrieval; and an "extrapolated U_0D" value, that appears to be on the same order as a jet mixer. *(Note: Caution should be used in comparing a propeller mixer to a jet mixer in this way. The principles of operation for the devices are different, and this may not be an accurate way to compare them).* Typical industrial applications for the submersible propeller mixers include waste water treatment plants, sewage

[1] Flygt is a trademark of the ITT Flygt Corporation, Svetsarvagen 12 Solna, Sweden Corporation, Sweden.

plants, pulp mills, off-shore drilling rigs, fish farms, chemical processing plants, breweries, mines, and steelworks. Section 4.0 describes the submersible propeller mixer principle of operation and the Flygt™ mixer in particular. Literature and Internet searches performed by the author did not reveal any comparable compact, direct drive, submersible, stainless steel propeller mixers to be available from other manufacturers.

In 1998, two Flygt™ submersible propeller mixers were successfully deployed in gunite Tank W-5 at the Oak Ridge National Laboratory (ORNL) to mobilize sludge from the tanks. The Savannah River Site (SRS) is currently testing three 50-hp Flygt™ mixers for potential use in final cleanout of Tank 19. To date, SRS, Flygt™, and Pacific Northwest National Laboratory (PNNL) have conducted four phases of a joint testing program to evaluate the application of Flygt™ mixers for retrieval operations within the DOE complex. The test program has been carried out for the Tank Focus Area with efforts focusing on supporting the SRS Tank 19 retrieval campaign. Considering the usage and development of the Flygt™ submersible propeller mixer at other sites, along with the wider needs of the Hanford Site waste retrieval program for mobilization/mixing devices, this case study was initiated to determine the suitability of the Flygt™ mixer for auxiliary solids mobilization and to present a basis to decide whether to pursue the propeller mixer technology.

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2.0 PURPOSE/OBJECTIVES

The purpose of this technology and engineering case study is to evaluate the Flygt™ submersible propeller mixer as a potential technology for auxiliary mobilization of DST HLW solids. Considering the usage and development to date by other sites in the development of this technology, this study also has the objective of expanding the knowledge base of the Flygt™ mixer concept with the broader perspective of Hanford Site tank waste retrieval. More specifically, the objectives of this study delineated from the work plan are described below.

- **Derive requirements for DST HLW solids mobilization.** Establish requirements for DST HLW solids mobilization that support, if needed, the future evaluation (new scope) of other potential technology candidates. This was addressed in a previous study (Tedeschi 2000).

- **Compilation of work from other DOE sites.** Compile a summary of Flygt™ mixer development work performed to date by SRS and the deployment of Flygt™ mixers at ORNL.

- **Vendor Consultation with ITT Flygt Corporation.** Present results of vendor consultation with Flygt™ including estimated mobilization performance for Tanks 241-AY-102 and 241-SY-102; necessary development; infrastructure and utility needs; and rough-order-of-magnitude (ROM) cost and schedule for vendor procurement materials and services.

- **Predicted Performance Assessment.** Evaluate Flygt™ performance prediction and assess whether a Flygt™ mixer can meet the minimum mobilization effectiveness criteria for auxiliary solids mobilization. Identify development work (models and tests) necessary to obtain a more reliable prediction of mobilization effectiveness (i.e., performance).

- **Waste Tank Compatibility.** Assess the suitability of the Flygt™ mixer equipment versus nonmixing-related functions and requirements (physical constraints and operation within the Hanford Site waste tank environment).

- **System Configuration.** Present a preliminary conceptual design of Flygt™ mixer assembly and support systems necessary for installation in a Hanford Site waste tank.

- **Overall Deployment Cost and Schedule Estimate**. Present a ROM cost and schedule for deployment of the Flygt™ mixer including development; design, fabrication, and procurement of equipment; field installation; testing; and startup.

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3.0 SLUDGE MOBILIZATION, MIXING, AND RETRIEVAL

It is important to recognize the different processes involved in the retrieval of sludge from a tank. These can be categorized into three areas: (1) mobilization, (2) mixing, and (3) retrieval (transport). It does not necessarily follow that a piece of equipment that is good for mixing or transport will also be good for mobilization. The given piece of equipment must be evaluated against the process needed. These three processes involved in sludge retrieval are described below.

1. **Mobilization** requires that particles be freed and separated from a continuum or solid surface. The shear stress generated by the equipment must be sufficient to overcome the mobilization resistance of the sludge, termed the critical shear stress for erosion (τ_c). When the applied stress is lower than τ_c, no significant erosion is observed. The maximum possible performance of a mobilization device is determined by the point at which the mixer's applied stress decays with distance to the point where it just equals the τ_c of the sludge.

   The sludge mobilization process is qualitatively different than the resuspension of settling solids. For our purposes, sludge is composed of very small, cohesive particles. To mobilize a given piece of sludge away from the sludge/slurry interface, the local shear stress must exceed some minimum value for some minimum amount of time. The exact value of the required shear stress and time is a function of the sludge properties and to some extent the slurry properties. Once these criteria are met, a particle or group of particles (flake) is removed from the sludge surface, thereby exposing the particles underneath to the erosive action of the flowing slurry. This process is continually repeated (Powell et al. 1999a).

2. **Mixing** requires that the erosion or mass flux of particles from the tank floor be equal to or greater than the rate of deposition. The strength of the bulk flow in the tank controls the efficiency of the mixing. The goal of the mixing process for Hanford Site sludge waste is to suspend the mobilized particles to create a uniform slurry for pumpout from the tank. For slow-settling particles, only a small amount of agitation is required to maintain them in suspension off the tank floor. Rapidly settling particles require a constant application of energy to stay in suspension, but generally less mixing energy is needed compared to the mobilization process.

3. **Retrieval** requires that material be mobilized and transported to some location such as the inlet of a retrieval pump. Depending on the elevation and flow rate of the retrieval pump inlet, however, a particle does not have to be suspended to be retrieved. Suspension of the particles into a uniform mixture is not required as long as the mixing equipment can move the material to the retrieval pump inlet. Equipment that can create bulk circulation patterns in a tank may be able to "push" solids to the retrieval pump inlet without suspending the particles, reducing the "dead zones" of material deposition within the tank (Enderlin 1999).

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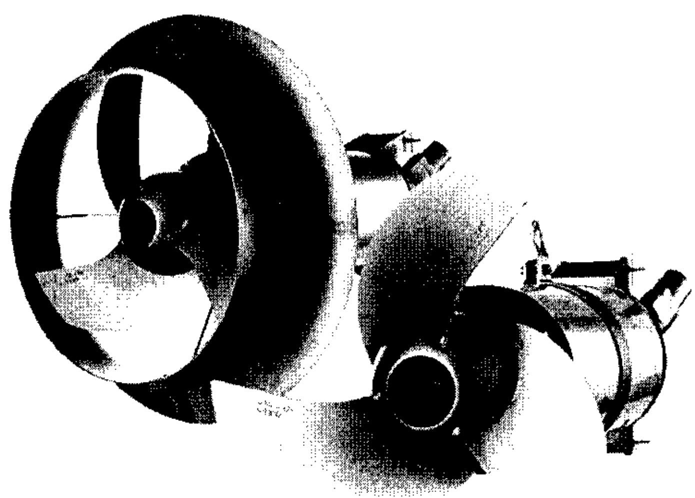
4.0 DESCRIPTION OF THE PROPELLER MIXER

A propeller mixer operates to move a large volume of fluid at a low pressure. Propellers are an axial flow device, meaning the principal direction of discharge coincides with the axis of impeller rotation. Inflow to the propeller is mostly radial when a direct-drive submersible motor is present, while outflow is mostly axial except for a tangential component (swirl). An axial flow propeller does not have its maximum flow at the center as does the jet produced from a pressurized nozzle. The maximum velocity is located in an annular ring. To improve the efficiency of the propeller mixer, a close-fitting shroud (also called a jet ring) may be installed. This results in an increase in far-field velocities and also reduces losses from blade tip recirculation. Figure 4-1 shows Flygt™ propeller mixers, with and without a jet ring.

Figure 4-1. Flygt™ Propeller Mixers, With and Without Jet Ring.



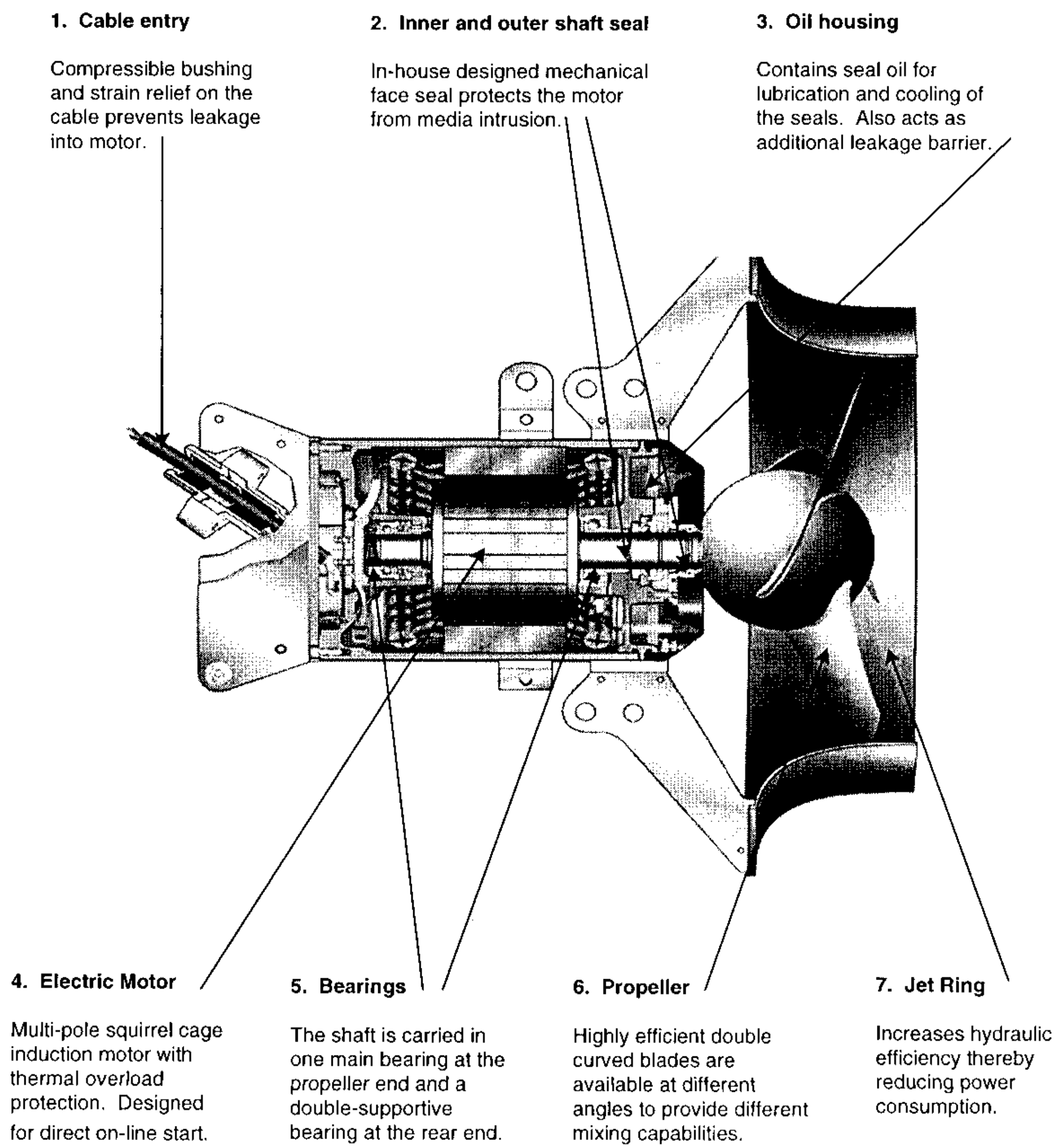
4.1 DESCRIPTION OF THE FLYGT™ SUBMERSIBLE PROPELLER MIXER

Flygt™ manufactures a line of compact, direct-drive, stainless steel, propeller mixers. These mixers can be found in wastewater treatment plants, sewage plants, pulp mills, offshore drilling rigs, fish farms, chemical processing plants, breweries, mines, and steelworks. The Flygt™ Model 600 series mixers range in motor capacity from 1 hp to 40 hp. Propeller diameters range from 8.50 in. to 30.25 in., at blade angles from 5° to 14°. Larger blade angles produce more thrust but also more loading on the motor. The largest size, the Model 4680 (40 hp), is of primary interest for the Hanford Site tank application given the challenging nature of sludge mobilization. The Model 4680 mixer with a jet ring (shroud) generates a flow rate of 30,000 gal/min and almost 7000 Newtons (1,570 lb) of thrust in water. As a point of comparison, the baseline jet mixer pump produces approximately 5,000 gal/min of flow through each nozzle and has a U_0D of approximately 29 ft^2s^{-1}.

The Flygt™ recently developed a 50-hp mixer with an extended shroud that produces 6,000 Newtons of thrust and will fit down a 24-in. riser. This unit is discussed in greater detail in Section 5.0. Flygt™ indicated it could possibly develop a 100-hp unit for a 24-in. riser if requested by a potential customer.

Vendor cutsheets from Flygt™ presenting detailed product description, performance, and configuration for the Model 4680 mixer are included in Appendix A. Figure 4-2 shows an equipment cross-section along with description of the principle components of the mixer.

Figure 4-2. Flygt™ Propeller Mixer Cross-Section.



4.2 FEATURES OF THE FLYGT™ SUBMERSIBLE PROPELLER MIXER

While there is no intent for this study to establish a comparison of the two technologies, the well known and well developed jet mixer pump offers a useful reference in understanding the main features of the submersible propeller mixer. Table 4-1 compares the Flygt™ submersible propeller mixer pump and the jet mixer pump.

Table 4-1. Flygt™ Mixer Versus Jet Mixer Pump Feature Comparison.

Flygt™ propeller mixer pump	Jet mixer pump
Unidirectional flow allows for bulk flow patterns to be created within the tank, which can aid the transport of solids.	Diametrically opposed nozzles result in equal and opposite flow rates, disrupting creation of any bulk flow patterns within tank.
Unidirectional flow allows additive effects of multiple mixers to be used to concentrate energy on limited regions of the tank. Thus in some instances mobilization may be possible even when the total mixer power is not large enough to effectively mix the entire tank. Likewise, poor orientation of multiple mixers in a tank can hinder mobilization and produce "dead zones" within the tank.	Diametrically opposed nozzles result in equal and opposite flow rates, disrupting creation of any bulk flow patterns within the tank. Rotational coverage can be affected by having to consider impingement effects of the backside jet on in-tank components.
Unidirectional flow results in large thrust force applied to supporting structure.	Diametrically opposed nozzles balance out thrust forces.
The units require no fresh water supply.	The baseline mixer pump design, built by Lawrence Pumps* for Project W-211, has a water-filled column.
The direct-drive, submersible design eliminates the need for a long line shaft.	The baseline mixer pump design, built by Lawrence Pump for Project W-211, uses a long line shaft that is lubricated by the water-filled column.
High-volume flow-per-unit power has demonstrated effectiveness in industrial solids suspension and blending applications.	High-velocity discharge from nozzles has demonstrated effectiveness in mobilizing sludge.
Propeller can not be located as close to floor as nozzles, but can be aimed toward floor.	Nozzles can be located closer to floor, advantageously concentrating energy near sludge.
Low power input to tank (50 hp or less) results in slower tank heat-up.	Current baseline design is 300 hp, resulting in faster tank heat-up. (Motor is not submerged; tank needs to dissipate hydraulic energy only.)
Propeller and submersible motor appear relatively easy to decontaminate.	Baseline design has liquid retention cavities because of the water-filled column.
Not developed for radioactive waste tank application.	Developed for radioactive waste tank application.
With proper mast design, unit can be pointed in almost any direction.	Vertical line shaft and dual nozzles limit ability to orient discharge in vertical plane.

*Lawrence Pumps is a trademark of Lawrence Pumps, Inc., Lawrence, Massachusetts.

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5.0 USE OF FLYGT™ MIXER AT OTHER U.S. DEPARTMENT OF ENERGY SITES

5.1 OAK RIDGE NATIONAL LABORATORY TANK APPLICATION EXPERIENCE

Hot deployment of Flygt™ mixers at ORNL was documented in Enderlin (1999). The following is a summary of the information provided in this report.

Flygt™ mixers were selected for deployment by the Gunite and Associated Tank Remediation Project at ORNL as an alternative system to remotely operated cleaning systems for waste retrieval. The remotely operated cleaning systems are designed to clean tank walls, remove large debris, break up hardpan sludge, and retrieve waste heels as needed. The goal of using the Flygt™ mixers was to reduce the overall cost of retrieval operations at ORNL by retrieving the less challenging portion of the waste within the tanks and limiting the operating time (wear) on the remotely operated cleaning systems.

Between July and November 1998, two 15-hp Flygt™ mixers were installed and operated in gunite Tank W-5 at ORNL. It is believed that the mixers were Model 4660 mixers; however, no model number was given. The mixers were deployed through existing risers and suspended on a mast assembly. The mast assembly supported all mixer loads from a structural steel platform, which was located above grade and spanned the entire diameter of the tank. During operation, the mixers were horizontal such that the mixer shaft was parallel to the tank floor. Liquid volume was not recorded during operation. Tank W-5 has a diameter of 50 ft. Based on the criteria of a minimum clearance of 1 ft between the mixers and the tank floor and the estimated average liquid height of 3.3 ft, it appears the liquid level was on average approximately 5 in. above the top of the mixers during operation. The following procedure was used to carry out retrieval operations:

- Add supernatant liquid to Tank W-5 from the holding tank (Tank W-8)
- Simultaneously operate both Flygt™ mixers to mix/suspend Tank W-5 sludge with the supernatant liquid
- Transfer the resultant slurry to Tank W-9 and allow to settle
- Transfer the supernatant from Tank W-9 to Tank W-8
- Repeat mixing campaign until sample data indicates that a "minimal return point" has been achieved.

The operating time of the mixers during a cycle varied from 4 to 72 h. Shorter durations of mixer operation were employed for the initial cycles of mobilization and waste transfer. The mixer operating time for a single mobilization cycle was progressively increased throughout the retrieval campaign. The total run time for each mixer was approximately 250 h.

The mixer orientation remained fixed during a mobilization cycle; however, the mixers could be reoriented between cycles. Visual observations were used to modify mixer operations. The mixers were repositioned to direct the discharge toward areas with the largest deposits of solids.

Samples of the suspended slurry were extracted from the tank during mixer operation as the campaign progressed and evaluated for the weight percent (wt%) solids, density, and radiochemical content analysis. The mobilization cycles continued until the solids content within the supernatant liquid was less than 0.10 wt%, which occurred after five cycles. An estimated liquid volume of 250,000 gal was cycled through Tank W-5 during the five waste mobilization cycles. No initial or final liquid levels were given for the various cycles.

It is estimated the five cycles of waste mobilization removed 70% of the solids and radioactive content that had existed in Tank W-5. The solids were reduced from 6,600 to 2,000 gal. An average of 2.0 wt% was retrieved. The radioactivity content was reduced from approximately 238 to 72 Ci. The performance of the Flygt™ mixers exceeded ORNL's expectations.

5.2 SAVANNAH RIVER SITE TESTING EXPERIENCE

In the early 1980s, two jet mixer pumps were used to dissolve and retrieve the saltcake in Tank 19 at SRS. Not all of the waste was removed during this retrieval campaign, however, and roughly 33,000 gal of waste solids remain. The solids are composed of sludge, zeolite, and salt. Based on the topography of the solids heel in Tank 19, it is suspected that the mixer pumps did not have sufficient power to maintain the faster-settling solids in suspension or that the mixer pump jets pushed the larger, settled solids out beyond the reach of the jets.

An effort was made to identify and design alternative waste retrieval techniques for the Tank 19 waste. During 1998, PNNL, ORNL, SRS, and Flygt™ staff members conducted a joint mixer testing program to evaluate the applicability of Flygt™ mixers to Tank 19 waste retrieval and waste retrieval in other DOE tanks. This test program evolved through three phases (A, B, and C) that are documented in Powell et al. (1999a, 1999b, 1999c), and a Phase D that has not yet been documented. Deployment of Flygt™ mixers in Tank 19 is anticipated by September 2000. The joint tests and current status are summarized in the sections below.

5.2.1 Phases A, B, and C Mixing Test Description

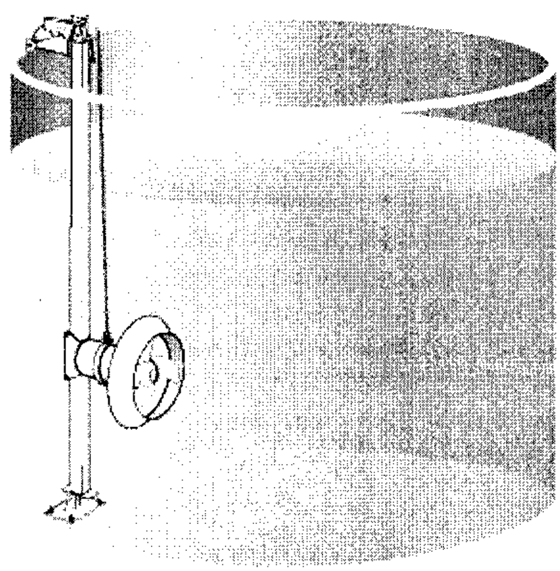
The information in Sections 5.2.1 and 5.2.2 is summarized from Powell et al. (1999a, 1999b, 1999c).

> *Note: None of the Phase A or B tests were geometrically, kinematically, and/or dynamically similar to the proposed Tank 19 mixing system with Model 4680 Flygt™ mixers nor to the waste tanks at the Hanford Site. Therefore, extrapolation of the Phases A and B data is required to make predictions for mobilization performance in a full-scale tank. The Phase C test was performed in a full-scale tank in water with a full-scale Flygt™ mixer.*

Phase A tests were performed at the Flygt™ laboratory in Trumbull, Connecticut, in a 1.5-ft-diameter, clear-bottom tank using small, stationary Flygt™ mixers (3-in. propeller diameter) positioned near the tank floor. The principal objectives of the small-scale Flygt™ mixer tests were (1) to measure the critical fluid velocities required for sludge mobilization and particle suspension, (2) to evaluate the applicability of the Gladki constant-wall-shear-stress (CWSS) scaling theory for predicting mixing intensity to maintain a suspension of solids in a just-suspended condition, and (3) to provide small-scale test results for comparison with larger-scale tests to observe the effects of scale-up.

Phase B tests involved larger-scale tests in PNNL's pilot-scale mixing tanks (6-ft diameter and 18.7-ft diameter) at the Hanford Site using stationary 4-hp Model 4640 Flygt™ mixers. The 18.7-ft-diameter tank is a quarter-scale replica of a DST at the Hanford Site. A variety of simulants were used for the Phase B tests. The test matrix included particle mobilization tests with zeolite and crushed limestone and sludge mobilization tests with clay-based sludge. Tests were performed using one mixer in the 6-ft tank, as shown in Figure 5-1, and three mixers in the 18.7-ft tank. The size of the mixer propellers used were more than three times larger than required by geometric scaling of the Tank 19 mixers.

Figure 5-1. Installation of Mixer in Test Tank.



The main objectives of the Phase B tests were to determine the average wall stress and fluid velocity required to mobilize sludge and to validate the CWSS theory for solids suspension. The data from the Phase B tests were compared to the Phase A tests where possible. The approach used in the Phases A and B sludge mobilization analyses related the sludge shear strength to the average wall shear stress, τ_0 (defined as the total mixer thrust divided by the wetted surface area within the tank) required to achieve 80% of the sludge mobilized. The 80% level was arbitrarily chosen to represent an acceptable degree of mobilization. This approach is referred to as the average-wall-shear-stress theory for solids mobilization.

The CWSS theory for predicting mixing intensity to maintain a suspension of solids in a just-suspended condition was proven to be invalid in the Phase B testing.

Phase C testing used stationary, full-scale Flygt™ Model 4680 mixers in the SRS TNX test facility. The TNX tank is 85 ft in diameter and 8 ft tall. Because the standard Model 4680 mixers are too large to fit in the 24-in.-diameter tank risers at SRS, Flygt™ developed a modified mixer design that uses a smaller propeller and more powerful motor. A wire-mesh screen was installed on the mixer intake to protect the propeller from debris known to be inside SRS Tank 19 and other DOE waste tanks. SRS also developed a deployment mast to install and orient the Model 4680 mixers in waste tanks such as Tank 19. The mixers were installed in the TNX tank in various positions (in most cases the positions corresponded to Tank 19 riser locations) and orientations. Figures 5-2 and 5-3 are photographs of the SRS configuration. Section 10.0 describes the SRS deployment mast configuration further.

Water was used for all the Phase C tests. The tests were conducted by operating the mixers at full speed (860 r/min) and measuring the fluid velocity at selected locations in the tanks for three different liquid levels and various mixer orientations. As seen in Figures 5-2 and 5-3, extended shrouds of various lengths were installed on the Flygt™ mixer in an effort to obtain an optimum length that maximizes far-field velocities.

Figure 5-2. Modified Flygt™ Mixer Deployed in Horizontal Position at Savannah River Site TNX Tank.

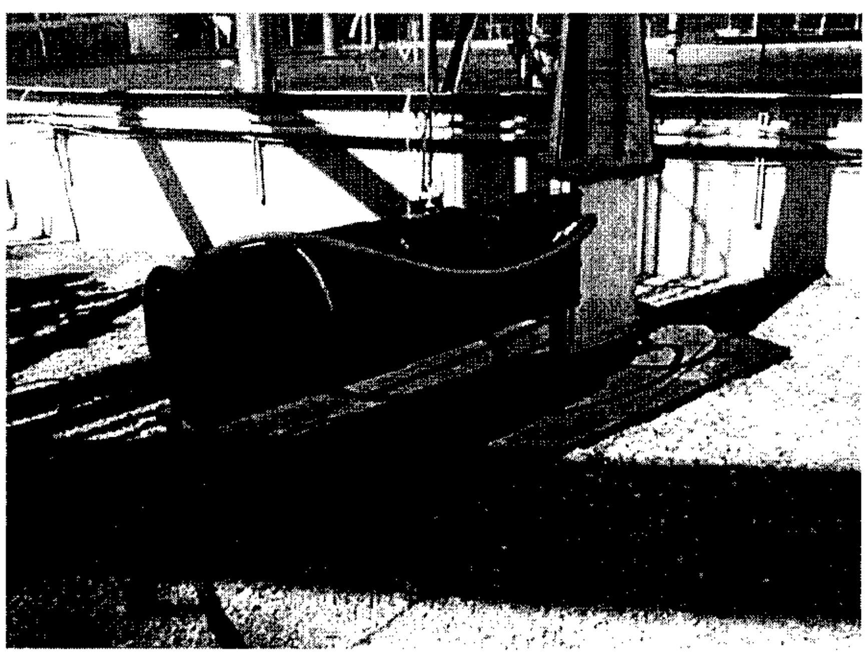
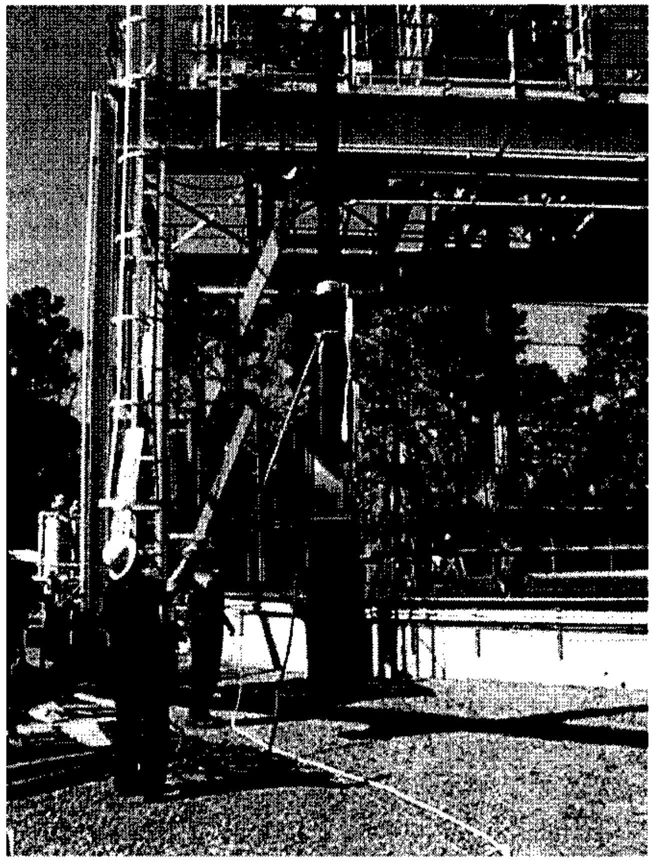


Figure 5-3. Modified Flygt™ Mixer and Deployment Mast in Vertical Position



5.2.2 Phases A, B, and C Mixing Test Conclusions

Key conclusions and recommendations drawn from the Phases A, B, and C experimental results that may have potential application to the Flygt™ mixer in waste tanks at the Hanford Site are summarized below (see Powell et al. 1999c for full listing). It should be noted that during these tests, geometric, kinematic, and dynamic similarity did not exist between the test cases and any full-size DOE tanks. Extrapolation of the test data is required to make predictions for mobilization performance in a full-scale tank.

- Constant power-per-unit-volume mixer scaling was consistent between the three tests and may be used to make a rough prediction of the number of mixers required in a tank. The accuracy of this scaling predictor is uncertain because the effects of changing the number of mixers and liquid-level-to-tank-diameter ratio are not well understood. Constant power-per-unit-volume scaling will overpredict power requirements for smaller particulates and underpredict power requirements for larger sizes (best applicable to particulates with median size of 0.4 mm to 0.8 mm).

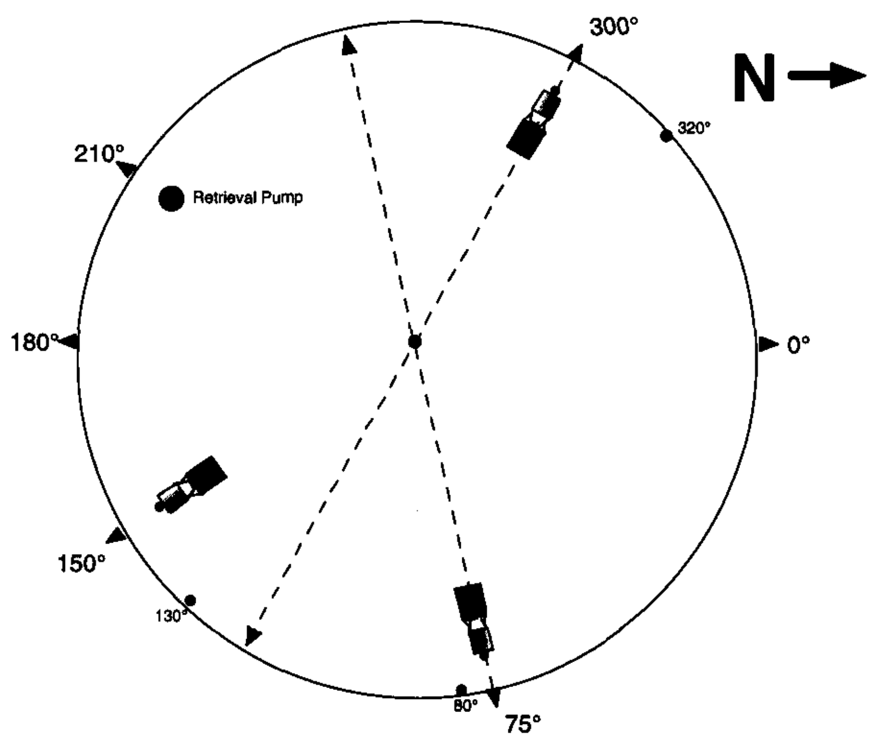
- Continuous rotation (or oscillation) or discrete positioning (cycling through fixed positions) of the Flygt™ mixers is expected to significantly improve their performance (periodically on a time scale of minutes).

- At the scales tested, the calculated average-wall-shear-stress, τ_0, required to mobilize about 80% of the sludge in a tank is on the order of 5% to 15% of the sludge shear strength. Evidence exists that these percentages increase with increasing scale, but it is not known if this effect is real or an artifact of differences in the simulants tested. This method does not appear to apply to rapidly settling particles in large tanks.

5.2.3 Phase D Test Description

The Phase D tests were performed in PNNL's quarter-scale mixing tank at the Hanford Site to evaluate potential operating sequences and provide recommendations for future Tank 19 operations. The retrieval tests used three 4-hp Model 4640 Flygt™ mixers each attached to an independently oscillating mast, which allowed for either continuous oscillation ("sweeping" of the tank floor) or periodic reorienting of the mixers during operation. Placement of the mixers within the tank is shown Figure 5-4 and was relative to the riser locations and height above floor in Tank 19. The simulants used were of relatively low shear strength.

Figure 5-4. Relative Orientations of Flygt™ Mixers and Retrieval Pump for Phase D Tests.



Experimentation was performed for various operating scenarios to determine which orientations maximized retrieval rates from the tank. Both continuous oscillation and discrete positioning were evaluated. In the case of discrete positioning, the mixers were maintained in a particular orientation for a fixed period of time or until a drop in the solids retrieval rate was measured. Depending on the configuration, the testing indicated that in "good orientations" a synergy can result where the retrieval effectiveness is greater than the sum of individual mixer performances, and conversely in "bad orientations" the retrieval rate could be impeded and excessive material deposited in dead zones within the tank. The Phase D test results are documented in

TTP RL3-6-WT-51, *FY00 Workscope, Milestone Completion Report A.1-4: Complete Test of 50-hp Flygt Mixer and Issue Phase D Test Report* (PNNL 2000), which has been released to the Tank Focus Area.

5.2.4 Modified Flygt™ Mixer Equipment Issues

> *Important: The issues discussed in this section are solely related to experimental physical modifications made to the vendor's standard equipment. This section is not applicable to the reliability of a standard "off-the-shelf" Flygt™ mixer unit.*

The modified Model 4680 Flygt™ mixers to be used in Tank 19 experienced component failures during testing by SRS and PNNL. These failures are connected to physical modifications made by SRS to the standard Flygt™ mixer unit for the purpose of enabling the most powerful mixer unit available to fit down a smaller riser than would otherwise be possible. A small-size and high-power propeller mixer is of great interest at the Hanford Site because of the limited size and availability of tank risers; therefore, SRS's experience is presented in detail below.

The failures on the modified mixers included one instance of a broken propeller, one broken shaft, and failure of the extended shroud and shroud-support structure. Cavitation, excessive vibration, and subpar motor performance (low power factor) were identified and/or measured on the units. According to information provided by SRS[2], the modified Model 4680 mixer used in Phase C testing had the following modifications versus a standard "off-the-shelf" Model 4680 mixer (not including the mast and deployment assembly).

- The standard 40-hp motor was rewound from a 16-pole to 8-pole (440 r/min to 880 r/min) to increase the total output horsepower to 50 hp.
- The standard power cable was changed to allow for the higher amps of the new motor resulting from rewinding.
- To make the unit fit within the SRS 24-in.-diameter riser, the standard 30-1/8 in. propeller for the Model 4680 was replaced by a 22-in. propeller from the standard 15-hp Model 4660 unit, which was then trimmed to 20 in. to fit within the shroud.
- The shaft diameter at the propeller hub was reduced to accommodate the modified propeller.
- An extended shroud was devised to try to focus the flow leaving the propeller as a turbulent free jet.
- A wire mesh screen was added to the mixer suction to protect the propeller from debris. The annular intake opening is significantly reduced from that of an off-the-shelf unit.

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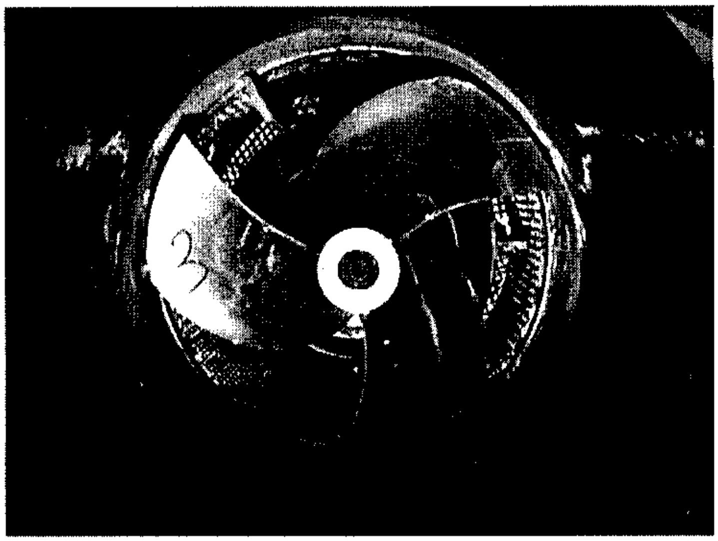
[2] Communication with B. Adkins, SRS Test Lead

SRS related significant troubleshooting and upgrading that has taken place on the modified mixer configuration since the Phase C testing. The original (standard) propeller (which had blades welded to the hub) has been replaced by a more robust, cast one-piece propeller, which is shown in Figure 5-5.

Figure 5-5. New Propeller Installed within Original Extended Shroud



The propeller hub is redesigned to accommodate a larger diameter shaft to reduce the probability of shaft breakage. (Note: Conjecture is that the extended shroud contributed to the propeller/shaft breakage problems because of its added back pressure above what the standard Model 4680 mixer [an axial flow device] was designed).

Cavitation and vibration detected during testing is suspected to have been caused by several items: a lack of concentricity between the blade and the shroud (which was extreme—as great as a 0.25-in. difference in blade clearance around the perimeter of the shroud, 3 times vane pass frequencies were measured corresponding to the three propeller blades), the trimming of the propeller blades to fit the 24-in.-diameter envelope, and the severe reduction in the mixer intake opening area that may be causing flow starvation. SRS has manufactured a new shroud machined to a 0.005-in. concentricity that, when mounted, resulted in a blade/shroud concentricity of less than 0.030 in.

Endurance testing of a modified Model 4680 mixer with new propeller and shaft, but with the old shroud, in 1.2-specific gravity slurry was performed by PNNL in early May 2000 at the Hanford Site quarter-scale tank. The objective of the endurance test was to verify that the SRS-modified Flygt™ mixers will perform reliably during the heel suspension and mixing phase of the waste removal operation for Tank 19. After 67 h of testing, the unit showed significant physical damage including cracked welds, numerous cracks in the support structure securing the shroud to the motor, blade tip damage, loose accelerometers, and missing portions of the inlet screen (Enderlin 2000). As of the publication date of the report, the testing has been halted pending further action.

Optimization testing of a modified Model 4680 mixer with new propeller, shaft, and shroud was performed at SRS TNX facility in early May 2000 (Adkins 2000). The mixer was assessed by SRS to have operated very well. Full-load motor current was reduced from 85 to 75 amps with the new shroud design. Vibration levels on the motor and shroud were high compared to industry standards for other pieces of rotating equipment such as pumps. Vibration levels increased by three to four times between 700 and 860 r/min, apparently as a result of a system natural frequency, which led to a recommendation to use adjustable speed drives in the field. Velocity data for the new shroud indicated that near-field velocities were increased by 33% as compared to the old shroud design with new propeller, whereas far-field velocities were nearly identical. The test data indicated that changes in the inlet region of the mixer play a significant role in mixer vibration, motor current load, vortex suppression, and discharge velocity. A 6-in. piece of sheet metal was placed around the circumference of the mixer at the inlet region of the mixer closest to the propeller to reduce the suction area and change the inlet flow angle of the mixer from radial to axial. Overall, motor and shroud vibration levels decreased significantly when this was performed while motor current increased from 75 to 84 amps.

Further testing may be performed to demonstrate the SRS-modified Flygt™ mixer can operate with sufficient reliability to complete the entire Tank 19 cleanout mission. *Once again, these reliability issues are a direct result of modifications made to the standard Flygt™ mixer design and do not seem to call into question the reliability of the standard Flygt™ mixer unit that has demonstrated longevity in varied industrial applications.*

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6.0 FUNCTIONS AND REQUIREMENTS FOR AUXILIARY SOLIDS MOBILIZATION IN HANFORD SITE TANKS

Auxiliary solids mobilization (also termed as extended sludge retrieval) is defined as the freeing or separation of particles from a sludge surface into a flowing slurry by the erosive action of a supplemental retrieval system to the primary, baseline jet mixer pumps. *Derived Requirements for Double-Shell Tank High-Level Waste Auxiliary Solids Mobilization* (Tedeschi 2000) defines the derived functions and requirements for the development of auxiliary, waste solids mobilization equipment for use in HLW tanks. These are the minimum requirements the Flygt™ mixer system shall be expected to meet to receive further consideration as an auxiliary waste mobilization system. The full list of requirements is included in Appendix B of this document.

The performance criteria given in Tedeschi (2000) are based on the needs of those tanks sequenced in the first phase of waste retrieval. The most recent published information was examined and included the baseline document, *Tank Waste Remediation System Operation and Utilization Plan,* (Kirkbride et al. 1999) and published case documentation for Retrieval Case 3S5 (Kirkbride 1999). This produced the following listing of HLW tanks consisting of eight DSTs and two SSTs: Tanks 241-AN-104, 241-AW-103, 241-AW-104, 241-AY-101, 241-AY-102, 241-AZ-101, 241-AZ-102, 241-C-104, 241-C-107, and 241-SY-102.

The two waste storage tanks most likely to require auxiliary solids mobilization are Tanks 241-AW-103 and 241-SY-102 based on modeling ECR results with two mixer pumps (Kirkbride et al. 1999). These two tanks are the primary source of requirements to ensure additional mobilization technology would be applicable to their conditions. The other eight tanks helped establish requirement ranges and bounding conditions. The derived requirements encompass performance and process criteria, tank environmental conditions, physical constraints, equipment deployment, operations and maintenance, safety, and radiological control. A table of requirements and a compilation of tank and related data are tabulated in Appendix B.

Tedeschi (2000) provides special emphasis on criteria deemed to be of overriding importance to the mission goal, in particular, those criteria that maximize tank applicability and ECR while maintaining tank integrity and protection of workers and site personnel. These criteria are summarized in Table 6-1.

Table 6-1. Mission Essential Criteria.

Auxiliary Mixing
<u>Minimum</u> – Equipment shall mobilize areas outside of the effective cleaning radius of a dual installed mixer system. (see Figure 1-1). <u>Maximum</u> – Equipment shall be capable of mobilizing solids at various tank locations, including the center of the tank or even under installed mixer pumps
Tank Applicability
<u>Minimum</u> – Equipment shall be installed and operated for auxiliary solids mobilization in double-shell tanks 241-AW-103 and 241-SY-102. <u>Maximum</u> – Application shall be extended to maximize usage in double-shell tanks 241-AN-104, 241-AW-104, 241-AY-101, 241-AY-102, 241-AZ-101, 241-AZ-102, and single-shell tanks 241-C-104 and 241-C-107. Consideration shall be given to extend use to remaining double-shell tanks.
Solids Mobilization
<u>Minimum</u> – Equipment shall mobilize solids in sludge with shear strength 3.38 kPa at a distance of 3.0 m (9.8 ft). Equipment shall also be able to operate at varied internal tank heights and controlled to variable discharge directions. <u>Maximum</u> – Equipment shall mobilize solids in a sludge with shear strength of 3.38 kPa at a distance of 6.0 m (19.6 ft). Consideration shall be given to mobilization of sludge with shear strengths of 4.8 kPa. Consideration shall be given to operation of equipment with varied tank heights and discharge directions without need for riser disconnection/removal or breaking of tank confinement.*
Property and Personnel Protection
<u>Criteria</u> – Equipment shall not erode tank internal surfaces. Equipment shall not displace or damage other installed and operational tank systems. Equipment shall meet all safety-derived requirements.

*Consideration shall also be given to maximize the following additional capabilities: waste dissolution enhancement, viscous liquid mixing, slurry mixing, and dislodgment of solid heels. While some of this activity will occur naturally dependent upon the technology, it is desirable to maximize these parameters to aid in pumping retrieval.

7.0 PROPOSED PROPELLER MIXER CONFIGURATION AND INITIAL PERFORMANCE PREDICTION BY ITT FLYGT CORPORATION

Flygt™ was contacted to provide information in support of this technical assessment. The key information requested was:

- Number of, and possible, mixer(s) configuration(s)
- Recommended mixer(s) characteristics (power and size)
- Predicted performance in the absence of experimental data for the considered application (mixing effectiveness)
- Necessary development (design adaption, testing, and modeling) that would be required to validate performance
- ROM cost/schedule for overall development and procurement leading to delivery of a first unit
- ROM cost of standard off-the-shelf units
- Identification of any design requirements that could be limiting and, if so, recommendations for alternative approaches
- Impact of tank access or physical constraints on performance
- Reliability data for the submersible mixer in related applications
- Infrastructure and utility needs.

The two tanks most likely to require auxiliary solids mobilization, Tanks 241-AW-103 and 241-SY-102, were initially selected for evaluation. It was revealed early on that the riser size constraints present in Tank 241-AW-103 (considering jet mixer pumps to be installed in the two outboard 42-in. risers) rule out deployment of Flygt™ mixers anywhere but the central pump pit in that tank (see Section 9.1). Tank 241-AY-102, the next most difficult tank to mobilize of the ten selected based on the sludge shear strength data included in Appendix B, was then selected.

Flygt™ performed evaluations to select candidate Flygt™ mixers for deployment in Tanks 241-AY-102 and 241-SY-102, working within the riser constraints identified in Section 9.1 and using the information provided in Tedeschi (2000) which includes tank environment data, waste properties, core sample profile data, and jet mixer pump-predicted ECRs. The evaluations as transmitted from Flygt™ are presented in Appendix C. They are focused on predicting the cleaning area of the Flygt™ propeller mixer using results from the Phases A, B, and C testing along with equipment performance data from the selected mixer. Equipment impacts and needs are discussed, but no cost or schedule data are included.

7.1 MOBILIZATION EFFECTIVENESS PREDICTION METHODOLOGY USED BY THE VENDOR

The Flygt™ mobilization prediction methodology applies the results from the Phases A, B, and C tests along with Flygt™ equipment performance data and some subjective assumptions to predict a cleaning radius and cleaning area. The methodology follows in the steps below (see Appendix C for more detail).

1. For a given tank, use Equation 1 (Section 1.0) to predict jet mixer ECR to determine the percentage of the tank floor swept by the primary jet mixer pumps.

2. Subtract the answer (from Step 1) from 100 to obtain the percentage of tank floor not covered by agitation.

3. Determine the entire wetted surface area of the tank up to the 4-ft level (bottom and wall) (assumption from Flygt™, see Appendix C).

4. Multiply the tank wetted surface area (obtained in Step 3) by the percentage of tank floor not covered by agitation (obtained in Step 2) to obtain the supplementary wetted area to be cleaned out.

5. Divide result (obtained in Step 4) by sum of "dead areas" in tank where an individual Flygt™ mixer can be installed for auxiliary cleaning.

6. Obtain average τ_s in tank.

7. Based on results of Phases A and B tests, multiply τ_s by 0.05 (i.e., 5%) to obtain the τ_c that will lead to mobilization of 80% of the sludge in the tank. (In this methodology, τ_c also equals the average wall shear stress.)

8. Select a propeller mixer.

9. Divide the thrust of the selected mixer by the τ_c determined in Step 7 to obtain the coverage area of the mixer.

10. Assume the shape of a coverage area produced by a stationary mixer can be compared to an ellipse. Convert the coverage area calculated in Step 9 into a half-ellipse.

11. Assume the ellipse has a longer radius 1.4 times greater than the smaller radius and solve the mathematical equation for an ellipse for the long radius. This is the predicted sweeping radius of the mixer.

12. Calculate the area of a circle with radius from Step 11. This is the supplementary floor area cleaned by the Flygt™ mixer. (It is assumed the mixer can rotate to cover 360°.)

13. Compare the answer from Step 12 (the floor area cleaned by the mixer) to Step 5 (the "dead area" needing mobilization by an individual mixer). If the number from Step 12 is greater than the number from Step 5 then the entire "dead area" is predicted to be mobilized.

Using the vendor's methodology above, Table 7-1 shows the predicted cleaning radii of mixer model configurations as a function of sludge shear strength and critical shear stress to induce mobilization. Sensitivity of the predicted cleaning radii to the key parameters of τ_s and τ_c is discussed further in Section 8.0.

Table 7-1. Cleaning Radii of Flygt™ Mixer Configurations Using Vendor Prediction Methodology (Unsubstantiated, Do Not Use).

	Flygt™ Mixer Model					
	4640	**4660**	**4660**	**4680**	**4680**	**SRS-modified 4680**
Horsepower	4	15	15	40	40	50
Configuration	Jet ring	Without jet ring	Jet ring	Without jet ring	Jet ring	Extended shroud
Propeller diameter (in.)	14-7/16	22-13/16	22-13/16	30-1/8	30-1/8	20
Riser size required (in.)	20	24	34	34	42	24
Thrust (Newtons)	900	1400	3000	5500	7000	6000
For τ_s = 1000 Pa and $\tau_c = 0.05\tau_s$ – Predicted cleaning radius using vendor methodology (ft)	19	23	34	46	52	48
For τ_s = 3000 Pa and $\tau_c = 0.05\tau_s$ – Predicted cleaning radius using vendor methodology (ft)	13	16	24	33	37	34
For τ_s = 3000 Pa and $\tau_c = 0.15\tau_s$ – Predicted cleaning radius using vendor methodology (ft)	6	8	11	15	17	16

SRS = Savannah River Site.

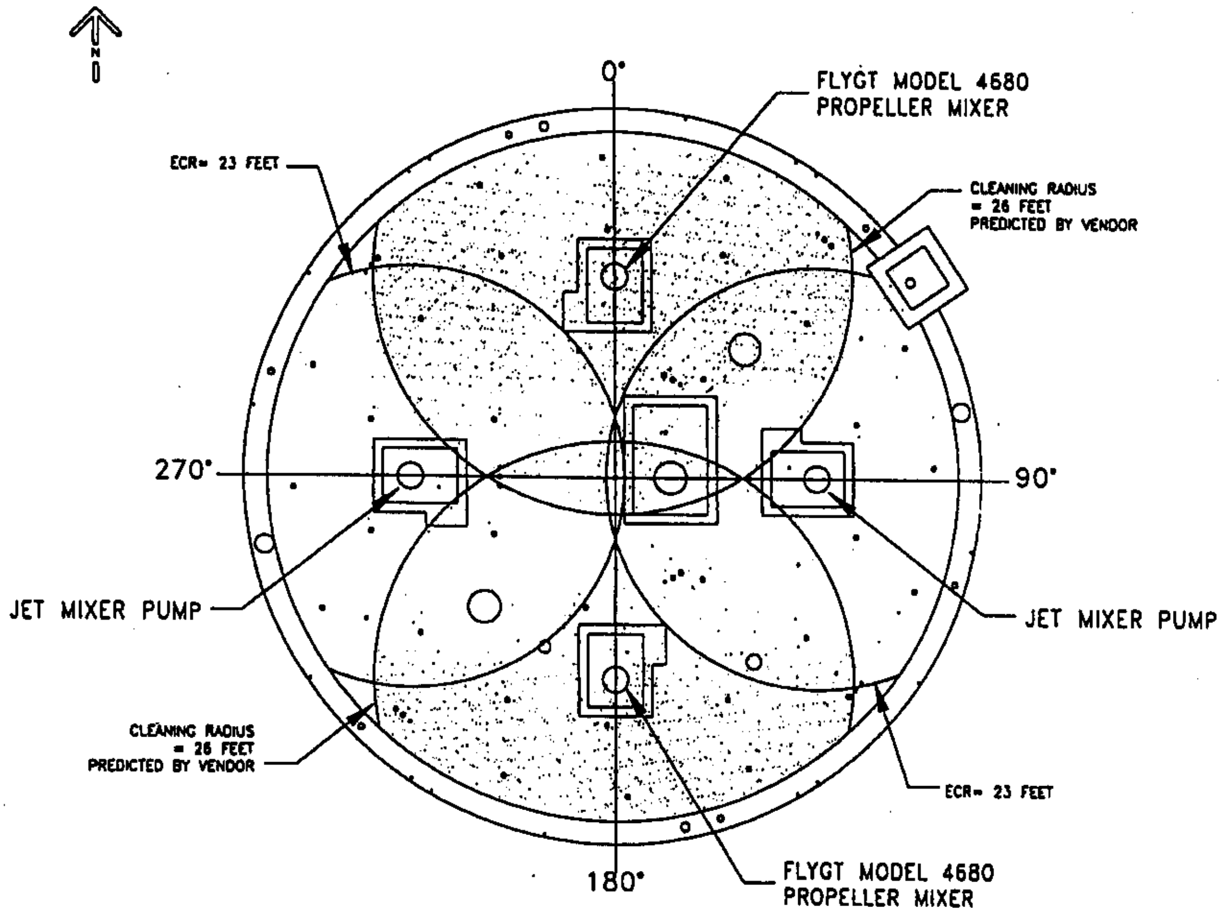
7.2 MOBILIZATION EFFECTIVENESS PREDICTION FOR TANK 241-AY-102

Transmittal letter T0406DD.doc included in Appendix C presents Flygt™'s proposed mixer selection, configuration, performance prediction methodology, and predicted mobilization results for Tank 241-AY-102. Their recommendation is to deploy two 40-hp, 14° blade angle, Model 4680 propeller mixers without jet ring in Risers 1B and 1D. Flygt™ predicts a cleaning radius of 26 ft for each mixer. This is presented graphically in Figure 7-1. The presence of airlift circulators within the tank was neglected for this prediction. Model selection was influenced by having only 34-in.-diameter risers available in Tank 241-AY-102, resulting in selection of an unshrouded mixer unit (with less thrust output) than if a 42-in. riser were available. It is very interesting to note that Flygt™ predicts their mixer to have a greater cleaning radius (26 ft) than the retrieval baseline jet mixer pump (ECR = 23 ft [Crawford 1999]). Flygt™ stated in verbal discussion their feeling was the accuracy was "high," but was unable to quantify the uncertainty present in the prediction. Section 8.0 contains an assessment of the prediction.

7.3 MOBILIZATION EFFECTIVENESS PREDICTION FOR TANK 241-SY-102

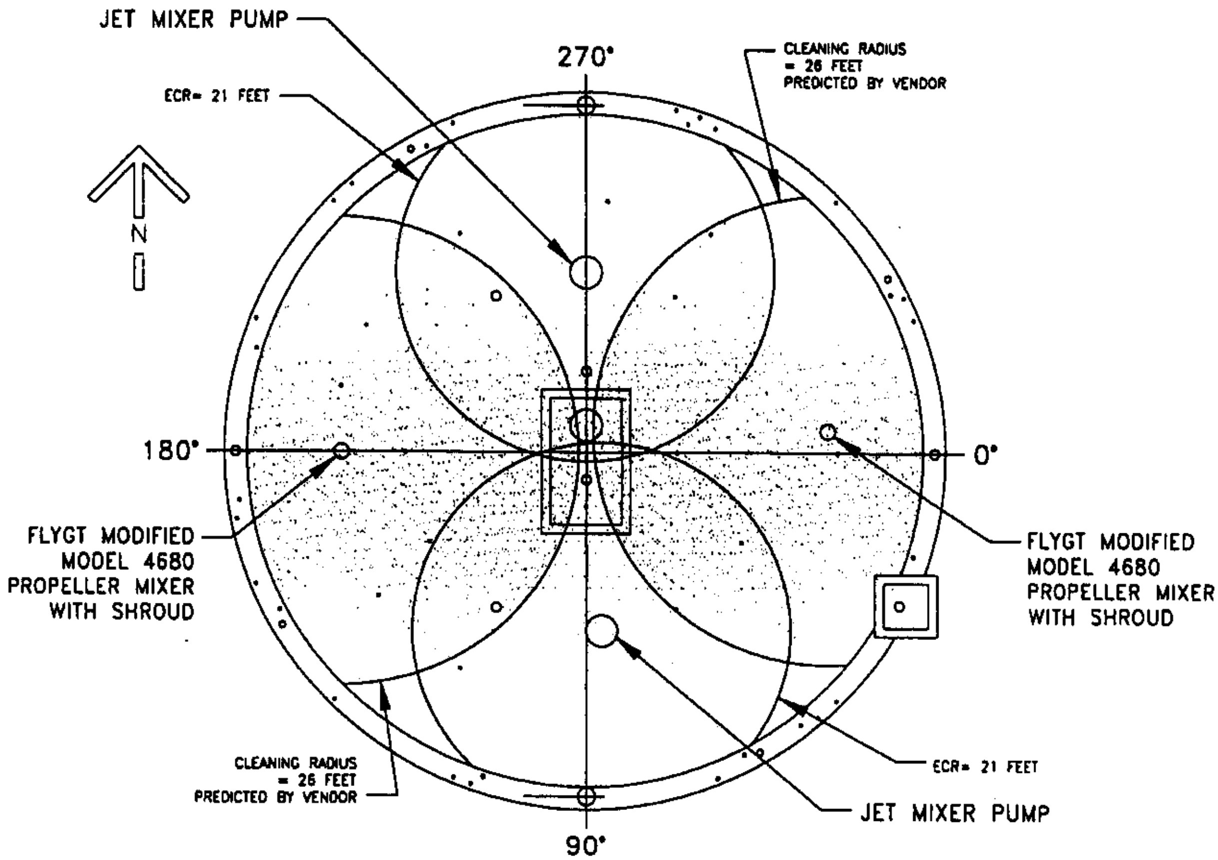
Transmittal letter T0520GL.doc included in Appendix C presents Flygt™'s proposed mixer selection, configuration, and predicted mobilization results for Tank 241-SY-102. Flygt™ presents three options for this tank. The selected option is to deploy two 50-hp, SRS-modified Model 4680 propeller mixers with extended shroud in Risers-024 and -025. Flygt™ predicts a cleaning radius of 26 ft for each mixer. This is presented graphically in Figure 7-2. Model selection was greatly influenced by having only 20-in.-diameter risers available in Tank 241-SY-102 (and then only by bringing two subsurface construction risers up to grade). The propeller of the SRS-modified mixer must be trimmed from 20 in. to 19 in. to fit through the riser. It is very interesting to note that Flygt™ predicts its mixer to have a greater cleaning radius (26 ft) than the retrieval baseline jet mixer pump (ECR = 21 ft [Crawford 1999]). Flygt™ stated in verbal discussion its feeling was the accuracy was "high," but was unable to quantify the uncertainty present in the prediction. See Section 8.0 for assessment of the prediction.

Figure 7-1. Summary of Flygt™ Recommendations and Performance Prediction for Tank 241-AY-102.



SELECTED MIXER(S): MODEL 4680 (14') SF (WITHOUT JET RING)
NUMBER OF MIXER(S): 2
RISER(S) UTILIZED: 1B AND 1D, 34" DIAMETER
WASTE AVERAGE SHEAR STRENGTH: 3060 PA
PREDICTED CLEANING RADIUS OF MIXER: 26 FEET
MIXER DATA: POWER: 40 HP PROPELLER SPEED: 440 RPM BLADE DIAMETER: 30 1/8" BLADE ANGLE: 14° FLOW RATE: 27,090 GPM THRUST: 5480 N

Figure 7-2. Summary of Flygt™ Recommendations and Performance Prediction for Tank 241-SY-102.



SELECTED MIXER(S): MODIFIED MODEL 4680 WITH SHROUD
NUMBER OF MIXER(S): 2
RISER(S) UTILIZED: -024 AND -025, 20" DIAMETER
WASTE AVERAGE SHEAR STRENGTH: 3880 PA
PREDICTED CLEANING RADIUS OF MIXER: 26 FEET (7.97 M)
MIXER DATA: POWER: 50 HP PROPELLER SPEED: 880 RPM BLADE DIAMETER: 19" BLADE ANGLE: UNKNOWN FLOW RATE: UNKNOWN GPM THRUST: 6917 N

7.4 ISSUES IDENTIFIED BY ITT FLYGT CORPORATION

Issues identified by the vendor requiring further consideration are summarized below. See Appendix C for additional detail.

- **Riser size and availability** – Section 9.1 contains further discussion.
- **Motor loads** - Motor loading of the Flygt™ mixers is expected to be 85% or greater as a result of maximizing thrust to provide greatest mobilization capability (i.e., cleaning radius) possible. Any combination of high-fluid density (specific gravity ≥1.2), viscosity (>100 cP), and temperature (>100 °F) necessitates reducing the mixer's operating shaft speed to lower load on the motor. Flygt™ recommends the use of a variable frequency drive for this purpose. Flygt™ predicts that reduction of operating speed will be offset by the increased density of the waste, resulting in no net loss in thrust.
- **Vertical placement and startup of mixer in tank** – In response to the question: "*How can the mixer reach the bottom and start operating in a horizontal position if there is a deep layer of sludge*?" The recommendation of Flygt™ is "*the mixer cannot be buried in sludge at the beginning, it must be vertically positioned to mobilize sludge layer after layer.*"
- **Deployment mast** – A powerful mixer such as the 40-hp unit requires a strong and stable mounting system to operate properly and maximize longevity. This should be the goal of the deployment mast development.
- **Vortex suppression** – The mixers need to be protected against vortexes via adequate submergence or by providing an antivortex suppressor when long-term mixer operation is expected using a mixer that is not completely submerged.
- **Operation in conjunction with jet mixer pumps** – Flygt™ recommended further evaluation of operation of their propeller mixer concurrently with jet mixer pumps.

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8.0 ASSESSMENT OF ITT FLYGT CORPORATION MOBILIZATION EFFECTIVENESS PREDICTION

In addition to the author's own evaluation, three independent evaluations of Flygt™ mobilization effectiveness prediction were performed. These evaluations were performed by knowledgeable individuals in the fields of fluid dynamics and pumps and are included in Appendix D.

The mutual consensus of the evaluations, discussed below in this section, is that the existing experimental data are too limited to accurately predict Flygt™ mixer performance in a full-sized Hanford Site waste tank. Regarding the Flygt™ Corp. prediction methodology, the evaluators' consensus is it contains a high degree of uncertainty based on its extrapolation of the small-scale mixer testing performed to date to mixer performance in a full-sized tank. An improved methodology and further testing are necessary to accurately predict the mixer's performance as a mobilization tool.

Assessing the potential effectiveness of the Flygt™ mixer as a mobilization device, the similarity in far-field velocities (10 or more diameters from the discharge) produced by a propeller mixer in water when compared to an idealized jet nozzle suggests a Flygt™ mixer could have a cleaning radius comparative to a jet mixer pump. On this basis, it is considered likely that a Flygt™ mixer in an optimum configuration is capable of providing the minimum mobilization efficiency (i.e., minimum ECR of 3 m (9.8 ft)) stated in Tedeschi (2000).

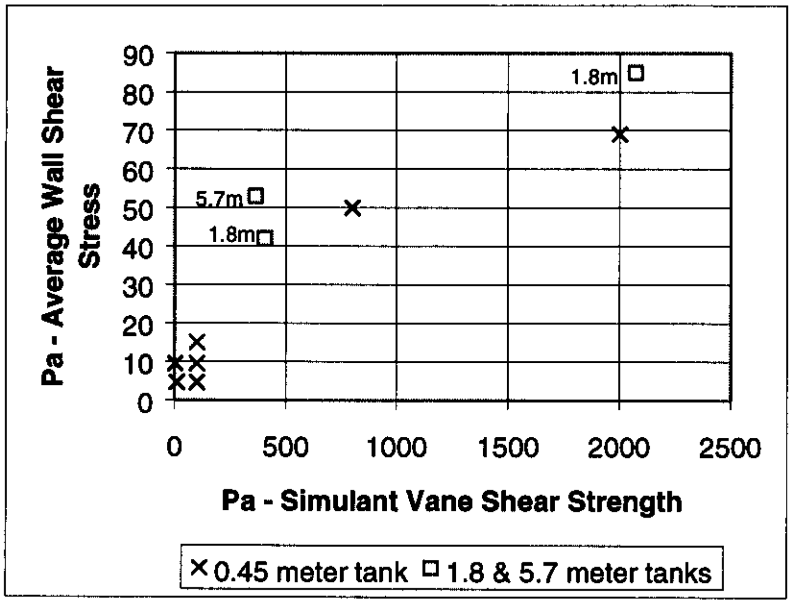
The assessment of Flygt™ performance prediction methodology and Flygt™ mixer performance is categorized below as follows:

- Validity versus scaling relationships and existing experimental data
- Evaluation of assumptions in Flygt™ performance prediction methodology
- Sensitivity of the methodology and mixer performance to changes in waste properties
- Comparison of propeller mixer far-field (downstream) velocities to that of an idealized jet.

Appendix D should be consulted for the individual evaluations and for additional detail.

Validity versus Scaling Relationships and Existing Experimental Data. The Flygt™ prediction methodology is based on the results of the Phases A and B testing. As seen in Figure 8-1, these tests produced a very limited number of data points (seven of the data points were collected in the 1.5-ft tank, two points were measured in the 6-ft tank, and one point was measured in the 18.7-ft tank), and the data points collected using similar sludge shear strengths in different sized tanks varied by as much as 20%. The tests used simulants with a shear strength that is two-thirds of the minimum 3.38 kPa shear strength stated in the requirements document. This small data set does not contribute to a high level of confidence in the ability to extrapolate mixer performance in a full-sized tank.

Figure 8-1. Average Wall Shear Stress vs. Shear Strength.



A major limitation of the Phase A and Phase B mobilization tests is that they were not were geometrically, kinematically, and/or dynamically similar to a full-size waste tank or to each other. In addition to making data comparison difficult, the lack of geometric similarity (i.e., diameter of propeller relative to diameter of a waste tank) combined with the relative closeness of the mixer to the wall in the majority of the tests (<10 propeller diameters, such that a fully developed jet can not exist) indicates Flygt™'s prediction methodology may not address the same mixing phenomena that will occur in the Hanford Site tanks. The mobilization occurring during those tests is probably a result of secondary flow back to the mixer.

Evaluation of Assumptions in Flygt™ Performance Prediction Methodology. The following assumptions made in the Flygt™ prediction methodology unsuccessfully tie the Phases A and B test results to an ECR such as has been determined through jet mixer nozzle testing.

1. Assumption of wall height for the wetted area calculation as 4 ft. Considering the diffusion angle of the propeller discharge jet, the wetted wall height under influence of the jet is greater than 4 ft. More difficult to assess, and a larger source of uncertainty, is how much wetted area should be considered in the calculation. The Flygt™ prediction method gives no boundary to the magnitude of circumference or height that should be used when scaled up to large tanks. (What wetted area should be used if the mixer is deployed in an extremely large tank where the jet cannot reach the wall?)

2. The assumption that the average wall shear stress to induce 80% mobilization of solids in a tank, based on testing of a stationary Flygt™ mixer in a small tank, can be *accurately* related to the cleaning radius of a rotating mixer located at an indeterminate height in a much larger tank, via assumption of a subjective elliptical coverage area, appears to be a large one.

Sensitivity of the Flygt™ Performance Prediction Methodology to Changes in Waste Properties. Sensitivity analysis of predicted cleaning radii to the key parameters of τ_c and average τ_s, as shown in Table 8-1, indicates a great variance in predicted cleaning radii. Based on the current state of knowledge, where neither τ_s and τ_c are known with a great degree of accuracy, it is not reasonable to expect any methodology using these parameters to provide any better accuracy. For example, for a Model 4680 mixer without jet ring for τ_s =3000 Pa and τ_c = 0.05, the predicted cleaning radius is 33 ft, while for τ_s =3000 Pa and τ_c = 0.15, the predicted cleaning radius is 15 ft.

Comparison of Far-Field Velocities to those of a Jet Mixer Nozzle. The similarity in far-field velocities (10 or more diameters from the discharge) produced in water by a propeller mixer to those of a jet mixer suggests the propeller mixer could potentially have similar mobilization capabilities. The Phase C testing and more recent testing performed by SRS (Adkins 2000) have measured the near-field and far-field velocities produced by the modified Model 4680 mixer in water. These velocities range from 12 to 16 ft/s at the propeller discharge to 2.5 to 4.5 ft/s at a distance of 25 ft.

Analytical methods permit the calculation of submerged jet velocities at distances from the source nozzle. These calculated velocities represent idealized conditions, but they can be used as a basis for performance comparisons between types of equipment. Equation 2 (Blevins 1984) is used to calculate the jet stream centerline velocities at distances from the nozzle.

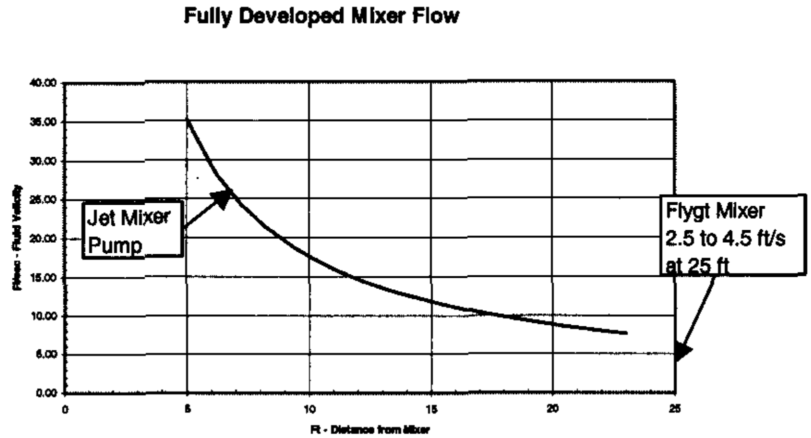
$$V_x = \frac{12\times(\text{Nozzle Exit Velocity})\times(\text{Nozzle Radius})}{\text{Distance From Nozzle}} \qquad (2)$$

where: Vx = velocity at distance x from nozzle.

Figure 8-2 is a plot of the calculated submerged jet centerline velocities produced by a mixer pump nozzle and measured values from a Flygt™ mixer at distances from the jet source. The plot represents a mixer pump with a 0.5-ft diameter nozzle and a 5,482-gal/min flow rate. These specifications match those of a single nozzle in the 300-hp dual nozzle pump installed in Tank 241-AZ-101. The Flygt™ mixer velocities represent a modified Model 4680 mixer with a 20-in.-diameter propeller and a 17,500-gal/min flow rate. Equation 2 provides values for the fully developed flow region; this is the only region plotted on Figure 8-2.

The velocities produced at far-field locations in water by the SRS-modified Flygt™ mixer are moderately less than those created by an idealized jet mixer pump nozzle at the waste tank's outer reaches. As discussed previously, predicted tank retrieval efficiencies from the empirical ECR equation for jet mixer pumps vary from 12 to 42 ft (Crawford 1999). The ECR equation is not directly applicable to the propeller mixer for several reasons (different centerline height above tank floor, swirl component of propeller discharge, etc.); however, the degree by which the jet mixer pump exceeds the minimum required cleaning radius (9.8 ft) of an auxiliary mobilization device, as compared to the small difference in far-field velocities produced by each device in water, suggests the propeller mixer has a good probability of meeting the minimum cleaning radius requirement.

Figure 8-2. Centerline Mixer Flow Velocities.



8.1 ELEMENTS FOR FUTURE DEVELOPMENT WORK

To more accurately assess the performance of the submersible propeller mixer as a mobilization device, the following activities are recommended:

- Mobilization tests scaled to the Hanford Site waste tank should be performed with higher shear strength simulants than were used in Phase B testing to validate key mixing parameters in this range. For example, testing thus far on lower shear strength simulants indicate the average wall shear stress τ_0 required to mobilize about 80% of the sludge in a tank is on the order of 5% of the sludge shear strength; however, Phase B tests suggest this value may be as large as 15% in larger tanks. Previous mobilization tests have focused on granular material with negligible cohesive strength. Additional tests should use materials that represent a wider range of waste characteristics since much of Hanford waste is composed of concentrated colloidal suspensions displaying high shear strengths.

- Scaled tests comparing the mobilization performance of submersible propeller mixers to that of the jet mixer nozzles should be performed. These tests should be designed using the principles of similarity and should focus on the geometry and conditions existing within the Hanford Site waste tanks. A similarity analysis will identify comparable parameters. Through these tests the dimensionless parameters describing the mobilization process can be identified and used to develop correlations for predicting performance.

- Mobilization tests involving multiple propeller mixers in a tank should be performed to quantify the additive effects of bulk flow on sludge erosion via orientation of the mixers. Testing performed to date in this area has focused on mixing and transport of low shear strength solids for SRS Tank 19 application.

9.0 ASSESSMENT OF ITT FLYGT CORPORATION PROPELLER MIXER VERSUS DERIVED FUNCTIONS AND REQUIREMENTS

Table 9-1 summarizes the assessment of the Flygt™ mixer versus each derived function and requirement for auxiliary solids mobilization presented in Tedeschi (2000) (see Appendix B.) The assessment is qualitative in nature. The main goal of this table is to assess whether the submersible propeller mixer device is acceptable, or can be made acceptable, for deployment and operation in the applicable waste tanks. The following scoring system was used:

1. – Meets criteria
2. – Could meet criteria with minor adaptation
3. – Could meet criteria with substantial adaptation
4. – Does not meet criteria
5. – Insufficient information available to fully assess.

The results of this assessment show that the Flygt™ mixer and its conceptual deployment hardware meet the vast majority of functions and requirements, or are capable of meeting them with minor adaptation. The major limitation for the auxiliary mobilization application is the lack of available large risers. This issue, along with additional assessment of several of the criteria is included in other sections of this report as noted.

9.1 TANK PHYSICAL CONSTRAINTS – RISER DIAMETER, LOCATION, AND AVAILABILITY

Key questions for application of the Flygt™ mixer are: *What are the size, location, and availability of risers in the DSTs needing auxiliary solids mobilization? Are risers of sufficient size available in the right locations?*

Size - How small can the propeller mixer equipment be and still have some usefulness in mobilizing tank solids? The riser diameter constrains the size of the propeller, which limits the fluid volume and thrust a propeller mixer can produce, reducing its mobilization performance potential. The Flygt™ Model 4600 direct-drive mixer comes in propeller diameters ranging from 8.50 in. to 30.25 in. (see Appendix A). According to the vendor, a 12-in.-diameter riser is the minimum size riser Flygt™ would attempt to deploy its equipment in.

Location - An available riser may not necessarily be a useful riser (i.e., if it is close to a riser used for primary mobilization equipment).

Table 9-1. Assessment of Flygt™ Propeller Mixer versus Derived Functions and Requirements. (3 sheets)

Function or Requirement	Value/Specification Range	Assessment Score[a]	Comments
Process Specifications			
Effective cleaning radius	3 m to 6 m (9.8 ft to 19.8 ft) Minimum performance criteria = 3 m, in sludge with shear strengths to 3.38 kPa	1	See Section 8.0 for detailed assessment.
Waste pH	Caustic, 12 to +14	1	Materials of construction are acceptable for pH range shown.
Radioactive dose	Peak dose rate = 10 to 1100 rd /h Total integrated dose = 3.6 E05 to 9.5 E07 rd	5	See Section 9.2 for detailed assessment.
Waste temperature	60 to 95 °F for Tanks 241-AW-103 and 241-SY-102 60 to 190 °F for remaining tanks	1 5	See Section 9.2 for detailed assessment.
Operational Configuration Boundaries			
Discharge angle	Adjustable angles in both the vertical and horizontal plane. Best operation would allow adjustment remotely without breaking of confinement.	2	See Section 10.0 for conceptual design of deployment assembly.
Mixer height	Variable (ability to mobilize waste on bottom and at increments 15 to 20 ft above bottom tank elevation)	2	See Section 10.0 for conceptual design of deployment assembly.
Installation Constraints			
Riser installation, width for pump, and related assembly/mast	Available nominal riser sizes: 4 in. diameter	4	See Section 9.1 for detailed assessment.
	6 in.	4	See Section 9.1 for detailed assessment.
	12 in.	3	See Section 9.1 for detailed assessment.
	42 in.	1	See Section 9.1 for detailed assessment.
Utilities availability	240/480 V ac Flush water through tanker or existing piping No instrument or compressed air	1	No water source or compressed air required to operate mixer.
Natural phenomena design	None	1	Detailed design should be capable of meeting. Weight of propeller mixer less than that of mixer pump

Table 9-1. Assessment of Flygt™ Propeller Mixer versus Derived Functions and Requirements. (3 sheets)

Function or Requirement	Value/Specification Range	Assessment Score[a]	Comments
Ventilation system impacts	<50 ft^3/min additional load	1/5	No additional air volume load on vent system. Impact of gas released from waste resulting from mixing action needs evaluation
Delivered horizontal displacement on vertical protuberances (e.g., thermocouple probes) in cleaning radius	Maximum 1 in, at tank bottom elevation	5	Calculations for specific tanks and waste protuberances will need to be made on a case-by-case basis. This requirement is a challenge to any slurry flow type mobilization technology.
Material of construction	Wetted materials shall maintain 5-yr life expectancy within waste conditions; minimum 304 stainless steel on all wetted parts	1	No incompatible materials were identified.
Pit confinement	Installation on potential risers within pits shall not intrude upon piping, and shall allow for reinstallation of all existing pit covers	1	Detailed design should be capable of meeting. Existing mixer pump oscillation systems and transfer pump winch systems meet criteria.
Safety Requirements			
Lift criteria	Installation/removal will be per critical lift requirements of the *Hanford Site Hoisting and Rigging Manual*[b]	1	Detailed design should be capable of meeting.
Electrical systems within tank vapor space, and pits	Meets NFPA 70, Class 1, Div. 1, Group B, design criteria[c] shall be reviewed by independent buyer expert group	2	See Section 9.3 for detailed assessment.
Electrical systems within submerged waste streams	Meets NFPA 70, Class 1, Div. 1, Group B, design criteria[c] or be demonstrated by process that submerged system provides no spark to tank vapor space	2	See Section 9.3 for detailed assessment.
Weight	Free supporting mast and pump assembly must meet allowable limits in addition to mixer pumps and retrieval pumps OR may be designed to rest on tank bottom, fully supported by floor	5	Entire assembly expected to weigh approximately 7,000 lb, not much more than a 42-in. riser shield plug (5,500 lb). Dome loading calculations for specific tanks will need to be made on a case-by-case basis.

Table 9-1. Assessment of Flygt™ Propeller Mixer versus Derived Functions and Requirements. (3 sheets)

Function or Requirement	Value/Specification Range	Assessment Score[a]	Comments
Control system	Capable of being interlocked or remotely shut down upon indication of high waste temperature or tank ventilation shutdown	1	Detailed design should be capable of meeting.
Heat input	Maximum sludge/waste temperature rise of 10 °F during continuous equipment operation and following 12 h	1	Heat input not expected to pose significant concern (50 hp or less). Heat input to tank significantly less than baseline jet mixer pump.
Operation, Maintenance, and Radiological Control Constraints			
Location of control mechanisms	Localized control at tank farm within tank farm control room (greater than 100 m away from tank)	1	Detailed design should be capable of meeting.
Location of electrical components requiring calibration	Not located within pits or shielded areas	1	No electrical components within pits or shielded areas should need calibration.
Riser seal	Shall maintain existing confinement; riser seal shall be gasketed. Rotating seals shall be liquid-sealed with drain back to the tank	1	Detailed design should be capable of meeting.
Decontamination	Free draining, internal flushable, with internal void areas for material trapping filled with compatible solids (e.g., foam)	1	Propeller/shroud is free draining. A mechanical seal between waste and oil chamber, and another between oil chamber and motor, prevent waste ingress to motor.
Shielding	System shall be provided with shielding for protection of workers during installation and removal for disposal	1	Detailed design should be capable of meeting.

[a]Assessment Score Key:
1 – Meets criteria
2 – Could meet criteria with minor adaptation
3 – Could meet criteria with substantial adaption
4 – Does not meet criteria
5 – Insufficient information available to properly assess.

[b] DOE/RL-92-36, 1993, *Hanford Site Hoisting and Rigging Manual,* U.S. Department of Energy, Richland Operations Office, Richland, Washington.

[c] NFPA 70, 1999, *National Electric Code*, Class 1, Div. 1, Group B, National Fire Protection Association, Quincy, Massachusetts.

Availability – A survey of the risers in candidate DSTs (called out in Tedeschi [2000]) was performed to determine which large-size risers house equipment necessary to the operation of the tank (such as ventilation system risers) and which risers are earmarked for primary solids mobilization. The remaining risers are then the "available" risers. Equipment such as camera systems and temperature probes located in 42-in. risers are assumed to be relocatable to accommodate auxiliary mixing devices. The following resources used for the survey: dome penetration schedules on H-14 drawings (essential drawings under configuration control); HNF-1507 (Rieck 1998) which gives projected riser use for Project W-211 mixer pumps; discussion with Project W-211 management, which identified several changes under way that may affect the riser use, and HNF-4408 (Brackenbury 1999) which identifies retrieval equipment to be installed as a part of Project W-521. Riser use for each candidate tank is presented in Appendix E. A summary of the available large risers for each candidate tank is shown in Table 9-2.

Table 9-2. Available Large Size Risers on Candidate Tanks. (2 sheets)

Tank	Avail-able Riser (#)	Dia-meter (in.)	Radius from tank center	Distance from primary mixer, centerline (ft)	Other equipment competing for riser	Comment
241-AN-104	-012	42	3 ft 0 in.	17	Camera	Central pump pit riser
241-AN-104	-013	12	9 ft 0 in.	11	Temperature probe	6 ft from riser-012
241-AY-101	-1B	34	22 ft 0 in.	31		Sluice pit B[a]
241-AY-101	-1D	34	22 ft 0 in.	31		Sluice pit D[a]
241-AY-101	-22	16	20 ft 0 in.	24		Spare
241-AY-101	-24	42	20 ft 0 in.	16	Camera	
241-AY-102	-1	34	22 ft 0 in.	31		Sluice pit B[a]
241-AY-102	-1	34	22 ft 0 in.	31		Sluice pit D[a]
241-AY-102	-22	16	20 ft 0 in.	24		Spare
241-AY-102	-24	42	20 ft 0 in.	16	Camera	
241-AW-103	-012	42	3 ft 0 in.	17		Central pump pit riser
241-AW-103	-013	12	9 ft 0 in.	11	Observation port	6 ft from riser-012
241-AW-104	-007	42	20 ft 0 in.	[b]	[b]	
241-AW-104	-007	42	20 ft 0 in.	[b]	[b]	

Table 9-2. Available Large Size Risers on Candidate Tanks. (2 sheets)

Tank	Avail-able Riser (#)	Dia-meter (in.)	Radius from tank center	Distance from primary mixer, centerline (ft)	Other equipment competing for riser	Comment
241-AW-104	-012	42	3 ft 0 in.	17		Central pump pit riser
241-AW-104	-013	12	9 ft 0 in.	11	Observation port	6 ft from riser-012
241-AZ-101	-1B	42	22 ft 0 in.	31		Sluice pit B
241-AZ-101	-1D	42	22 ft 0 in.	31		Sluice pit D
241-AZ-102	-1B	42	22 ft 0 in.	31		Sluice pit B
241-AZ-102	-1D	42	22 ft 0 in.	31		Sluice pit D
241-C-104	(c)			c	c	
241-C-107	(d)			d	d	
241-SY-102	-013	42	3 ft 0 in.	17	Camera	Central pump pit riser
241-SY-102	-014	12	9 ft 0 in.	11	Observation port	6 ft from riser-013
241-SY-102	-023	12	30 ft 0 in.	11		S Evaporator feed pump pit
241-SY-102	-024	20	27 ft 0 in.	34	e	e
241-SY-102	-025	20	27 ft 0 in.	34	e	e

[a] Project baseline is expected to be revised from four 150-hp primary mixer pumps to two 300-hp primary mixer pumps. If this does not occur, then this riser is not available.

[b] Neither Project W-211 nor W-521 baseline planning installs primary mixer pumps in Tank 241-AW-104. The outboard 42-in. risers are currently shown as available.

[c] Neither Project W-211 nor W-521 baseline planning installs primary mixer pumps in Tank 241-C-104. This is a single-shell tank, and there is significant uncertainty where the primary mixer pump(s) might be placed.

[d] Neither Project W-211 nor W-521 baseline planning installs primary mixer pumps in Tank 241-C-107. This is a single-shell tank, and there is significant uncertainty where the primary mixer pump(s) might be placed. This tank has no riser greater than 12-in. in diameter, and is very riser-limited.

[e] This is a construction riser that is currently capped below grade. Modification is required to make this a useful riser.

Overall riser availability is summarized for each candidate tank in Table 9-3. A qualitative judgement has been made regarding the usefulness of each large riser for auxiliary solids mobilization based on the available riser's location on the tank and its distance from the primary mobilization mixer pumps. When reviewing this table it is important to note the assumptions made in Table 9-3 for Tanks 241-AY-101, 241-AY-102, 241-AW-104, and 241-SY-102. Each of these tanks could go from two or more available risers to one or zero available with a simple change of assumption.

Table 9-3. Summary of Candidate Tank Large Riser Availability.

Tank	Number of Large Risers Available in Locations Likely to be Unmobilized "Dead" Areas
241-AY-101, 241-AY-102, 241-AZ-101, 241-AZ-102, 241-SY-102	2 or more
None	1
241-AN-104, 241-AW-103	0
241-AW-104, 241-C-104	Unknown
241-C-107	Unknown, but appears to be zero

Tanks 241-AW-104, 241-C-104, and 241-C-107 are listed as unknown because the installation and location of primary mixers within this tank are not defined at this time. Based on their assessment, only five out of the ten Phase 1 HLW feed tanks lend themselves to auxiliary mobilization with Flygt™ mixers.

9.2 MOTOR TEMPERATURE AND RADIATION RESISTANCE

The long-term functionality of the Flygt™ motor under high temperatures (>100 °F) and high radiation dose (peak dose to 1,100 Rd/h) is unknown and deserves further evaluation. The Flygt™ submersible mixer has very limited operating experience in a highly radioactive environment, consisting of the ORNL experience described earlier in the report. Hanford Site tank farms have used a limited number of Flygt™ Model B-2060 submersible centrifugal pumps in waste tanks in the past, resulting in below average longevity (Leshikar 1998) for reasons unknown. The B-2060 pumps used were site-modified from a horizontal discharge to vertical discharge configuration. The Model 4600 series motor and B-2060 motor are of very similar design. The longevity of Model B -2060 pumps installed in low-solids, low-radiation environments on site (such as in catch tanks) has been very good. The only other submersible motor pump design operated at tank farms, the 241-SY-101 mixer pump, currently has an operating longevity of 7 yr.

The radiation resistance and operating temperature capability of the vendor's off-the-shelf equipment are issues that can likely be overcome by design modifications, if necessary. These issues should not impede consideration of the submersible propeller mixer technology.

9.3 FLAMMABLE GAS SAFETY REQUIREMENTS

According to the vendor information presented in Appendix A, the submersible Flygt™ mixer comes in both a standard version and an explosion-proof version. Both versions are CSA-approved to Underwriters Laboratory Standard 778 (UL 778). The explosion-proof version is additionally designed for use in explosive environments in accordance with the following approvals:

EN	European Norm	Eex d IIB T4
FM	Factory Mutual	Class I Div 1 Group C and D
		Class II Div 1 Group E, F, and G
		Class III Div 1

The RPP authorization basis manages potential ignition sources that can initiate a fire or flammable gas deflagration through Administrative Control (AC) 5.10 of the *Tank Waste Remediation System Technical Safety Requirements* (Jones 2000). The region classification applicable to the mixer equipment is WASTE INTRUSIVE. Ignition Source Control Set (ISCS) #1 defined in AC 5.10 lists the flammable gas ignition control requirements for WASTE INTRUSIVE equipment. One particular requirement of ISCS 1 is:

> Electrical equipment shall be designed to meet NFPA 70, Class I, Division I, Group B criteria or provide equivalent safety. As a minimum, this shall be interpreted to mean that no single point failure of energized equipment can result in an arc, spark, or gas burn propagation to the environment external to the source enclosure (NFPA 70). In the case of WASTE-submerged equipment containing potential ignition sources, demonstration by design that the equipment is nonsparking under normal operation and is designed to be isolated from the WASTE environment is an acceptable alternative.

A Flammable Gas Equipment Advisory Board (FGEAB) exists to evaluate potential deviations from the ISCSs. Recently a Flygt™ Model BS-2060 electric submersible pump was brought before the FGEAB. FGEAB provided ruling FGEAB-00-002, Rev. 1, (Schlosser 2000) for the application of pumping the annulus of the DSTs under a condition of primary to secondary leak. The FGEAB approved the BS-2060 for the DST annulus application subject to the conditions listed in Schlosser (2000). The BS-2060 is CSA-approved to UL 778. The EX-approved version of the Model 4600 submersible propeller mixer is of similar design to the BS-2060 and has the additional explosive environment qualifications by independent testing agency listed in the earlier paragraph (albeit not to Class I, Division I, Group B criteria). A "best guess" is the Model 4600 mixer can be found suitable for ISCS 1 service subject to the conditions of the BS-2060 ruling. The following paragraph is excerpted from FGEAB-00-002, Rev. 1:

> The Flygt™ Model BS-2060 Electric Submersible Pump is fitted with seal barriers and an oil barrier fluid for shaft sealing. The motor is not normally sparking. The electrical cable enters a junction chamber and internal wiring from the junction chamber to the motor through resilient seal barriers. Therefore, a single failure of one of the seals or arcing of the motor winding is accommodated, providing equivalent safety to Ignition Source Control Set 1. The motor has a

thermal switch that must meet intrinsic safety requirements if the switch is to be used. The electrical cable feed to the junction chamber must **meet ISC1 requirements (NEC Class 1, Division 1, Group B).** The motor starter and thermal overload (if used) must be located in a nonintrusive region.

No problem is anticipated in the Flygt™ mixer meeting RPP flammable gas safety requirements.

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10.0 CONCEPTUAL DESIGN FOR A DEPLOYMENT MAST

The Flygt™ mixer as procured from the vendor consists of their standard mixer unit only. A means to suspend and orient the mixer within the waste tank is necessary. For jet mixer pumps, the deployment mast, controls, and pump itself have traditionally been procured and specified as a complete assembly. In multiple discussions with Flygt™ representatives by both Hanford Site and SRS personnel, Flygt™ has shown no inclination to design and fabricate a complete mixer assembly package. As a result, and as described in Section 5.0, SRS designed and fabricated a deployment mast for use in Tank 19.

The SRS configuration is structurally supported both above the riser and by the tank floor (on an antifriction, thrust-bearing/ball joint, assembly-mixer thrust forces are resisted by friction while the ball joint aids angular rotation). For the Hanford Site application it might not be acceptable to support in-tank equipment on the tank bottom (at minimum, this feature would receive heavy scrutiny). Also most of the tanks reviewed in this report contain a significant height of solids that could make burrowing of the equipment to the tank bottom difficult. Therefore a standard "cantilevered" design (i.e., supported at riser only) was prepared as the baseline deployment mast configuration for this report. A very attractive feature of the Flygt™ mixer with cantilevered mast design is it can be initially deployed to a relatively high position within the tank, then it can be operated in a vertical or near-vertical orientation to burrow the solids out beneath it. Subsequently the mixer elevation can be lowered and operated vertically when necessary. This is a tremendous advantage over the SRS design, and also over jet mixer pumps that have no up-and-down swivel capability.

The functions and requirements a deployment mast must meet for Hanford Site auxiliary mobilization activities are shown previously. The most critical of these functions and requirements include the capability to:

- Vary discharge angle in both the vertical (up and down) and horizontal (rotation) planes
- Vary the elevation of the mixer to start movement of lower density material before impacting on thicker sludge
- Maintain confinement of the waste environment at the riser
- Comply with structural loading criteria
- Be decontaminated relatively easy.

Figure 10-1 (see Appendix F for additional sketches) shows the conceptual design of a deployment mast for the Flygt™ mixer in a Hanford Site waste tank that appears capable of meeting the criteria. Figure 10-2 shows the SRS configuration. The conceptual, cantilevered design is substantially the same as the SRS configuration, with the following exceptions: the assembly is fully supported above the riser, a different mechanism for vertical height adjustment is used (air cylinder/slider bars versus cam roller/slots), and an I-beam mast is used versus a round pipe column (advantageous in that no seal is required).

Figure 10-1. Conceptual Adjustable Length Flygt™ Mixer Assembly.

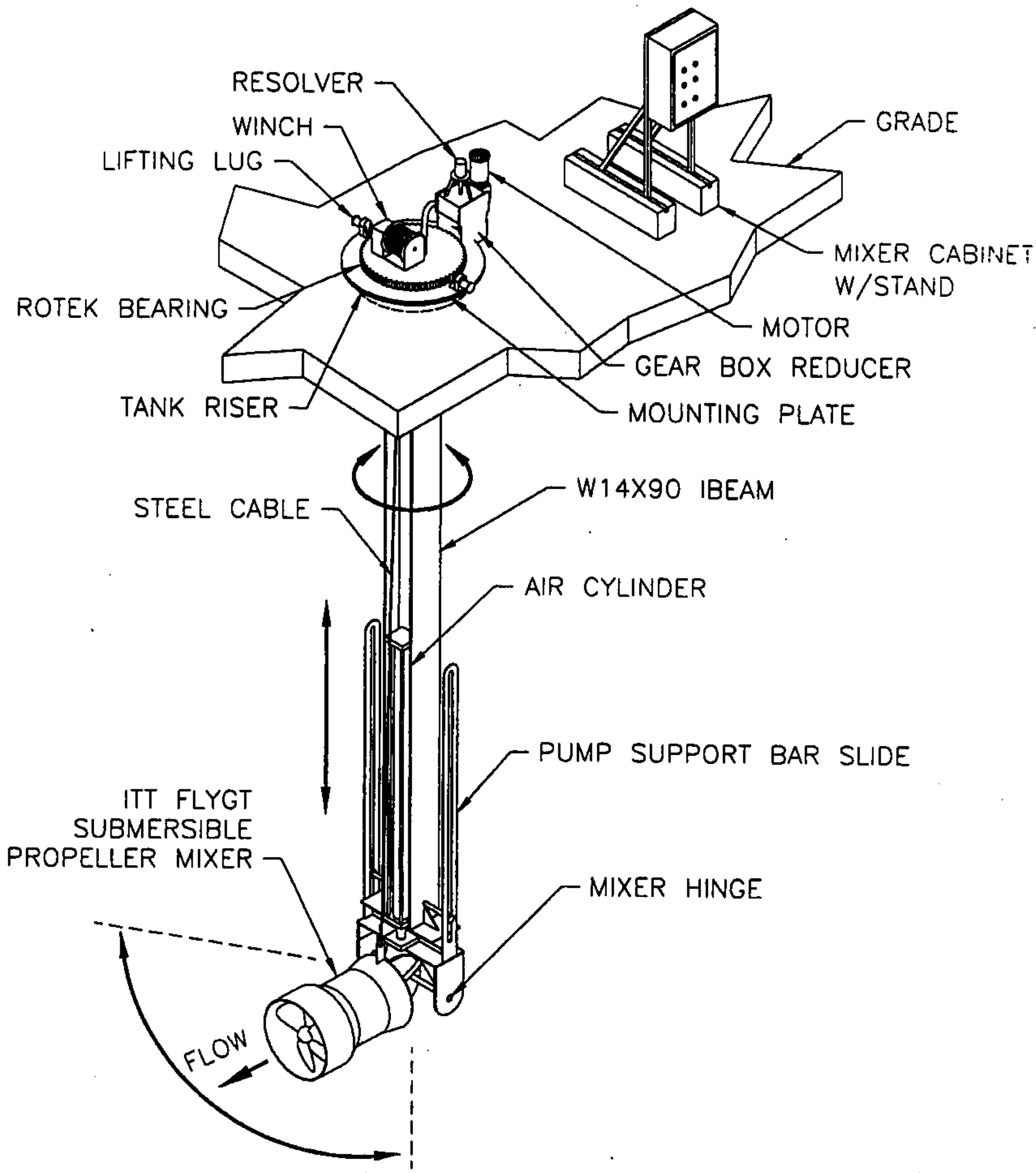
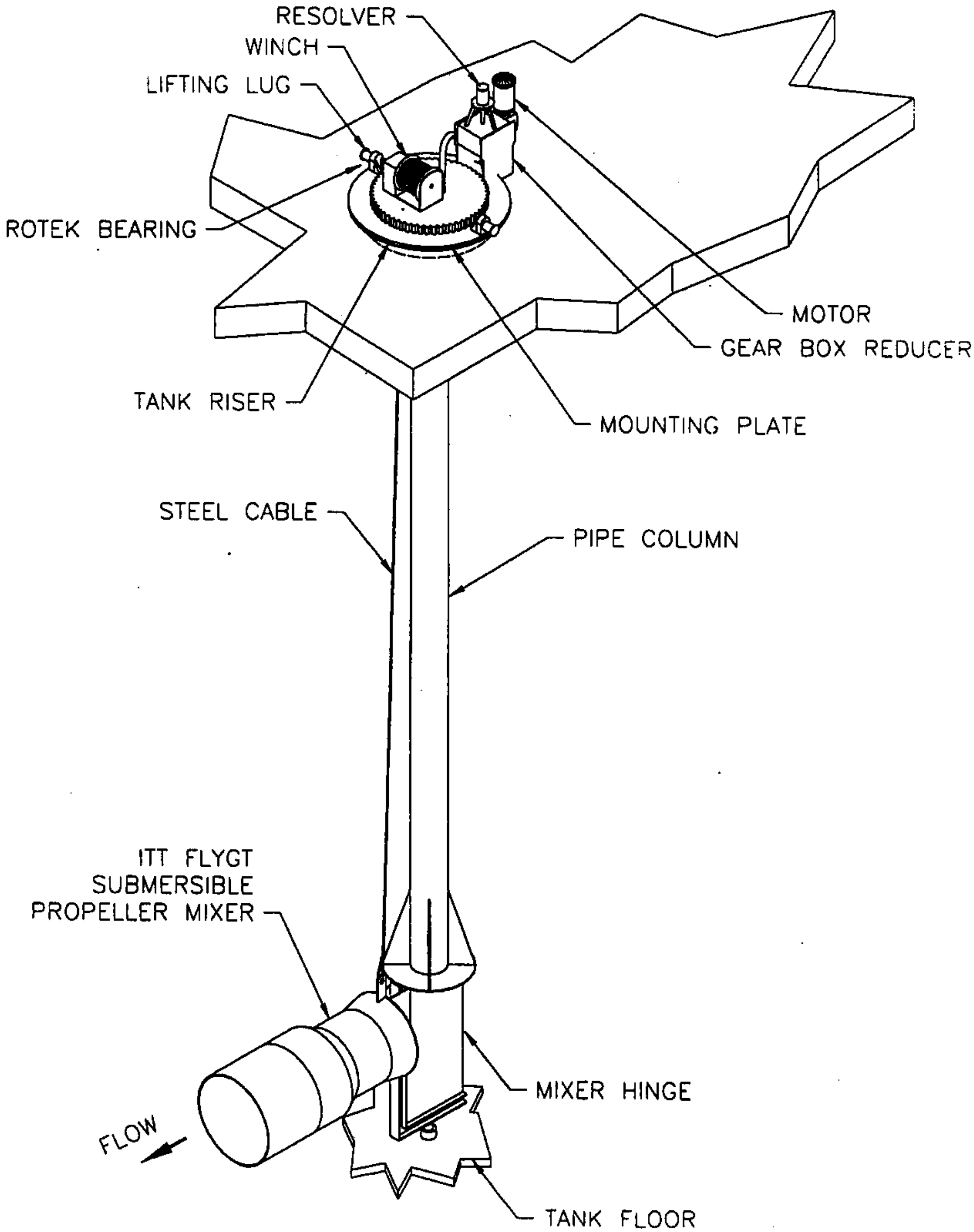


Figure 10-2. Savannah River Site Adjustable Length Bottom Supported Flygt™ Mixer Assembly.



Both configurations are installed and removed from the tank with the propeller discharge facing vertically downward. The mixer is hinged to the mast. A cable attached to a winch allows it to be pulled up to the desired discharge orientation. A Rotek[3] bearing/gearbox reducer/motor assembly provides rotation of the entire mast/mixer in the horizontal plane. The air cylinder provides up-and-down adjustment of the entire mixer unit. The power cable is routed up along the web of the I-beam through the Rotek™ bearing plate, on which the winch is also mounted. Control panels including of motor starter or variable frequency drive, Rotek™ bearing control system (angular orientation control – discrete positioning or oscillation, rotation motor), and winch control (if not manually operated) are required. A compressed air bottle/station is required to support the air cylinder height-adjustment capability.

Weight of the deployment mast and Flygt™ mixer together is expected to be about 7,000 lb (see Appendix F). The weight of the Flygt™ mixer alone is approximately 1,000 lb. Additional structural support at the riser may be required to withstand the mixer thrust force of approximately 1,500 lb. Rough calculations indicate a W 14 x 90 beam will provide adequate resistance to mixer thrust forces; significant flexibility exists to increase mast size if detailed analysis proves otherwise.

[3] Rotek is a trademark of Rotek Incorporated, Ravenna, Ohio.

11.0 ESTIMATED COST AND SCHEDULE FOR DEPLOYMENT

A ROM cost and schedule to deploy the Flygt™ mixer is presented in Table 11-1. The deployment activities cover development, design, procurement, installation, testing, and startup activities. The ROM cost estimate is included in Appendix G and includes a breakdown of all anticipated activities with contingency. Table 11-1 summarizes the estimated costs by a simplified work breakdown structure.

Table 11-1. Cost Summary to Deploy Flygt™ Mixers.

Activity	Cost, $
Project Management	1,000,000
Engineering	1,800,000
Development	1,700,000
Procurement	260,000
Construction	2,100,000
Startup/Testing	2,000,000
Total	8,900,000

Total overall cost for **initial** deployment of two Flygt™ mixers in a DST is estimated to be $8,900,000. The cost for follow-on units is expected to be less than simply subtracting development cost and design costs from overall cost. Costs across the board should be lower after the experience gained from initial deployment (engineering, testing, procedures, and authorization basis). The major assumptions involved in the cost estimate are listed below.

- Risers are open and available for the mixers. (No existing installed equipment needs to be removed.)
- Scope of deployment is two Flygt™ mixers in a DST.
- Developmental costs are on the order of those generated during the joint tests of SRS and PNNL.
- Construction, installation, and operability testing costs are based on previous experience of similar projects within tank farms.
- A pump-supporting structure and foundation is required at each riser.
- Sufficient power is available in the Instrument and Control Building to feed the mixers. Power cables are installed underground from the Instrument and Control Building up to a local rack at the tank, then are run aboveground to the applicable riser.

- A test facility is available onsite to test the full-length deployment mast and mixers before installation. (No such facility currently exists.)

- Safety assessment uncovers no critical issues involving costly resolution.

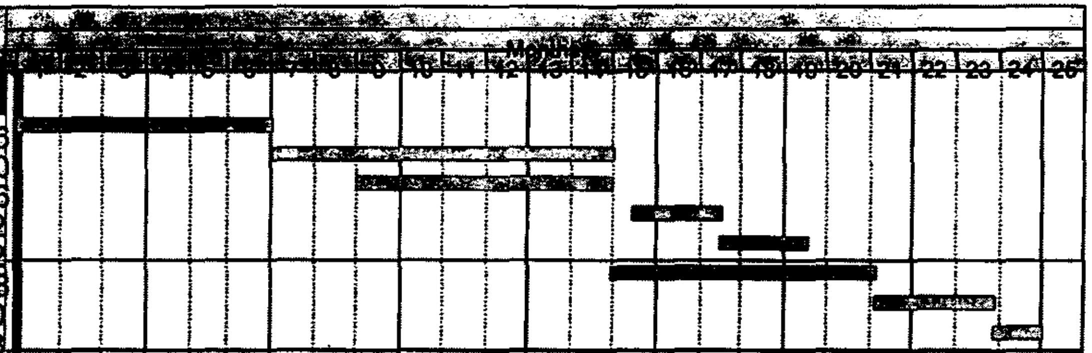
- A Standard Startup Review checklist process is used to assess readiness of the system for operation. Neither of the more involved Operational Readiness Review process or Readiness Review process is necessary.

- Equipment is left in place after use. Removal and disposal costs are not accounted for but presumed to be equivalent or less than those for a mixer pump.

Table 11-2 presents a ROM schedule for deployment of the Flygt™ mixer once a decision is made to move forward. The duration of the deployment is 24 mo. A more aggressive, "fast-track" approach where mixer development is performed in parallel with engineering design is expected to reduce the time to operational readiness to 18 mo.

Table 11-2. Schedule to Deploy Flygt™ Mixers.

Activity Description	Orig Dur
Mixer Performance Validation Tests	126
Engineering Design	170
Procurement	126
Fabrication	42
Acceptance Testing (Mixer Assembly)	42
Field Construction	128
Operations/Startup Testing	60
Readiness for Operation	23



Start Date	02OCT00	Early Bar	2FLY
Finish Date	26SEP02	Progress Bar	Sheet 1 of 1
Data Date	02OCT00	Critical Activity	Initial Deploy 2 Flygt Mixers in DST
Run Date	20JUN00 08:18		

Date	Revision	Checked	Approved

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12.0 OVERALL ASSESSMENT AND RECOMMENDATIONS

12.1 GENERAL ASSESSMENT

Based on the investigation performed in this report, the Flygt™ submersible propeller mixer appears to deserve further consideration and development as a waste retrieval technology. The advantages of the Flygt™ mixer are described below.

- The Flygt™ mixer produces a high, unidirectional flow (>20,000 gal/min) that can produce bulk flow patterns within the tank. When multiple mixers are used and oriented properly, the additive effects of the bulk flow circulation may be able to induce mobilization greater than what would be expected for the total mixer power applied.
- With adequate mast design, the submersible motor and unidirectional discharge aspects of the unit allow it to be pointed in almost any direction, vertically or horizontally. For example, the unit could be pointed vertically downward initially to mobilize solids directly underneath it, essentially burrowing itself a hole in the solids into which it could be lowered and then operated horizontally to mobilize the waste in the surrounding area.
- The technology has a long track record of effectiveness in industrial solids suspension and blending application and may have some effectiveness in solids mobilization. (However, the degree of effectiveness has not been characterized yet.)
- No fresh water supply or recycle of supernate from another facility is required.
- The power input (50 hp or less) from the Flygt™ mixer to the tank results in slower heat-up of the tank when compared to the retrieval baseline jet mixer pump. Slower tank heat-up is particularly desirable because of the limited heat-removal capacity of the ventilation system.
- Cost of the propeller mixer units is relatively low.
- The compact submersible unit and propeller should be relatively easy to decontaminate.

Conversely, the submersible propeller mixer has certain disadvantages. These disadvantages are described below.

- The size of the units restrict its use to 12-in.-diameter risers or greater. Performance is heavily dependent on propeller diameter, and large risers (34-in. or 42-in.) are required to obtain maximum performance.
- The effectiveness of the Flygt™ mixer as a sludge mobilization device is not well characterized. The unit can not be deployed as close to the floor of the tank as a jet mixer nozzle.
- The high thrust produced by the unit because of its unidirectional discharge requires a strong and sturdy mast and attachment at the riser compared to other technologies.

- The submersible motor must be very robust to provide longevity in withstanding the high radiation tank waste environment and the challenging combination of waste properties (density, viscosity, and temperature) expected to be encountered in the mobilization activity.

- The mixer must be submerged a certain distance below the liquid surface to prevent vortexing. Vortex limiters can help reduce this distance. Operation may be affected for tanks with low liquid levels or in narrow supernate layers.

- The mixer is a fixed, permanent-type configuration (is not easily portable from riser to riser). The mixer requires up to 50-hp power supply and accessories such as up/down and rotational control panels, and variable frequency drive (possibly) to operate.

12.2 CONCLUSIONS FOR HIGH-LEVEL WASTE AUXILIARY SOLIDS MOBILIZATION

The specific findings of this report for deployment of the Flygt™ mixer for HLW auxiliary solids mobilization are as follows:

1. For the two tanks considered for this study, Tanks 241-AY-102 and 241-SY-102, it is likely that a Flygt™ mixer in an optimum configuration is capable of meeting the minimum mobilization effectiveness requirement (an ECR ≥3 m [9.8 ft]). However, the experimental data thus far are clearly too limited to make an accurate prediction for a full-sized tank. Further development testing should provide the data necessary to produce a more definitive prediction.

2. Deployment of the Flygt™ mixer for the purpose of auxiliary solids mobilization in HLW tanks is constrained by tank physical constraints (i.e., riser size, location, and availability). The only DST farms where large risers may be available outside of the central pump pit are the AY Farm and the AZ Farm and, if construction risers are brought up to grade, the SY Farm. This represents five of the first ten Phase 1 HLW tanks. Assessment of Flygt™ mixer performance shows very high confidence that the minimum mobilization effectiveness would not be met in risers <12 in. in diameter. The development of the technology solely for this specific application does not seem warranted from this standpoint.

3. The propeller mixer technology also should be assessed for missions of solids suspension and transport at the Hanford Site based on the success of a tank waste retrieval campaign using two Flygt™ propeller mixers at ORNL and the results of testing performed by SRS and PNNL to support installation of these devices for final cleanout of Tank 19 zeolite heel. The Flygt™ propeller mixer has a proven track record in industrial applications such as mixing, blending, and solids suspension. The Phase D testing by PNNL indicates that proper positioning and orientation of multiple unidirectional mixers in a tank can work synergistically to create bulk flow patterns in the tank, which could prove valuable for other retrieval missions such as low-activity waste retrieval.

4. The long-term functionality of the Flygt™ motor under high temperatures (>100 °F) and high radiation dose (peak dose to 1100 Rd/h) is unknown. This issue can likely be overcome either by further evaluation of the Flygt™ mixer equipment or design modifications. Higher tank temperatures, resulting from the use of the high-horsepower primary jet mixers, are expected to be encountered. Use of a variable frequency drive can partially offset the motor temperature capability by reducing load on the motor with no net loss in thrust, but this will result in reduced far-field flow velocities.

5. The Flygt™ mixer design appears to be capable of meeting the flammable gas environment requirements for operation in RPP waste tanks.

6. Total overall cost for initial deployment of two (2) Flygt™ mixers in a Hanford Site waste tank is estimated to be $8,900,000. The cost to deploy follow-on units is expected to be significantly less. A "fast-track" program could be expected to result in operational readiness within a period of 18 mo. A more conservative approach, where mixer development work is concluded before initiating deployment activities, is expected to require a period of 24 mo.

12.3 RECOMMENDATIONS

The following actions are recommended.

- Investigation of the Flygt™ mixer for mixing, blending, and solids suspension applications, such as low-activity waste retrieval (e.g. double-shell slurry/double-shell slurry feed salt waste dissolution), is recommended. The high volume exchange rate per power input of the propeller mixer technology is optimized for such applications. If a suitable mission is found, additional experimentation to qualify the synergistic effects of multiple Flygt™ mixers to create bulk flow patterns within a tank is recommended.

- Further investigation is warranted on the Flygt™ mixer as a potential alternative or complement to the baseline sludge mobilization technology. The current knowledge base does not disprove proposing the propeller mixer cleaning capability as equivalent to the Hanford Site baseline jet mixer pumps. If true, this equipment has the potential to improve retrieval efficiencies or form an alternative to the baseline mixer pumps. The development work proposed in Section 8.1 regarding scaled testing with high shear strength simulants to increase the accuracy of mobilization effectiveness predictions and testing focusing on comparison of jet mixer technology to propeller mixer technology is recommended.

- The usage and reliability of Flygt™ mixers after their deployment at SRS should be monitored.

- Study of the effects of the Flygt™ mixer on in-tank components, such as airlift circulators, is warranted before its deployment.

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13.0 REFERENCES

Adkins, B., 2000, *Flygt™ Mixer Design Optimization Test Summary*, (Internal Memo HLW-STE-2000-00196 to M. Miller, E. Saldivar, and B. Martin, Westinghouse Savannah River Company, Aiken, South Carolina.

Akins, J., 1999, *Viscosity Report*, (Internal Memo 82400-99-047 to T. W. Crawford), Lockheed Martin Hanford Corporation, Richland, Washington.

Bamberger, J. A., 1999, *An Assessment of Technologies to Provide Extended Sludge Retrieval from Underground Storage Tanks at the Hanford Site*, PNNL-13048, Pacific Northwest National Laboratory, Richland, Washington.

Blevins, R. D., 1984, *Applied Fluid Dynamics Handbook*, Krieger Publishing Company, Malabar, Florida.

Brackenbury, P. J., 1999, *Project Definition Criteria for Project W-521, Waste Feed Delivery Systems*, HNF-4408, Rev. 0, Numatec Hanford Company for Lockheed Martin Hanford Corporation, Richland, Washington.

Crawford, T. W., 1999, *Update of Estimate Retrieval Efficiencies for Phase I High-Level Waste Feed Tanks*, (Letter 82400-99-020 to T. M. Hohl, COGEMA Engineering Corporation), CH2M HILL Hanford Group, Inc., Richland, Washington.

DOE/RL-92-36, 1993, *Hanford Site Hoisting and Rigging Manual*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Enderlin, C. W., 1999, *Letter Report for RPD&E Milestone B.1-2 ORNL Flygt™ Mixer Data Analysis*, (Internal Memo to M. W. Rinker), Pacific Northwest National Laboratory, Richland, Washington.

Enderlin, C. W., 2000, *Status of 50-Hp Flygt™ Mixer Longevity Testing*, (Internal Memo dated May 17), Pacific Northwest National Laboratory, Richland, Washington.

Grams, W. H., 1995, *Double-Shell Tank Retrievable Allowable Heel Trade Analysis*, WHC-SD-WM-TA-162, Rev. 0, Westinghouse Hanford Company, Richland, Washington

Jones, G. L., 2000, *Tank Waste Remediation System Technical Safety Requirements*, HNF-SD-WM-TSR-006, Rev. 1 as amended, CH2M HILL Hanford Group, Inc., Richland, Washington.

Kirkbride, R. A., 1999, *Case 3S5 Summary*, Presentation, November 19, 1999, Numatec Hanford Corporation, Richland, Washington.

Kirkbride, R. A., G. K. Allen, P. J. Certa, A. F. Manuel, R. M. Orme, L. W. Shelton, E. J. Slaathaug, R. S. Wittman, G. T. MacLean, and D. L. Penwell, 1999, *Tank Waste Remediation System Operation and Utilization Plan*, HNF-SD-WM-SP-012, Rev. 1, Vol. I and II, Numatec Hanford Corporation for Fluor Daniel Hanford, Inc., Richland, Washington.

Leshikar, G. A., 1998, *DST Transfer Pump History and Reliability Report*, HNF-3218, Rev. 0 COGEMA Engineering Corporation for Fluor Daniel Hanford, Inc., Richland, Washington.

NFPA 70, 1999, *National Electric Code*, Class 1, Div. 1, Group B, National Fire Protection Association, Quincy, Massachusetts.

Powell, M. R., Y. Onishi, and R. Shekarriz, 1997, *Research on Jet Mixing of Settling Sludges in Nuclear Waste Tanks at Hanford and Other DOE Sites: A Historical Perspective*, PNNL-11686, Pacific Northwest National Laboratory, Richland, Washington

Powell, M. R., J R. Farmer, H. Gladki, B. K. Hatchell, M. R. Poirier, and P. O. Rodwell, 1999a, *Evaluation of Flygt™ Mixers for Application in Savannah River Site Tank 19, Test Results from Phase A: Small-Scale Testing at ITT Flygt™*, PNNL-12094, Pacific Northwest National Laboratory, Richland, Washington.

Powell, M. R., W. H. Combs, J. R. Farmer, H. Gladki, B. K. Hatchell, M. A. Johnson, M. R. Poirier, and P. O. Rodwell, 1999b, *Evaluation of Flygt™ Mixers for Application in Savannah River Site Tank 19, Test Results from Phase B: Mid-Scale Testing at PNNL*, PNNL-12093, Pacific Northwest National Laboratory, Richland, Washington.

Powell, M. R., J. R. Farmer, H. Gladki, B. K. Hatchell, M. A. Johnson, M. R. Poirier, and P. O. Rodwell, 1999c, *Evaluation of Flygt™ Mixers for Application in Savannah River Site Tank, Summary Test Results for Phase A, B, and C, Testing*, PNNL-12168, Pacific Northwest National Laboratory, Richland, Washington.

PNNL, 2000, *FY00 Workscope, Milestone Completion Report A.1-4: Complete Test of 50-hp Flygt Mixer and Issue Phase D Test Report*, TTP RL3-6-WT-51, Pacific Northwest National Laboratory, Richland, Washington.

Rasmussen, J. H., 2000, *Double-Shell Tank Process Waste Sampling Subsystem Specification*, HNF-4154, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Rieck, C. A., 1998, *Interface Document, Project W-211, Initial Tank Retrieval Systems*, HNF-1507, Rev. 0, Numatec Hanford Company for Fluor Daniel Hanford, Inc., Richland, Washington.

Schlosser, R. L., 2000, *Flammable Gas Equipment Advisory Board Interpretation/Recommendation Report*, FGEAB-00-002-1, Rev. 1, CH2M HILL Hanford Group. Inc., Richland, Washington.

Tedeschi, A. R., 2000, *Derived Requirements for Double-Shell Tank High-Level Waste Auxiliary Solids Mobilization*, RPP-5664, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

UL 778, 1999, *UL Standard for Safety for Motor-Operated Water Pumps*, Underwriters Laboratories Inc., Northbrook, Illinois.

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APPENDIX A. FLYGT® MIXER DATA FROM VENDOR

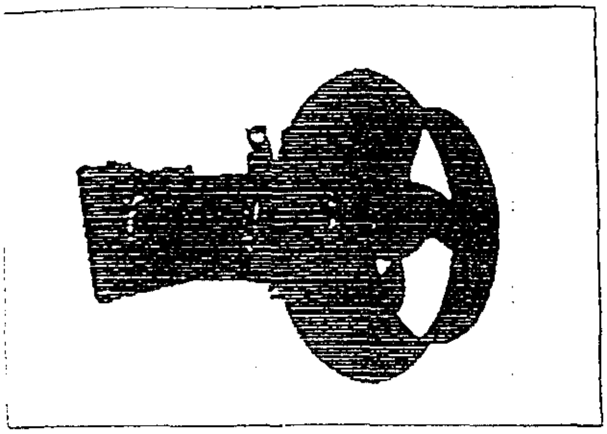
FLYGT

4680

Submersible Mixer

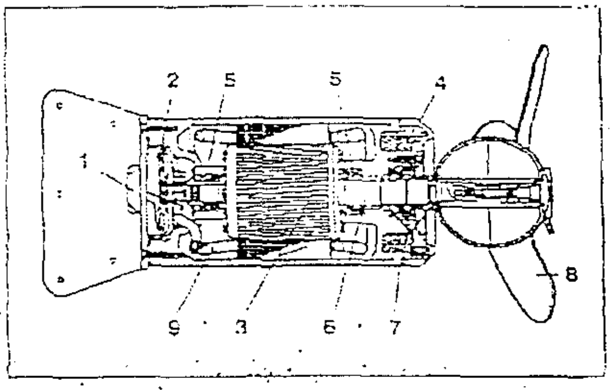
Heavy duty, direct drive mixer

Flows from 14,450 to 31,890 GPM



Applications:

4680 mixers are used in industrial processes such as Pulp & Paper, Chemicals, Food & Beverage and more. Also found in Municipal and Industrial waste treatment, Mining, Marine and Agricultural uses.



Materials of Construction:

Available in a choice of the following

- 304 stainless steel with 316 stainless steel components
- 316 Stainless Steel
- Exotic Stainless Steel per ASTM S31254 (ProAcid 254)

Approvals:

CSA tested and approved to UL Standard for Safety #778.

Factory Mutual Research tested and approved.

Suitable for use in:

Class I Div 1 groups C and D

Class II Div 1 groups E, F and G

Class III Div 1 Hazardous locations

Factory Mutual System Approved

CSA NRTL/C

Specifications

1. Cable Entry

Cable entry consists of two compressible rubber bushings to seal off motor area and relieve strain on the cable. Twice as many sealing bushings as previous designs means high reliability in difficult applications.

2. Junction Box

Box is completely sealed off from surrounding liquid and stator casing via terminal board and an O-ring.

3. Motor

Squirrel cage, 3 phase induction shell type design NEMA B motors are specifically designed for each mixer frame size. Non-overloading for full performance range. Motor insulation is Class F with a maximum working temperature of 155°C (311°F), 40°C (104°F) ambient including a temperature rise of 115°C (239°F). Combined service factor of 1.10. Motors can be run continuously or intermittently. The stator is cooled by the surrounding mixed media.

4. Oil Casing

An environmentally friendly white paraffin based, FDA approved, non-toxic oil lubricates and cools the seals and acts as an additional barrier to prevent liquid from penetrating the motor area. Pressure build-up within the casing is reduced by an inner and outer oil compartment design which transports any foreign liquids away from rotating components.

5. Bearings

Bearings are of a preloaded design rated in excess of 100,000 hours of operation (B-10 rated life). Shaft is supported by a single row angular contact ball bearing and single row cylindrical roller bearing, plus a heavy duty single row angular contact ball bearing on the propeller side.

6. Shaft

Motor shaft and rotor are a single integral unit. Shaft is completely isolated and cannot come in contact with the mixed media.

7. Shaft Seals

Outer mechanical seal isolates the oil housing and surrounding liquids and is tungsten carbide lapped end faced running in oil. Inner mechanical seal operates between oil casing and stator casing. Only seal faces operate in the mixed media, all other components are within motor housing.

8. Propeller

Three bladed, 316 stainless steel propeller. Blades have large width, thin profile and smooth surface with a back swept design for optimum efficiency and non clogging operation. The blades are laser cut to exacting tolerances. Propeller is available in other materials - consult Flygt.

9. Monitoring Equipment

The stator incorporates three thermal switches connected in series (one in each phase) which open at 260°F (125°C).

Flygt is a member of the following associations:

AED · AMA american rental association · CIMA · Submersible Wastewater Pump Association SWPA · National Mining Association

PRODUCT DESCRIPTION

General Description

These care and maintenance instructions apply to both the standard version and the explosion proof version of the submersible Flygt mixers and PP-pumps.

The explosion proof version (EX-approved) is designed for use in explosive environments in accordance with the approvals, see page 2.

The submersible mixer and the PP-pump in the 4600-series have the below features:

— direct driven electric multipole motors.
— propellers with different diameters and blade angles.
— different materials.
— different seals.
— different installation modes.

The pH of the liquid: 1—12.

Liquid temperature: max. 40°C (105°F).

Warm liquid version max. 90°C (195°F). This version has model designation ending with -W.

Depth of immersion: max. 40 m (130 ft).

Note, EX-approved machines are permitted for max depth of 20 m (65 ft)

NOTE! The machine should always work completely submerged in the liquid.

WARNING!

Only EX-approved machines may be used in explosive or flammable environments or for mixing/pumping flammable liquids.

Applications

For other applications than mentioned below, contact your nearest Flygt representative for information.

Mixer

The mixer is intended to be used in:

— sewage plants, sludge tanks and aeration basins, anaerobic or oxygen saturated water, presence of rags etc.
— industrial processes, heavy environments with high demands of operational security, water with usually metallic salt, paper pulp and cellulose, food and chemical industry.
— industrial sewage processes, some wearing, presence of rags and metallic salt.
— mineral slurries with high wearing characteristics, presence of rags acceptable.
— fish farms and current creating in dams, oxygen supply, demands of environmental approved materials. Sweet, brackish or salt water.
— liquid manure, presence of straw, strings, board-pieces etc, floating sludge with a thickness of up to 1 meter (3.3 ft).

The mixer is designed for use in many different situations where high flow capacity in relation to power consumption is required.

The mixing effect is dependent upon the density and the viscosity of the liquid and on the volume/shape of the tank.

More than one mixer is required for larger tanks.

Flange Mounted Mixer

The flange mounted mixer is intended to be used in:

— Oil industry/oil tanks.
— Pulp and paper industry.
— Various process industry.

PP-pump

The PP-pump is intended to be used for:

— clean water pumping at land drainage,
— irrigation and controlling of water course systems,
— waste water treatment, recirculation within treatment processes or return sludge pumping.

The hydraulic parts together with the installation accessories are specially designed to optimize the performance of the pump.

NOTES FOR EXPLOSION APPROVED MACHINES

The explosion proof version (EX-approved) is designed for use in explosive environments in accordance with the following approval:

EN European Norm, EEx d IIB T4

FM Factory Mutual, Class I Div 1 Grp C and D
Class II Div 1 Grp E, F and G
Class III Div 1

Approval plates see page 5.

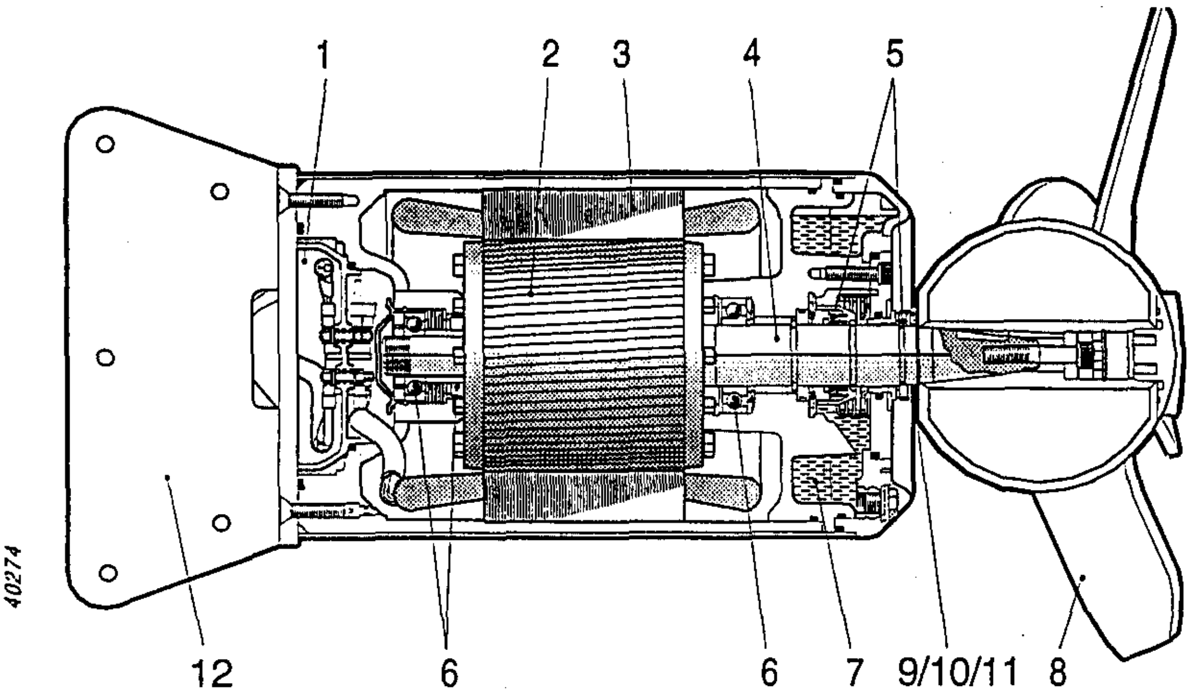
Depth of immersion: max. 20 m (65 ft).

Motorcable: SUBCAB® or SUBCAB® AWG

Thermal contacts must always be used on EX-approved machine due to approval conditions.

All work on the explosion-proof motor section must be performed by personnel authorized by Flygt.

Flygt disclaims all responsibility for work done by untrained, unauthorized personnel.



Cable entry

The cable entry has two compressible rubber bushings to seal off and to relieve the cable.

1. Junction box

The junction box is completely sealed off from the surrounding liquid and the stator casing.

2. Motor

Squirrel-cage 3-phase induction motor for 50 Hz or 60 Hz.

The motor is started by means of direct on-line start.

The motor can be run continuously or intermittently with a maximum of 15 evenly spaced starts per hour.

The stator is insulated in accordance with class F (155°C, 310°F). The motor is designed to supply its rated output at ± 5 % variation of the rated voltage. Without overheating the motor, ± 10 % variation of the rated voltage can be accepted provided that the motor does not run continuously at full load. The motor is designed to operate with a voltage imbalance of up to 2 % between the phases.

3. Monitoring equipment

The stator incorporates three thermal contacts connected in series.

The thermal contacts open at 125°C (260°F).

NOTE! The thermal contacts should be connected for liquid temperature up to 40°C (105°F) and **always** for EX approved machines.

See also "Electrical connections" and separate instructions for starter equipment.

The machine can be equipped with sensors, CLS for sensing water in the oil and/or FLS for sensing water in the stator casing. The CLS sensor is not applicate for EX-approved machines.

NOTE! 4630 and 4640 can only be equipped with FLS.

4. Shaft

The motor shaft is delivered with the rotor as an integral part.

The motor shaft is completely sealed and will not come in contact with the liquid.

5. Shaft seals

The outer mechanical seal is a mechanical face seal and seals between the surrounding liquid and the oil casing. Two alternative types of outer seals are available, sleeve seal (type S) and tube seal (type T).

The inner seal, which is a mechanical seal, seals off the oil chamber from the surrounding liquid. The seal's cavity is made very versatile in order to meet every application with high effective seal arrangement related to cost/performance.

6. Bearings

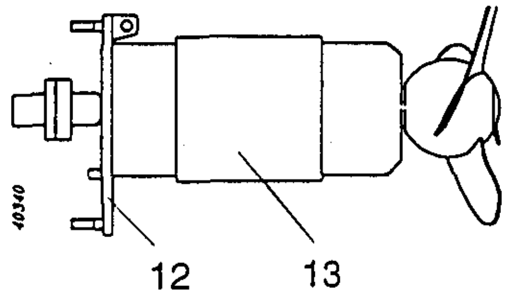
The shaft is carried in one single-row angular contact ball bearing and a single-row cylindrical roller bearing together with a single-row angular contact ball bearing.

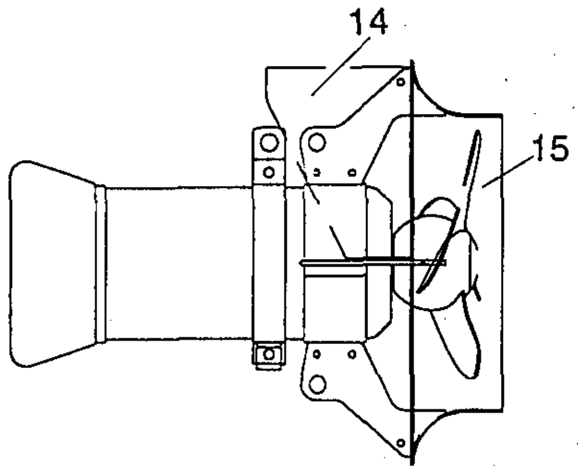
The bearings are dimensioned for more than 100 000 (L 10 aa) hours of operation.

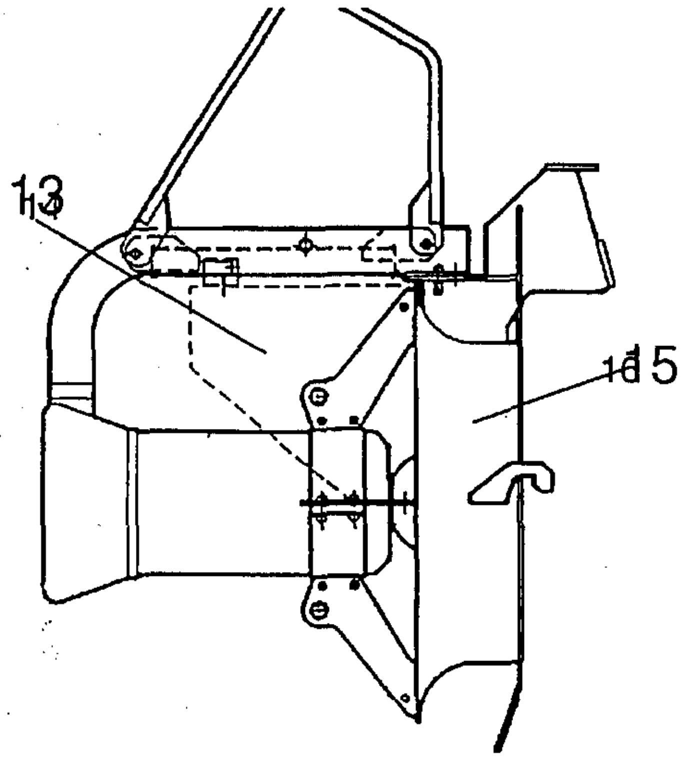
7. Oil casing

The oil lubricates and cools the seals and acts as an additional barrier against penetrating liquid.

Pressure build-up within the oil casing is reduced by means of a built-in air volume.







8. Propeller

The propeller is three-bladed and the blades have a large width, a thin profile, a smooth surface and are back-swept. This gives a highly efficient and clog-free operation.

The propeller angle can be adjusted to meet requirements. Angles between 4° and 19° are possible, but restricted upwards depending on version and applications due to available power.

9. Flush protection

The mixer and the PP-pump can be equipped with accessories for water or air flushing systems. Flushing the propeller hub area and the outer seal reduces the risk of sticking when mixing reactive slurries.

10. Cutting rings

The propeller can be equipped with cutting rings to prevent clogging of the hub area.

The cutting rings can be used with or without flushing. These are intended to be used for mixer applications, where liquids with long fibres are to be mixed.

11. Seal protector

The mixer and PP-pump can be equipped with seal protector to prevent clogging.

12. Fixing plate

The mixer is available with two types of fixing plate, one for guiding bar installation and one for flange mounted mixer.

13. Cooling jacket

Normally the stator is cooled by the surrounding liquid. External cooling (cooling jacket) is available as option.

14. Vortex protection shield

In order to avoid vortex the machine can be equipped with a protective shield.

15. Jet ring for mixer

The mixer can be operated with or without a jet ring. The jet ring improves the efficiency and directs the jet.

NOTE. Operation without jet ring affects the power consumption.

16. Inlet cone for PP-pump

The inlet cone is designed to give the best influence on the created flow .

Discharge connection for PP-pump

The function of the discharge connection is to fix the inlet cone onto a pipe or a diffusor.

Guiding equipment for PP-pump

The guiding equipment consists of two pipes (guide bars) and upper guide bar holders.

Installation for PP-pump

The PP-pump should be installed horizontally on a wall and guided vertically along the wall.

The pump slides down along guide bars and connects automatically to the discharge connection. The flange of the inlet cone directs the pump at guiding and secures the correct position on the discharge connection.

Flygt supplies equipment for a method of installation which permits mixing over the horizontal and the vertical plane.

Avoid installations where:

— there are obstacles in front of the mixer,
— the flow on the suction side of the mixer is obstructed due to the design of the tank,
— the propeller can suck down air - vortex.

To avoid vortex use a vortex protective disc or place the mixer deeper in the liquid.

This is an absolute requirement for continuously operating mixers.

The mixer can be mounted on fixed structures, pillars, stands, gratings, on an anchored raft etc.

When installing, keep in mind the reaction force of the mixer, which can be up to, for:

4630	500 N
4640	900 N
4650	1800 N
4660	3000 N
4670	3900 N
4680	6600 N

> **NOTE!**
> **All welded joints must be pickled and polished before they come into contact with the liquid.**

Run the cables so that they do not have any sharp bends and are not pinched.

NOTE! The end of the cable must not be submerged. Leads have to be above flood level, as water may penetrate through the cable into the junction box or the motor.

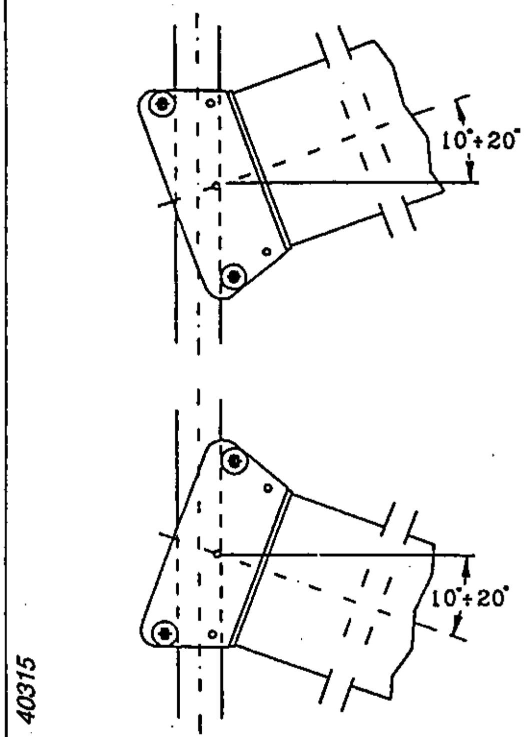
Consult your nearest Flygt representative regarding:

— choice of peripheral equipment.
— other problems in connection with installation.

> **NOTE!**
> **In all installations, make sure that the motor cable cannot be drawn into the propeller.**
>
> **Treat the cable as fragile, beware that no sharp bends occure throughout (during) installation procedure especially by entrance flange.**

guide bar

The mixer can be installed on the guide bar in horizontal position or with standard angle of c:a +/-10°or +/-20°. See "Dimensions for Mixer" page 11—13. For other angle contact Flygt.



Always test that the mixer will go easily up and down the guide bar, before the mixer has been lowered to the desired working depth.

> **NOTE!**
> **If the mixer is operated without jet ring there must be a stop function on the guide bar to avoid the propeller from being swung into the wall during operation.**
>
> **NOTE!**
> **Don't position the mixer during operation.**

Flange mounted mixer

Flange mounted mixer is an unique method for installing mixers in tanks where guide bar or bottom stand installation is not the optimum solution. The mixer is assembled to a flange mounted cover by studs, nuts and a gasket. The flange mounted cover is calculated according to the Swedish standard TKN-87 (Tryckkärlsnorm 1987), a standard for pressurised vessels. The flange mounted cover is made locally, contact your nearest Flygt representative for information.

4600 Propeller Performance

Mixers without Jet Ring

Section 4 | 4600 Series Mixers | Issued: 11/99 | Supersedes: 5/99

Mixer	Prop. Code	Ø	Poles	Max. Motor HP Rating	Shaft HP*	% Full Load	Power Input (kW)	Prop. Speed (RPM)	Prop. Dia. (Inches)	Prop. Blade Angles (Degree)	Flow (GPM)
4630	083705SF	3	8	2.5	2.0	60	1.95	855	14 7/16"	5°	4,010
	083706SF	3	8	2.5	2.1	64	2.10	855	14 7/16"	6°	4,240
4640	083705SF	3	8	4.0	2.1	53	2.05	860	14 7/16"	5°	4,030
	083706SF	3	8	4.0	2.3	58	2.25	860	14 7/16"	6°	4,260
	083707SF	3	8	4.0	2.6	65	2.50	860	14 7/16"	7°	4,490
	083708SF	3	8	4.0	2.9	73	2.80	860	14 7/16"	8°	4,680
	083709SF	3	8	4.0	3.2	80	3.10	860	14 7/16"	9°	4,840
4650**	125803SF	3	12	7.5	6.1	81	6.00	580	22 13/16"	3°	9,280
4660	125803SF	3	12	15.0	6.5	43	6.25	580	22 13/16"	3°	9,280
	125805SF	3	12	15.0	7.6	51	7.40	580	22 13/16"	5°	10,480
	125806SF	3	12	15.0	8.2	55	7.90	580	22 13/16"	6°	11,080
	125807SF	3	12	15.0	9.1	61	8.70	580	22 13/16"	7°	11,680
	125809SF	3	12	15.0	11.2	75	10.55	580	22 13/16"	9°	12,720
	125810SF	3	12	15.0	12.8	85	12.05	580	22 13/16"	10°	13,180
4670	167705SF	3	16	20.0	13.7	69	13.00	440	30 1/8"	5°	18,600
	167707SF	3	16	20.0	16.0	80	15.25	440	30 1/8"	7°	20,730
4680	167705SF	3	16	40.0	14.6	37	13.85	440	30 1/8"	5°	18,600
	167707SF	3	16	40.0	17.2	43	16.30	440	30 1/8"	7°	20,730
	167709SF	3	16	40.0	20.7	52	19.40	440	30 1/8"	9°	22,590
	167711SF	3	16	40.0	24.9	62	23.25	440	30 1/8"	11°	24,400
	167713SF	3	16	40.0	30.5	76	27.75	440	30 1/8"	13°	26,200
	167714SF	3	16	40.0	33.9	85	30.85	440	30 1/8"	14°	27,090

* Horsepower Consumed in Clear Water. ** Available on special order

NOTES:

Liquid Temperature: Warm Liquid versions available up to 195°F.
Consult your Flygt Regional Applications Engineer or Regional Sales Office for specific model and propeller selection.

Important: Please provide Specific Gravity with applications details.

All of the above versions are available in Cast Iron-Carbon Steel, Stainless Steel, Proacid 254.
All versions can be equipped with Seal Flush Device. Explosion-proof Mixers are available.

4600 Propeller Performance

Mixers with Jet Ring

Section 4 | 4600 Series Mixers | Issued: 11/99 | Supersedes: 5/99

Mixer	Prop. Code	Ø	Poles	Max. Motor HP Rating	Shaft HP*	% Full Load	Power Input (kW)	Prop. Speed (RPM)	Prop. Dia. (inches)	Prop. Blade Angles (Degree)	Flow (GPM)
4630	083705SJ	3	8	2.5	1.7	68	1.65	855	14 7/16"	5°	4,010
	083706SJ	3	8	2.5	1.9	76	1.80	855	14 7/16"	6°	4,240
	083707SJ	3	8	2.5	2.0	80	1.95	855	14 7/16"	7°	4,470
	083708SJ	3	8	2.5	2.1	84	2.10	855	14 7/16"	8°	4,650
4640	083705SJ	3	8	4.0	1.7	43	1.70	860	14 7/16"	5°	4,030
	083706SJ	3	8	4.0	1.9	48	1.85	860	14 7/16"	6°	4,260
	083707SJ	3	8	4.0	2.0	50	2.00	860	14 7/16"	7°	4,490
	083708SJ	3	8	4.0	2.2	55	2.20	860	14 7/16"	8°	4,680
	083709SJ	3	8	4.0	2.6	65	2.40	860	14 7/16"	9°	4,840
	083711SJ	3	8	4.0	3.0	75	2.90	860	14 7/16"	11°	5,300
	083712SJ	3	8	4.0	3.3	83	3.20	860	14 7/16"	12°	5,530
4650	125803SJ	3	12	7.5	5.1	68	5.05	580	22 13/16"	3°	9,280
	125805SJ	3	12	7.5	5.9	79	5.80	580	22 13/16"	5°	10,480
	125806SJ	3	12	7.5	6.4	85	6.20	580	22 13/16"	6°	11,080
4660	125803SJ	3	12	15.0	5.5	37	5.35	580	22 13/16"	3°	9,280
	125805SJ	3	12	15.0	6.1	41	5.95	580	22 13/16"	5°	10,480
	125806SJ	3	12	15.0	6.6	44	6.35	580	22 13/16"	6°	11,080
	125807SJ	3	12	15.0	7.0	47	6.80	580	22 13/16"	7°	11,680
	125809SJ	3	12	15.0	8.1	54	7.85	580	22 13/16"	9°	12,720
	125810SJ	3	12	15.0	8.9	59	8.65	580	22 13/16"	10°	13,180
	125811SJ	3	12	15.0	10.1	67	9.50	580	22 13/16"	11°	13,770
	125813SJ	3	12	15.0	11.8	79	11.05	580	22 13/16"	13°	14,820
	125814SJ	3	12	15.0	12.8	85	12.05	580	22 13/16"	14°	15,270
4670	167705SJ	3	16	20.0	10.7	54	10.75	440	30 1/8"	5°	18,250
	167707SJ	3	16	20.0	12.7	64	12.35	440	30 1/8"	7°	20,320
	167709SJ	3	16	20.0	15.6	78	14.85	440	30 1/8"	9°	21,900
	167711SJ	3	16	20.0	17.4	87	16.45	440	30 1/8"	11°	24,430
4680	167705SJ	3	16	40.0	12.3	31	11.65	440	30 1/8"	5°	18,250
	167707SJ	3	16	40.0	13.9	35	13.25	440	30 1/8"	7°	20,320
	167709SJ	3	16	40.0	16.1	40	15.30	440	30 1/8"	9°	21,900
	167711SJ	3	16	40.0	18.7	47	17.75	440	30 1/8"	11°	24,130
	167713SJ	3	16	40.0	21.7	54	20.65	440	30 1/8"	13°	26,190
	167714SJ	3	16	40.0	23.4	59	22.20	440	30 1/8"	14°	27,090
	167715SJ	3	16	40.0	25.5	64	23.75	440	30 1/8"	15°	27,780
	167717SJ	3	16	40.0	29.6	74	26.90	440	30 1/8"	17°	29,820
	167718SJ	3	16	40.0	32.7	82	29.80	440	30 1/8"	18°	30,810

* Horsepower Consumed in Clear Water.

NOTES:

Liquid Temperature: Warm Liquid versions available up to 195°F. Consult your Flygt Regional Applications Engineer or Regional Sales Office for specific model and propeller selection.

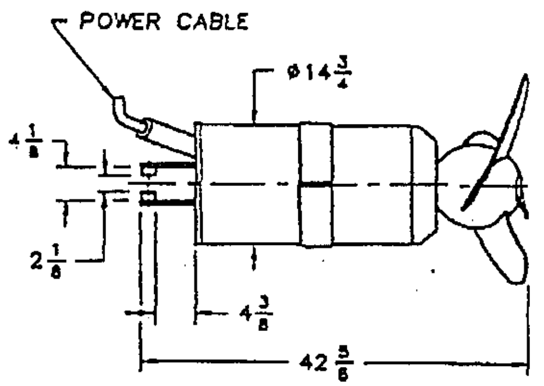
Important: Please provide Specific Gravity with applications details.

All of the above versions are available in Cast Iron-Carbon Steel, Stainless Steel, Proacid 254. All versions can be equipped with Seal Flush Device. Explosion-proof Mixers are available.

4680, 4680(X) Mixers

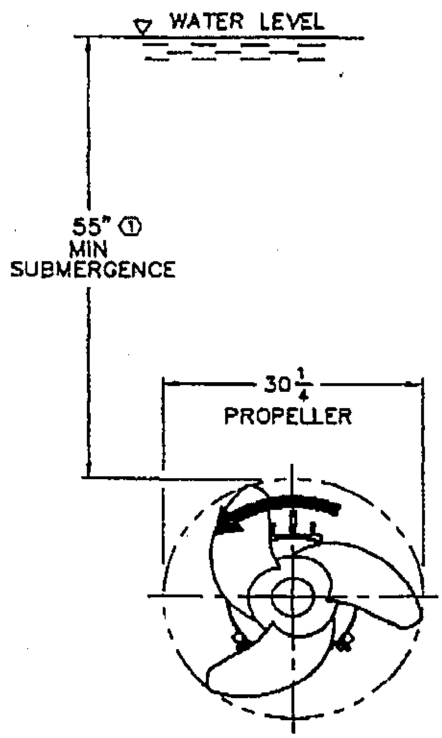
Outline Dimensions without Jet Ring - System 4 Mounting (4" Mixer Mast)

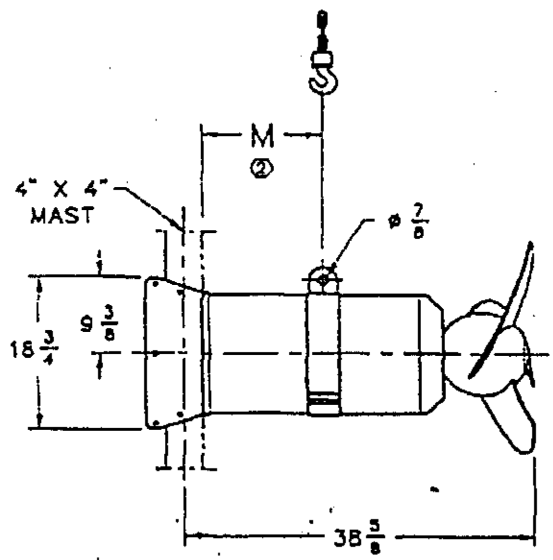
Section 4	FLYGT	4600 Series Mixers	Issued: 3/99	Supersedes: 7/95



○ NOTES:

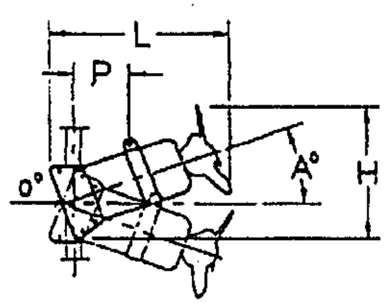
1. SUBMERGENCE CAN BE DECREASED TO 28" IN THICK LIQUID, OR FLOW RATES MAY BE REDUCED IN LOW VISCOSITY LIQUIDS IN ORDER TO PREVENT VORTEXES.
2. LOCATION OF WHERE TO MOUNT LIFTING HANDLE ON MIXER.





ALL DIMENSIONS IN INCHES

DIMENSIONAL CHART					
A°	−20	−10	0	+10	+20
H	38 3/4	32 3/8	30 1/4	32 3/8	38 3/4
L	50 1/2	48 3/8	42 5/8	48 3/8	50 1/2
M	9	10 3/4	13	15	16 3/4
P	16 3/4	15 3/4	15	16 1/2	16 3/4

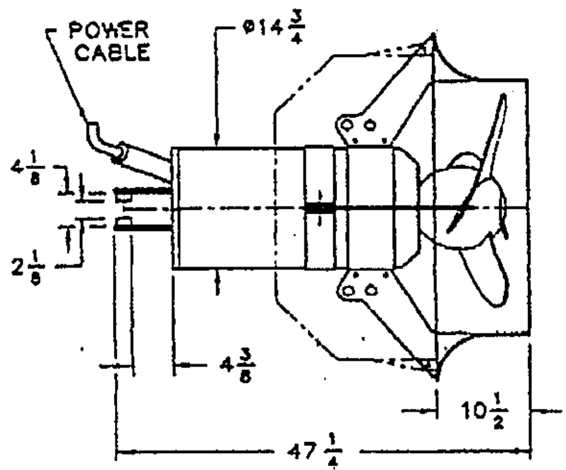


WEIGHT(LBS)
880

4680, 4680(X) Mixers

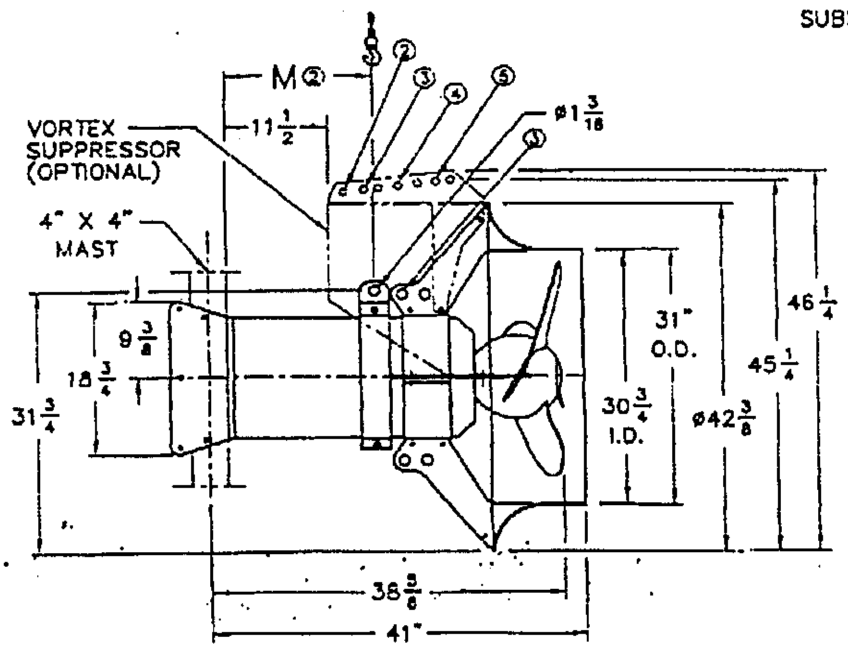
Outline Dimensions with Jet Ring - System 4 Mounting (4" Mixer Mast)

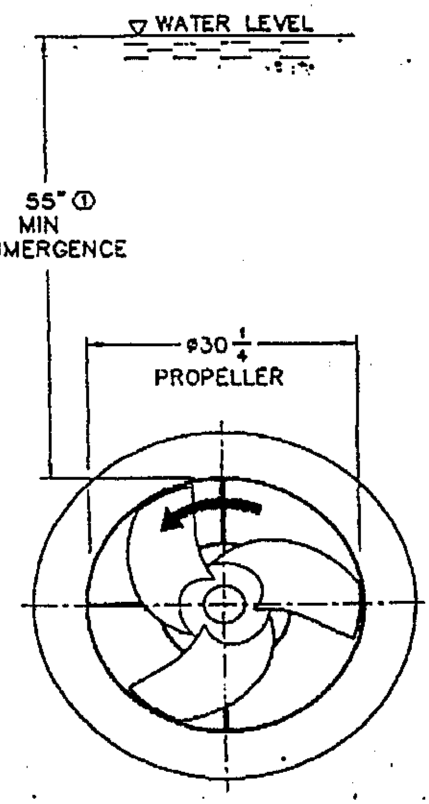
Section 4	FLYGT	4600 Series Mixers	Issued: 3/99	Supersedes: 7/95



○ NOTES:

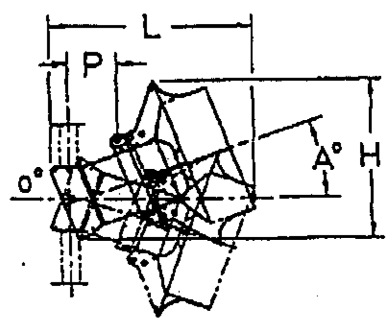
1. SUBMERGENCE CAN BE DECREASED TO 28" IN THICK LIQUID, OR FLOW RATES MAY BE REDUCED IN LOW VISCOSITY LIQUIDS IN ORDER TO PREVENT VORTEXES.
2. LOCATION OF WHERE TO MOUNT LIFTING HANDLE ON MIXER.
3. USE THIS HOLE ON JET RING ARM FOR LIFTING AT +20°.





ALL DIMENSIONS IN INCHES

DIMENSIONAL CHART					
A°	−20	−10	0	+10	+20
H	41 3/4	41 3/4	42 3/8	41 3/4	41 3/4
L	52 7/8	50 3/4	47 1/2	50 3/4	52 7/8
M	11 1/2	12 3/4	15	③	③
HOLE 7/8 DIA	–	2	3	4	5
P	18 3/4	17 3/4	17	17 1/2	19



WEIGHT (LBS)
1025

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APPENDIX B. AUXILIARY SOLIDS MOBILIZATION DERIVED FUNCTIONS AND REQUIREMENTS - (FROM RPP-5664)

5.0 Derived Requirements

Table 5.1 summarizes all derived requirements. They are grouped in five categories consistent with original work plan direction. The primary units identified are consistent with the units in the original reference

Table 5.1 Auxiliary High-Level Waste Solids Mobilization Equipment Requirement Summary

Function or Requirement	Value/Specification Range	Basis	Reference
Process Specifications – Waste Properties			
Effective cleaning radius	3m to 6m (9.8ft – 19.8ft) Minimum performance criteria = 3m	The lower value represents a typical distance from 4"/6" risers to the interior tank sidewall. Available 42" risers are approximately 6m from the sidewall.	H-14-010507 Sht 1
Total waste volume (includes saltcake and supernate)	579 Kl (153 Kgal) to 4,232 Kl (1118 Kgal)	The range of reported total waste volume for the included tanks.	(Hanlon 1999)
Sludge shear strength	1.96 kPa (19,631 dynes/cm^2, 41 lb/ft^2) to 4.8 kPa (47,900 dynes/cm^2, 100 lb/ft^2) *Minimum performance* criteria = 3.38 kPa	The lower value is commonly reported data from past AZ-102 analyses. The higher value represents the highest limit reported in the Tank Waste Remediation System Operation and Utilization Plan.	(Kirkbride 1999a), (Shaw, 1999)
Sludge volume	269 Kl (71Kgal) to 1196 Kl (316 Kgal)	The lower value is the reported volume in 214-SY-102. The higher value is the reported volume for AW-103. The highest value also represents the largest reported sludge volume for the included tanks. While several of the noted tanks have no sludge, SY-102 data was used for lower data because it was a highlighted tank for auxiliary mixing. (Obviously 0 sludge would be a the maximum low end, but not practical for this scope.)	(Hanlon 1999)
Sludge bulk density	1- 2 gm/ml	Core sample results of bottom sludge layers for AW-103 (#194) and SY-102 (#213) (TWINS database)	See Basis
Sludge viscosity	6.0 E-01 to 1.0 E+05 poise	Solids viscosity for AZ-101 and other reported slurry viscosities range from 5.0 E-01 to 1.0 poise; Other reported data for solids are noted at 10,000 cp. The referenced PNNL report is an internal letter report that references other reporting data; characterization data on sludge viscosities is limited.	(Antoniak 1996), and (Kirkbride 1999a)

Function or Requirement	Value/Specification Range	Basis	Reference
Weight percent solids of in-tank settled sludge	30-60%	From AW-103 core sampling data extrapolated from reported percent water values (TWINS database core 194)	See Basis
Solids Particle Size	0.2-50 microns	Commonly reported data for sludges – typical smaller sizes causing which tend to be highly cohesive; translates to high yield stresses in both shear and compressive modes	(Kirkbride 1999a) (Powell 1997)
Supernatant Volume/Levels	0 to 87 Kgals 0 to 293 inches (See Appendix A for tank specific)	(Assuming a nominal ratio of 2750 gallons per inch)	(Hanlon 1999)
Supernatant specific gravity	1.0 to 1.2	Supernatant grab sample results obtained from TWINS database	See Basis
Supernatant Viscosity	0.3 to 3.0 cp	Reported values from tank data and simulation runs	(Akins 1999) (Kirkbride et al 1999a)
Waste pH	Caustic, 12 to +14	Commonly reported data; waste streams are a variety of sodium and other metallic salts	See Basis
Radioactive dose	Peak dose rate 10 to 1100 R/hr Total Integrated Dose 3.6 E05 to 9.5 E07 R	Reported ranges	(Claghorn 1998)
Waste temperature	60-95 °F for AW-103 & SY-102 60-190 °F for remaining tanks	Reported ranges	Surveillance Monitoring (TMACs) for AW-103 and SY-102 and Temperature profile data from Characterization database (Twins)
Operational Configuration Boundaries			
Discharge angle	Adjustable angles in both the vertical and horizontal plane. Best operation would allow adjustment remotely without breaking of confinement.	Mixing may be adequate with a fixed angle position directed at a single dead zone or buildup area. Waste performance and shear strengths may require a variable angle to enhance mixing and impacting of thicker sludges.	Operation/design team request
Mixer height	Variable (ability to mobilize waste on bottom and at increments 15-20 feet above bottom tank elevation)	Mixing may be adequate with a fixed position unit set on tank floor directed at a single dead zone or buildup area. Waste properties, specifically shear strengths, may require a phased lowering of the mixer to start movement of lower density material before impacting on thicker sludges. Also, mixer may need to be elevated to mobilize suspended solids in waste layers.	Operation/design team request

Function or Requirement	Value/Specification Range	Basis	Reference
Installation Constraints			
Riser installation width for pump and related assembly/mast	Available nominal riser sizes: 4", 6", 12", & 42"	Varied spare risers, and risers used for operations which could be accessed (e.g., *construction ports, defunct* installed equipment, camera ports etc.)	H-2-64447 Rv 7 H-14-010501 Sht 4 Rv 2 H-14-010502 Sht 2 Rv 1 H-14-010502 Sht 4 Rv 1 H-14-010507 Sht 1 Rv 0 H-14-010507 Sht 2 Rv 0 H-14-010531 Sht 2 Rv 2
Utilities availability	• 240/480 VAC • Flush water through tanker or existing piping • No instrument or compressed air	Current tank farm configurations; systems requiring compressed air or continual flushing will need to install auxiliary provisions	N/A
Natural Phenomena Design	None	Final Safety Analysis Report/Technical Safety Requirements, however dependent upon final design	(LMHC 1999a)
Ventilation system impacts	<50 scfm additional load	Conservative design estimate with existing ventilation systems	Estimate
Delivered horizontal displacement on vertical protuberances (e.g., thermocouple probes) in cleaning radius	Maximum 1 inch at tank bottom elevation	Calculations for specific tanks and waste protuberances will need to be made on a case-by-case basis. The reported range value is derived from calculation in AZ-101 but represents a conservative target for further evaluation	(Julyk 1997)
Material of construction	Wetted materials shall maintain 5-year life expectancy within waste conditions; minimum 304 stainless steel on all wetted parts	5 years estimated maximum life for staging tank application	Estimate
Pit confinement	Installation on potential risers within pits shall not intrude upon piping, and shall allow for reinstallation of all existing pit covers.	Minimization of operational and project impact	Operation cost effectiveness
Safety Requirements			
Lift criteria	Installation/removal will be per critical lift requirements of Hanford Hoisting & Rigging Manual	Final Safety Analysis Report/Technical Safety Requirement dome loading controls	(LMHC 1999a) AC 5.16
Electrical systems within tank vapor space, and pits	Meets NFPA Class 1, Div 1, Group B; design criteria shall be reviewed by independent buyer expert group	Final Safety Analysis Report/Technical Safety Requirement ignition controls	(LMHC 1999a) AC 5.10

Function or Requirement	Value/Specification Range	Basis	Reference
Electrical systems within submerged waste streams	Meets NFPA Class 1, Div 1, Group B or be demonstrated by process that submerged system provides no spark to tank vapor space	Final Safety Analysis Report/Technical Safety Requirement ignition controls	(LMHC 1999a) AC 5.10
Weight	Free supporting mast and pump assembly must meet allowable limits in addition to mixer pumps and retrieval pumps OR may be designed to rest on tank bottom, fully supported by floor	Final Safety Analysis Report/Technical Safety Requirement Dome Loading Controls; value will need specific calculation however generic rule is that riser may support 50 ton load limit	(LMHC 1999a) AC 5.16
Control system	Capable of being interlocked or remotely shut down upon indication of high waste temperature or tank ventilation shutdown	Final Safety Analysis Report/Technical Safety Requirement waste temperature and ventilation controls	(LMHC 1999a) LCOs 3.2.1, 3.2.2, 3.2.3, 3.3.1, and 3.3.2
Heat input	Maximum sludge/waste temperature rise of 10 °F during continuous equipment operation and following 12 hours	Final Safety Analysis Report/Technical Safety Requirement waste temperature controls, estimated conservative value based upon safety requirements; target motor energy output should be in the range of 50 – 100 hp	(LMHC 1999a) and engineering estimation
Operation, Maintenance, & Radiological Control Constraints			
Location of control mechanisms	Localized control at tank farm within tank farm control room (greater than 100 meters away from tank)	ALARA, and Conduct of operations	None
Location of electrical components requiring calibration	Not located within pits or shielded areas	ALARA, and Conduct of operations allowing routine access for calibration without removing shielding	None
Riser seal	Shall maintain existing confinement; riser seal shall be gasketed. Rotating seals shall be liquid sealed with drain back to the tank	ALARA	None
Decontamination	Free draining, internal flushable, with internal void areas for material trapping filled with compatible solids (e.g., foam)	Conduct of operations; current planning does not involve reuse of mixer	None
Shielding	System shall be provide with shielding for protection of workers during installation and removal for disposal	ALARA; current planning does not involve reuse of mixer	None

APPENDIX A

Tank Tabulation Data

Tank # (Kirkbride 1999b)	Tank Type (Kirkbride 1999b)	Retrieval Sequence (Kirkbride 1999b)	Waste Physical Properties: Shear Strength (kdynes/cm²) (Note 1)	Waste Physical Properties: Level [Total-Supernate, Saltcake, Sludge] (Hanlon 1999) (Kgals) (Note 2)	Waste Physical Properties: Tank Waste Temp. Range-°F (TWINS)	Maximum # of Mixer Pumps (Kirkbride1999a)	Available Risers (without mixer pumps, i.e. 42" risers may be used for mixer pumps)	Flammable Gas Group (LMHC 1999a)
AN-104	Intermediate – Minimum order	6	None reported	1053- 604, 449, 0	105-123	2-3	1-4" 2-8" 1-12" 1-42" (H-14-010501)	1
AW-103	Source – Extended order	8	47.9 (Grams 1995)	510- 147, 47, 316	60-75	2-3	1-4" 1-12" 2-42" (H-14-010502 sht 3)	2
AW-104	Source and Staging – Extended order	9	None reported	1118- 887, 231, 0	76-104	2-3	1-4" 2-42" (H-14-010502 sht 4)	2
AY-101	Source and Staging – Minimum order	4	None reported	152- 58, 0, 94	98-125	2-3	1-4" 1-16" 1-42" (H-2-64447)	2
AY-102	Source and Staging	3	Top 53.6 Mid 16.7 Bot 21.7 (Kirkbride1999a) 30.6 (Grams 1995)	615- 399, 0, 216 (includes transferred material from C-106)	72-126	4	1-4" 1-16" 1-42" (H-2-64447)	2
AZ-101	Source and Staging – Minimum order	1	1st 2.1 & 2.6 2nd 15 (Kirkbride 1999a) 8.6k (Grams 1995)	846- 800, 0, 46	144-186	2	2-3" 7-4" 6-6" 3-42" (H-14-010507 sht 1)	2
AZ-102	Source and Staging – Minimum order	2	Seg 1: 15.4 & 13.1 Seg 2: 26.5 (Kirkbride 1999a) 19.6 (Grams 1995)	941- 853, 0, 88	160-188	2	2-3" 11-6" 3-42" (H-14-010507 sht 2)	2
C-104	Source – Minimum order	5	None reported	295- 0, 0, 295	80-101	2-3	N/A	2
C-107	Source – Extended order	7	None reported	257- 0, 0, 257	115-129	2-3	N/A	3
SY-102	Source – Minimum order	6	38.8 (Grams 1995)	756- 685, 0, 71	64-110	2-3	4-4" 2-42" (H-14-010531 sht 2)	2

Notes

1 For comparison, simulant shear strengths per (Powell et 1997): 50% kaolin 13% plaster water simulant had a shear strength of 2.5 kPa (25 k-dynes/cm²); a 22.5% kaolin, 40% plaster, 37.5% water simulant had a shear strength of 150 kPa (1500 k-dynes/cm²)

2 Height of supernatant liquids can be approximated by the correlation of 1 in/2750 gallons

APPENDIX C. FLYGT® CONSULTATION AND PERFORMANCE PREDICTIONS

TELEFAX MESSAGE FROM FLYGT SYSTEMS ENGINEERING

ITT Industries

ITT Flygt Corporation
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Trumbull, CT 06611-0943
Telephone: (203) 380-4700
Engineering Fax: (203)380-4711

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PAGE 1 of 17

DATE: MARCH 17, 2000

FILE: T0229DD

MESSAGE TO: DAVID DAY

COMPANY: FLYGT WA

MESSAGE FROM: HANNA

SUBJECT: FLYGT MIXER EVALUATION FOR HANFORD WASTE TANK APPLICATION

Dear Dave,

To make a mixer evaluation for Hanford is not an easy task. In spite of my participating in the mixer testing at PNNL and SRS, there are so many unknown factors that we need to be very careful when any suggestion is made or any advice is delivered.

I am sure that Flygt mixers can be very useful and successful equipment for Hanford waste tanks. However, the number or size of the mixer in the tank depends on: the type of sludge, its concentration, specific gravity, viscosity and shear strength, pH, and also tank dimensions (or area/volume required to be mobilized) and riser size (their location). For example, at Oak Ridge National Lab, (3) Flygt 4 HP (4640) mixers successfully mobilized the salt cake from the tank bottom. Unfortunately, according to the "River Protection Project", the shear strength of the sludge in the Hanford tanks is relatively high and requires very high mixer thrust/power for mobilization. At the same time, high specific gravity and viscosity limit utilizing the maximum thrust/power (full load) of the mixer due to the required power margin.

Flygt 4600 series mixers are used for heavy industrial and wastewater treatment slurry and sludge. The standard Flygt maximum motor HP ratings range from 1.2 HP to 40 HP. The higher the power, the larger the motor and propeller dimensions. The propeller thrust ranges from 100 N to almost 7000 N. Because the Hanford sludge requires very high forces for mobilization, I will present only 40 HP standard mixers here. The specification for these mixers is enclosed.

In addition to the standard mixer, Flygt US built a 50 HP mixer for SRS. We are also working on the possibility of developing a mixer over 100 HP for a potential customer at his request. These 50 HP and 100 HP mixers have blades already trimmed to the size of the risers (24").

This memo is based on the information I received from Hanford (Derived Requirements for Double-Shell Tank High-Level Waste Auxiliary Solids Mobilization). I tried to give you my evaluation of a Flygt 4680 mixer used for auxiliary solids mobilization of double-shell tank waste.

The 4680 mixers without shrouds can be employed in the tank through the 42" riser without any problems and positioned horizontally within the tank. At the Savannah River Site, a deployment mast was developed for high-level waste allowing the 4680 mixer to be lowered into the tank through the riser in a vertical position, and then the mixer position could be changed to horizontal.

The 4680 mixer with a jet-ring (shroud) has almost 7000 N thrust when the motor is under an 82% load, and the same mixer without a shroud has 5500 N thrust when the motor is under an 85% load. If there is higher specific gravity, viscosity or temperature, the load on the mixer is required to be lower. However, a larger power margin results in lower thrust. Lower thrust means that the effective sludge mobilization area of the stationary mixer will be smaller. Then again, the effective sludge mobilization area for the determined thrust is also related to the shear strength of the sludge. At PNNL, we tested the critical shear stress τ_{cr} required to mobilize 80% sludge from the bottom for different sludge strengths and up to 2000 Pa. The test was done in three different sized tanks. A paper on this subject will be presented at the 10[th] European Conference on Mixing this year (it is attached). According to test results, the critical shear stress τ_{cr} equals about 5% of shear strength τ_s. For instance:

for τ_s = 2000 Pa shear strength, the τ_{cr} = 100 Pa,
τ_s = 3500 Pa shear strength, the τ_{cr} = 175 Pa.

If we employ 1*4680-167711SF (stainless steel mixer without a shroud). Thrust F from this particular mixer is 4450 N and the motor is under a 62% load. When we divide the thrust by τ_{cr} (critical shear stress), the area swept by the mixer is:

for τ_s = 2000 Pa, the mobilized surface area is 44.5 m^2 (478 ft^2),
τ_s = 3500 Pa, the mobilized surface area is 25.4 m^2 (273 ft^2).

For a stationary mixer, the influence area will be extended only in one direction. If we assume that the shape of this area is close to the ellipse, then the so-called effective radius R_{ef} in one direction for the stationary mixer is about:

for τ_s = 2000 Pa the effective radius R_{ef} is 11 m (36 ft)
τ_s = 3500 Pa the effective radius R_{ef} is 8 m (26.5 ft).

If this mixer had an extended shroud and was able to rotate, the reach of the effective radius and surface area of the mobilized bottom could expand. It was tested and proved by joint tests with Westinghouse and PNNL.

If I consider two tanks, AW-103 and SY-102, where Flygt mixers could be applied as auxiliary equipment to mobilize deposit pockets, and which was not covered by the jet mixer pumps, my comments are as follows:

- I estimate (from the drawing) that these deposit areas, about 1/8 of the total tank bottom, together equal about 50 m^2. It means that we could mobilize this sludge with two 4680 mixers (as I described above), using one mixer in each problem area. Each mixer could probably mobilize sludge with about 3500 Pa strength, as shown in my calculations above.

- I based the mixer selection on an assumed maximum specific gravity for slurry, no higher than 1.5, and a maximum viscosity of about 100cp. The maximum temperature is 90°F.

- Determining the critical shear stress for 3500 Pa strength sludge was based on a test (paper attached). During this test, the highest shear strength for sludge was 2000 N. It means that some extrapolation was applied to the calculations. This test is possible to repeat for a higher sludge shear strength if needed. It can be made in a small scale.

- I see another problem that we have to solve together during our discussions, or I need more information on the above project. It concerns the exact shape and dimensions of the problem area, as well as the riser location that we can use for the mixers. If we want to use one stationary mixer per problem area, we need to select the specific mixer location to mobilize the desired zone. It can be tricky or not possible at all if the risers are not located in the proper place. If this is the case, the next solution could be a rotation device for the mixer (there is one designed by Westinghouse).

- The above mixer was selected for a riser opening of 42". If we only have access to a smaller sized riser, we need to reconsider a smaller sized standard mixer or mixers. We can also bear in mind that Flygt US has a 50 HP specially built mixer that can be used together with a deployment (Westinghouse) mast in the 24" riser. Please also keep in mind that Flygt US is ready to build a 100 HP or larger mixer that can pass through a small riser (such as 24").

- I assumed that the proposed mixers will mobilize sludge in dead-zones when the mixer pumps will not be operating. During this time, suspended solids will be translocated to the ECR area swept by the mixer pumps or pump-down.

- The mixer will mobilize the sludge surface layer after layer, but it cannot be buried in the sludge at the beginning (if there is a deeper sludge layer on the bottom).

- The mixer should operate completely submerged as long as possible to provide operation without problems.

- We need to consider anti-vortex suppressors when long-term mixer operation is expected using a mixer that is not completely submerged.

I think that I covered most areas required by the customer. The above suggested mixer sizing is only preliminary since we have to discuss more details before final sizing can be completed.

Best regards,

Hanna Gladki

c. Stefan Abelin
Danny Adams-SER
Mike Dillard-SER
Pat Grella
Harry Langford-SER

TELEFAX MESSAGE FROM FLYGT SYSTEMS ENGINEERING

ITT Industries

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DATE: APRIL 11, 2000

FILE: T0406DD.DOC

MESSAGE TO: GREG LESHIKAR

COMPANY: FLYGT SEATTLE

MESSAGE FROM: HANNA GLADKI AND DAVID DAY

SUBJECT: FLYGT MIXER EVALUATION FOR HANFORD WASTE TANK AY-102

Dear Greg,

I am transmitting this memo to you from Hanna Gladki. It concerns the telephone conversation she had with you.

The telephone conversation was very useful since she could confirm her base data for the mixer selection, as well as clarify a couple of problems related to the mixer installation and operation within the tank. Right now, we will not select mixers for the AW-103 tank since risers are not available in this particular tank.

The memo is as follows:

During my conversation with Greg, we decided that I'll make the first mixer selection for the **AY-102** tank. This tank has two risers available for Flygt mixers. Each riser has a 34" diameter opening. They are very conveniently located along the tank's north-south diameter. I estimated that the distance of the center of the riser from the wall of the tank is about 16 ft. Two mixer pumps are located along the west-east diameter of the tank, and the center of the riser is also at a distance of about 16 ft. from the tank wall. I assumed the average value of the effective cleaning radius (ECR) for this tank equals 23 ft. If you make a circle of the ECR from each mixer pump, you can determine the cleaning area swept by the pumps. Part of this area is behind the tank wall due to the difference in distance of the mixer pump from the wall (16 ft) and ECR = 23 ft. These circles elapse a little in the middle of the tank. The mixer pump cleaning area does not cover the north and south parts of the tank.

The waste retrieval effectiveness of these two mixer pumps, with 23 ft ECR, was defined at the 64% level. I assumed that this percentage of the effectiveness level is directly proportional to the area of the bottom covered by the ECR. It means that 36% of the tank's wetted area is not covered by agitation of any kind, and here we need the Flygt mixers.

For the next step, I calculated the entire wetted area of the tank in which I included the tank bottom and wall at the 4 ft depth. In this particular tank, the total liquid depth is higher than 4 ft, which is desirable to avoid vortexes, but I ignored the higher depth for this calculation. I did this for two reasons: the mixers will be positioned horizontally at the bottom, and the core forces will be focused mostly at the lower level. Theoretically, shear stress distribution in the open channel section is the highest along the bottom and decreases upward from the walls to the liquid surface.

In the above method, the determined wetted surface area equals 499 m^2. If an assumed effectiveness of retrieval is 64%, the supplementary area to be cleaned out is about 180 m^2. This 180 m^2 is divided by two, with one 90 m^2 located at the north part of tank, and the second 90 m^2 located in the south part of the tank.

To clean these two parts of the tank, we could use Flygt 4680 / 40HP mixers. The 4680(18°)SJ mixer with a shroud has an 82% load on the motor and a thrust force of 6980N. It would be the best choice due to the high thrust, but the shroud geometry makes it too large for the 34" opening of the riser. In the future, we can discuss how to overcome this problem, but right now we have to go ahead with another mixer which can better fit the 34" riser. This is the 4680(14°)SF mixer without a shroud and with an 85% load on the motor. It delivers a thrust of 5480 N.

The average waste strength τ_s in this specific tank is 3060 Pa. According to the research done by M. Powell et al (you have a copy of this paper from my previous correspondence), the critical shear stress applied for 80% mobilization within the tank equals $0.05^*\tau_s$ (value of 5% shear strength). In the above case, the calculated critical shear stress τ_c=153 Pa. for the AY-102 tank.

If you install one 4680(14°)SF mixer in a fixed position in the tank (with a thrust of 5480 N), it can only cover a 35.8 m^2 area (of the 180 m^2 which is needed) with an average critical shear stress of τ_{cr} = 153 Pa.

Based on this 35.8 m^2 area, I calculated the effective radius from the mixer making a subjective assumption. First, I assumed that the 35.8 m^2 areas shape, covered by a stationary mixer, could be compared to an ellipse. It is a proper assumption since the highest momentum from the propeller travels in the center of the prop jet-line. It is why we cannot compare the shape of the area to a circle, but rather to an elongated circle. Second, my assumption concerns the ellipse geometry. I assumed that the longer radius of the ellipse is 1.4 times greater than the smaller one.

Based on the above assumptions, I found that the sweeping radius of the 4680(14°)SF mixer is about 8 m (26 ft). If this mixer is mounted at a rotating table and can circulate almost 360°, it will be able to mobilize an area of about 200 m^2. Hence, the two 4680 mixers will clean an area of about 400 m^2, which is much larger than they need (180 m^2). Unfortunately, they will need two mixers due to the mixer-jet-pumps, as well as the riser locations.

The above determined and depicted mixer cleaning area is valid when a 4680(14°)SF mixer is operating at full speed (440 RPM) / frequency.

The selected mixer, as I mentioned earlier, has the motor loaded at 85%. If the surrounding liquid temperature or slurry's specific gravity increases above the ambient, the power also rises. I would say that the mixer can operate without a problem up to an approximate 95% load. To stay on the safer side, I would advise applying a VFD, and we need to decrease the frequency when the power reaches its limit.

Let's assume the worse scenario for the AY-102 tank. The temperature rises to about 100°F and the Specific Gravity of the slurry is SG_s = 1.2. To keep the motor load no higher than 95%, we need to reduce the mixer speed / frequency. Hence, I determined that we need to reduce the mixer speed to 403 RPM (of 440 RPM full speed) and the frequency from 60 to 55Hz. The speed reduction will cause a decrease in the thrust to 4597N (of 5480N at full speed). But the increased specific gravity of the slurry (SG_s = 1.2) will cause a thrust boost to **5516** N. It means the lower frequency does not have any effect on the mixing results.

I am glad that all my calculations are very encouraging, and we can do an excellent job for the AY-102 tank. We have some extra forces from the mixers that can help to mix the tank well even with obstructions inside it. However, there are a number of problems that are solvable. I spoke to Greg about most of this matter, but we still need to discuss details. For instance, to reach its best performance and expected results, we need a special deployment mast for the mixer, as well as a rotating table. We need to protect the mixer blades against debris that might be found in the tank. In this case, a special mesh screen is usually attached to the mixer shroud.

To protect the motor from overloading, we will definitely need a VFD, as I mentioned earlier.

We have to protect the mixers against vortexes: to let them be submerged enough, or provide an anti-vortex suppressor.

We have to consider how the mixer can reach the bottom and start operating in a horizontal position if there is a deep layer of sludge. This problem is related to the deployment mast construction, but it is important to remember that the mixer has to have a very strong and stable mounting system to operate properly. It particularly concerns a very powerful mixer such as a 40 HP unit. The longevity of the mixer depends on a good, stable mounting structure.

Last, but not least, is the Flygt mixer's working in conjunction with the existing mixer-jet-pumps. This is a problem that has to be discussed sometime later.

We will discuss my calculations and other matters with Greg, and it would be helpful if you could transfer my memo directly to Greg.

Best regards,

Hanna Gladki

Greg, Please call me to discuss your comments and response to the information. We can set up another conference with Hanna as you require. Hopefully, I can meet with you during the mixer test that PNNL is doing at the Battelle Lab.

Regards,

David Day

TELEFAX MESSAGE FROM FLYGT SYSTEMS ENGINEERING

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DATE: MAY 18, 2000

FILE: T0520GL.DOC

MESSAGE TO: GREG LESHIKAR

COMPANY: COGEMA ENGINEERING

MESSAGE FROM: HANNA

SUBJECT: FLYGT MIXER EVALUATION FOR HANFORD WASTE TANK SY-102

Dear Greg:

I am sorry my answer was delayed, but we had job emergency.

As agreed, I will do this project the same way as for Tank AY-102, but I will not include details of my calculations in this memo.

During our last phone conference, we concluded that this tank is much more difficult to mix than AY-102 because of:

- two smaller (20") diameter risers,
- higher specific gravity (SG = 1.3),
- high shear strength (3880 Pa),
- shorter ECR = 21 ft,
- smaller percentage of cleared area (58%) by the mixer jet pumps,
- higher critical shear stress needed (τ_{cr} = 194 Pa) to mobilize 80% of the sludge from the tank bottom.

The riser locations along the south-north centerline (approximately ¼ of the diameter from the wall) are the encouraging part of this project.

The tank diameter is 75 ft. The calculated total wetted surface area is S = 499 m^2, which includes a 4 ft depth at the wall. If the mixer jet-pumps clear 58% of this area, the Flygt mixer's task is to clean the rest: about 209.6 m^2. Because we projected two mixers, each mixer has to clean about 104.8 m^2. It means the cleaning radius for the Flygt mixer is about 5.77 m.

Based on the above data, I prepared a couple of options for you:

1. **4640-083712SJ**, 4 HP, 83% load motor, 820 N thrust. This mixer does not need to have a trimmed propeller, however, the shroud has to be modified and a VFD is needed in the 1.3 specific gravity liquid. I assumed that the reduced thrust by the VFD would be compensated by the 1.3 specific gravity. Then based on the 820 N thrust, I determined the mixer cleaning radius such as 2.64 m (5.77 m radius is needed). It means that 1*4640 mixer can only clean a 21.8 m^2 area (of 104.8 m^2 area to be cleaned).

Page 2
05/18/00

2. **4660-125814SJ,** 15 HP, 85% load motor, 2890 N thrust. This mixer has to have trimmed prop blades and a modified shroud. I assumed that a prop blade diameter equaling 22-$^{13}/_{16}$ inches (0.50 m) will be trimmed to 19 inches (0.48 m). The decreased diameter will affect the thrust which will be reduced to 1356 N, but it recovers in the tank with an SG = 1.3, to a value of 1762 N. The one 4660 mixer with the trimmed prop (in liquid with 1.3 SG) has a cleaning radius of 3.53 m (5.77 m needed). The area mobilized by this mixer is 39.1 m^2 (of 104.8 m^2 needed). The smaller propeller reduces the power from 12 kW to 5 kW according to the affinity laws, then a VFD will not be needed. In this case, we have to be careful since it is very difficult to predict real results from diameter reduction. A 3+" (almost 4") diameter reduction can affect mixer performance more than I can predict by calculation. In this case, it is better to run a test to check the real mixer performance.

3. **50 HP mixer** which has just been tested at PNNL; has a 20" diameter, and a thrust of 6160 N. If we trim the prop diameter 1" to 19", the thrust will be reduced to 5231 N. However, in the 1.3 specific gravity liquid, the thrust recovers to 6917 N. It results in a cleaning radius of 7.97 m (5.77 m radius needed), and it covers a 199.7 m^2 area for sludge mobilization. According to the affinity laws, the power will be reduced from 37 kW to 30 kW. When PNNL finishes their test, we will know if we need to use a VFD or not. However, I would advise using a VFD as well as modifying the extended shroud on this mixer to a regular short jet-ring around the prop.

I attached some pages with dimensional drawings for mixers that I mentioned above. Later, we can discuss the mixer installation in detail when you decide which solution suits you the best.

Have a nice weekend and best regards,

Hanna

c. David Day - WA

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APPENDIX D. ASSESSMENTS OF VENDOR PERFORMANCE PREDICTIONS

June 13, 2000

Greg Leshikar
COGEMA Engineering Corp.
P.O. Box 840, H3-27
Richland, WA 99352-0840

Dear Greg:

Subject: Review of ITT Flygt Corporation Predictions for Flygt Mixer Performance in Hanford Double Shell Waste Tanks.

This letter is in response to your request for an assessment of the following memos provided by individuals of the ITT Flygt corporation. The memos are in regard to the application of Flygt Mixers in double shell tanks (DSTs) at Hanford. The following items were reviewed:

1. Memo dated March 17, 2000, from Hanna Gladki of ITT Flygt Corporation to David Day of ITT Flygt Corporation.

2. Memo dated April 11, 2000, from Hanna Gladki and David Day of ITT Flygt Corporation to Greg Leshikar of COGEMA Engineering.

3. Memo dated May 18, 2000, from Hanna Gladki and David Day of ITT Flygt Corporation to Greg Leshikar of COGEMA Engineering.

I am familiar with Flygt Mixers having obtained experience by performing the following:

- Technical consulting for the Tanks Focus Area (TFA) Phase B testing of Flygt Mixers (Powell et al. 1999b).
- Task leader for TFA 1999 Retrieval Process Development & Enhancement (RPD&E) assessment of alternate mixing and mobilization subtasks which included evaluation of Oak Ridge Site deployment of Flygt Mixers.
- Project manager for TFA Phase D testing of Flygt Mixers (Enderlin et al. 2000).
- Project manager for TFA full-scale longevity testing of 50-hp Flygt Mixer (Enderlin et al. 2000).

My overall assessment is that Flygt Mixers merit further evaluation for application in Hanford waste tanks. There currently does not appear to exist a sufficient method for obtaining predictions for the performance of Flygt Mixers in Hanford waste tanks, and I have strong reservations regarding the methodology employed by ITT Flygt for making operational

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predictions for Hanford tanks. The majority of the data used by Flygt to develop their methodology was obtained from tests conducted in a 45-cm diameter tank that did not approach geometric, dynamic, or kinematic similarity. A brief discussion regarding the scaled tests performed by Flygt is presented later.

The mobilization and mixing to be performed in the Hanford waste tanks requires a somewhat different approach than is typically used throughout industry. The majority of mixing processes within industry use large mechanical mixers with blade diameters that are on the order of one-half to one-fourth the diameter of the tank. Momentum is transferred directly to the fluid via the mechanical blades and the flow patterns within the tank consist of relatively high velocity secondary flows compared to the velocity of the fluid passing through the blades. The ratios for the tank diameter to the liquid height in industrial mixing processes are often on the order of 2:1 to 1:2.

The Hanford tanks contain small access ports (12 in. to 42 in.) which limit the size of the equipment that can be deployed. A 40 inch diameter mixer would have a diameter that is approximately 1/22 the diameter of the tank. In the Hanford tanks, whether employing jet -mixer pumps or Flygt Mixers, momentum is transferred to the bulk of the fluid via turbulence. In other words, the total energy added to the fluid is essentially being supplied at a point compared to a long mixer blade which may sweep over one-fourth of the tank floor. In a Hanford tank, the velocity of the secondary flow produced by a single mixer is relatively low compared to the primary flow along the centerline of the device. The ratios for the tank diameter to the liquid height in the Hanford tanks during mobilization and retrieval operations are predicted to range from 3:1 to 19:1.

These differences between standard industry mixing configurations and those to be employed in Hanford waste tanks is why much of the published mixing literature is not applicable for making sound predictions of performance. Work has been carried out here at Hanford in an attempt to improve the capability for predicting full-scale performance of mixing equipment in large waste tanks that may potentially be deployed throughout the DOE complex. One such effort has been the development of correlations for predicting the effective cleaning radius (ECR) for jet mixer pumps. This work has been conducted using jets scaled to the configuration proposed for jet mixer pump applications in large waste tanks. A wide range of simulants with varying shear strengths were used, however, the geometrical configuration evaluated remained fixed. This work resulted in correlations developed from curve fits of the data. The correlations take the form:

$$ECR = KU_oD(\tau_{ss})^n$$

Where:
K = Experimentally determined coefficient
U_o=Fluid velocity at exit of jet nozzle
τ_{ss}=Shear strength of settled layer of solids
n = Experimentally determined constant

The ITT Flygt memos discuss the "ECR of the tank" and use this concept without discussing the configuration of the mixer or the coefficients employed. The ECR is the distance down stream of the jet, measured on the jet centerline, at which the shear stress applied by the jet to the solid material is not sufficient to mobilize material. The shear stress applied by the jet is not only a function of the jet exit velocity and diameter, but also the height of the jet relative to the solid boundary. A jet that is not influenced by a boundary is referred to as a free jet and it does apply a shear stress to the boundary. A jet that is initiated at a solid boundary is referred to as a wall jet and imposes a shear stress at the boundary immediately downstream of the jet exit. A jet that is raised above the boundary and whose downstream flow is influenced by the boundary is referred to as an attaching jet. The jet exits the nozzle as a free jet and then experiences a transition zone where it transitions from a free jet to a floor jet. Within this region of transition, the height of the peak velocity actually changes location. The shear stress applied by an attaching jet on the boundary will increase with distance from the jet, reach a peak, and then decay with axial distance from the jet.

An idealized jet contains axial flow only and contains no tangential flow (often referred to as swirl). It has been observed in past experimental work that the behavior of an attaching jet and the measured ECR are effected if a swirl component exists in the jet flow. The rotating propeller of a Flygt Mixer introduces significant tangential flow to the fluid. During past experimental work conducted at PNNL during Phase-D testing, It was observed that the area eroded by the small-scale Flygt Mixers was significantly different than that observed for jets. The aspect ratio, width vs. length, of the area cleared was less than that observed for a jet, and the farthest distance cleared of material did not exist on the centerline of the jet. It is unknown how Flygt selected the coefficients used for determining the ECR of the Flygt Mixers in their predictions. It is not considered valid to apply an ECR correlation developed from data obtained for a jet in a specific configuration to make predictions for Flygt Mixers that produce a different flow profile. The distance from the floor assumed for making the performance predictions should also be provided.

The majority of data used to develop the methodology employed by Flygt was obtained from tests conducted in a 45-cm diameter tank. While the Phase A work conducted by TFA (Powell et al. 1999a) does not present the original work used to develop the methodology, it does describe the setup and the type of tests conducted. Testing conducted in the 45-cm (18 in.) tank used a non-shrouded (no standard jet ring) mixer that was approximately 8 cm in diameter. This is geometrically similar to using a 4.1-m (13.3-ft) diameter mixer in the waste tanks.

Based on test photos the mixer was approximately 16 cm long. Therefore, the maximum down stream distance between the propeller and the tank wall was approximately 3.6 mixer diameters. If the flow produced by the mixer is compared to that of a jet, the wall exists within the core of the jet. Therefore, no decay of the centerline jet velocity would have occurred. If a 76 cm (30 in.) Flygt mixer or a 15.2 cm (6 in.) diameter jet nozzle is placed in the center of a 22.9 m (75 ft) tank, the wall will be approximately 15 and 75 diameters downstream, respectively. Significant reduction in the centerline velocity for both devices will exist by the time the flow reaches the tank wall.

The aspect ratio of the tank diameter to the liquid height in Flygt's tests was between 2.6:1 and 1: 1.75 compared to 3:1 to 19:1 expected in the Hanford tanks. The relative size of the propeller in the Flygt tests means that the velocity of the secondary flow will be relatively higher than those that will occur in a 75-ft tank.

The Phase B report (Powell et al. 1999b) presents the results of similar tests using a larger diameter tank (1.8 m). However, geometric similarity was not maintained between the two-scaled tests and the applicability of the conditions employed in the 1.8-m tests to the Hanford waste tanks is also in question. The data from test conducted in the 1.8-m diameter tank using fast settling (< 1 cm/s) granular particles did not support the methodology of using an average wall shear stress. It is unknown where successful scale up of Fygt's methodology has been tested using at a minimum geometric similarity.

Flygt also employs a constant height of 1.2-m (4 ft) to the tank wall when calculating the area for determining the average wall shear stress. It is unknown how the height of 1.2 m was chosen. In the 45-cm tests the ratio of the wetted wall height to the mixer diameter was 3.4:1. For a 30-in. diameter mixer in the Hanford waste tank, 1.2-m (4 ft) gives a wetted wall height to mixer diameter (assuming 30-in. mixer) of 1.6:1.

The large discrepancy in geometric similarity between the Flygt tests and the conditions to be encountered in the Hanford tanks makes it difficult to accept this methodology for making even rough predictions for performance in the Hanford tanks. Considering the fact that in the Flygt tests the mixer is so close to the wall that a fully developed jet cannot exist, the Flygt tests do not seem to address the same mixing phenomena that will occur in the Hanford tanks. Test data for Flygt's methodology should be collected and evaluated for geometrically similar conditions.

It should be mentioned that the scaling of the flow produced by the rotating propeller is more complicated than that produced by a pressurized nozzle. The rotational speed of the propeller, the hub diameter, blade pitch, etc., are additional parameters that must be considered and that are not just resolved by geometric scaling.

It is highly recommended that tests be conducted to characterize the flow created by the Flygt Mixers and evaluate the effects of changes in scale. Comparative tests should also be conducted to compare Flygt Mixer performance to that of a jet-mixer pump at the same scale.

<u>References</u>

Enderlin, C.W., W. H. Combs, M. White, and B. K. Hatchell. 2000. *Evaluation of Flygt Mixers for Application in Savannah River Site Tank 19.* Letter Report documenting Completion of Department of Energy TTP RL3-6-WT-51 Milestone A.1-4.

Powell, M.R. J.R. Farmer, H. Gladki, B. K. Hatchell, M. R. Poirer, and P.O. Rodwell. 1999a. *Evaluation of Flygt Mixers for Application in Savannah River Site Tank 19, Test Results from Phase A: Small-Scale Testing at ITT Flygt.* PNNL-12094, Pacific Northwest National Laboratory, Richland, Washington.

Powell, M.R., W.H. Combs, J.R. Farmer, H. Gladki, M.A. Johnson, B. K. Hatchell, M. R. Poirer, and P.O. Rodwell. 1999b. *Evaluation of Flygt Mixers for Application in Savannah River Site Tank 19, Test Results from Phase B: Mid-Scale Testing at PNNL.* PNNL-12093, Pacific Northwest National Laboratory, Richland, Washington.

Transmittal 00-1560-001

To:	David Day	ITT Flygt Industries
cc:	Hanna Gladki Eric Pacquet	ITT Flygt Industries Numatec Hanford Corporation
From:	Greg Leshikar	
Date:	April 21, 2000	
Subject:	Comments on Flygt Model 4680 Performance Prediction for Tank AY-102	

Reference: Telefax Message, April 12, 2000, Hanna Gladki and David Day to Greg Leshikar, T0406DD.

The following are my personal comments and questions regarding the Flygt Model 4680 propeller mixer performance prediction (Ref.) for Tank AY-102.

1. The predicted effective cleaning radius (ECR) for the Flygt Model 4680 mixer (26 ft) is greater than the predicted ECR for our jet mixers (23 ft). Assuming both these predictions are accurate, this tells me we would be better off replacing our primary mobilization jet mixers with the propeller mixer (?). When I plug lower values of waste shear strength into the given equations assuming critical shear stress (τ_c) equals 5% of average waste shear strength (τ_s), the results can be very large ECR's. For example, for τ_s =1000 Pa, I get a ECR = 46 feet. For τ_s = 363 Pa which was used in Phase B kaolin clay test in 5.7m tank, I get an ECR = 76 feet. These seem questionably large ECRs to me. On the flip side, the Phase B test report indicates critical shear stress may be as great as 15% of average waste shear strength. When I run the numbers for τ_s =3060 Pa at .15τ_c I get an ECR of 15 feet (4.6 m), versus 26 feet for 5%. When used as a sweeping radius to cover 360° the area mobilized is 67 m^2 which does not clean out the entire area of 90 m^2.

It seems to me that tying the Phase B testing average wall stress method to an ECR through the radius of an ellipse assumption is a stretch (comparing "apples-to-oranges") and introduces substantial uncertainty to the accuracy of the prediction. However I can't say I know a better way to do it. I thought of one way, which was to rely only on average wall stress method by dividing thrust (5480 N) by wetted area to be cleaned out by each pump (18% or 90 m^2) to get a τ_c = 61 Pa. Then dividing τ_c / τ_s , 61/3060 = 2% of waste shear strength. This indicates a stationary mixer not capable of mixing the entire area, but maybe a rotating mixer could. The problem then is determining how much waste surface area or ECR the mixer needs to cover in a particular orientation which leads one back to Hanna's ellipse assumption.

Our minimum ECR requirement per RPP-5664 (included with original transmittal) is 3 m (9.8 ft). Considering sensitivity of key parameters above, the prediction method shows reasonable probability the minimum mobilization criteria can be met. My questions are: Do you have a feel for the approximate accuracy of the prediction method? How can we increase accuracy of prediction method (future development work)? Is there a range of applicability (of shear stresses) to this prediction method? Does this method scale up unchanged from small-scale tests to the full scale tank?

2. The assumption is made to consider the wall height for the wetted area calculation as 4 feet. Is this consistent with Flygt's general practice? Where do you normally "draw the line" for the height, is it normally the full tank? It seems to me in our application the propeller mixer might be affecting a wall height greater than 4 feet as the jet disperses in the fluid toward the wall. Also, in reviewing Test 8 from the Phase B testing, the mobilization results increased dramatically when the test tank was pumped down from 2 m to 1 m. Is there a good way to estimate mobilization performance as a function of liquid height, or is this a needed area of future development work?

3. I understand when the specific gravity of the fluid goes up, speed may reduced commensurately for no net change in thrust provided (equivalent to higher density fluid being pumped at a lower flow rate). But the downstream velocity will be less, does this affect the mobilization effectiveness? I noticed it was of great importance during Phase A, B, and C testing to measure the downstream velocity. I don't fully understand what is more important to sludge mobilization, thrust provided by the unit or the value of the downstream velocity. Any insight would be appreciated.

These are my main questions and comments regarding the mixing prediction. Dave and Hanna, either call me to discuss or send me response and then we can discuss. Then we can also discuss the mechanical equipment (VFD, deployment mast, etc.). Unfortunately I am beginning to run short of time to finish my report. After we work these through then we need to hit the SY-102 evaluation. My assumption is the same method will be applied there, so it should go pretty quickly.

DON'T SAY IT — *Write It!*

TO:	Greg Leshikar	S0-08	DATE:	April 20,2000	
Cc:	Eric Pacquet	R3-47	FROM:	Craig Shaw	R3-74
				Telephone: 376-0814	

SUBJECT: Flygt Mixer Evaluation

To attempt understanding the Flygt Mixer Evaluation memo of 4/11/00 one must read in detail the testing report of the PNNL and Savannah River testing, RPP-5664, and the first Flygt memo Hanna Gladki to David Day 3/17/00. My impression after reading all of these is that a Flygt Mixer's prospect of waste mobilization success is no better or worse than the present baseline mixer pumps. Inferred performance of either mixer is limited by lack of in situ waste shear strength knowledge. Reading the report on the PNNL and Savannah River testing, I feel the testing was designed to evaluate Savannah River's retrieval approach. SRS uses partial tank recovery by adding a few feet of liquid to the surface, mixing it up, pumping it out and repeating the process (this is good because SRS paid for the test). However, Hanford plans to mobilize and homogenize an entire tank at a time. Hanford's approach would have a very large "wetted area" that would imply a very large thrust would be needed for mobilization.

The Flygt mixer pump testing uses different relationships of parameters to predict mobilization effectiveness i.e. (thrust divided by wetted area to compute) average wall shear stress being above a certain percentage of waste shear strength to achieve mobilization. Submerged jets driven by centrifugal pumps use fluid velocity and momentum (U_0D) to predict an effective cleaning radius. I was never able to understand how these two different methods to predict mobilization effectiveness were connected in the 7,8,9 th paragraphs of the 4/11/00 memo. The 4/11/00 memo (for AY102) predicts a 26 ft ECR for a Flygt pump of 5480 newtons thrust while the U_0D method predicts 23 ft ECR for a submerged jet U_0D = 29.4 ft2/sec; U_0D = 29.4 ft2/sec is 6000 newtons thrust!

How big is the vortexing problem? The model mixer Flygt proposes moves 30,000 gpm while submerged jet mixers move 10,000 gpm and encounter vortexing at 36" submergence. Will Flygt pumps need more submergence? How well would a Flygt mixer work in a fluid viscosity of 500 to 1000 cP, does viscosity simply increase power required the same as centrifugal pumps?

The low cost of about $50k for a Flygt can be misleading because it doesn't include the cost of the mast, turntable etc. As a comparison, the third hydrogen mitigation mixer pump for 101SY cost $1.3 million with only $350k for the pump itself. $950k was for the equivalent of the mast, turntable etc. It should be pointed out the SY101 mixer pump can operate with the asymmetric thrust of a plugged nozzle which would be roughly equivalent to the unbalanced thrust of a Flygt mixer, designing the ability to handle asymmetric thrust is not cheap.

There are some very attractive features to a Flygt pump if it's built with a very sturdy mast and properly deployed and operated. In tanks where a mixer pump must be vertically raised up and down a Flygt could also swivel up and down as well as rotate giving it a tremendous advantage to burrow to the bottom. Flygt mixers also have other advantages; a major one being that lower horsepower will not heat the tank as fast. Slower tank heat up is particularly desirable because

A-3000-723 (01/98)

of the limited heat removal capacity of the ventilation system. Informal analysis shows the baseline of two 300 hp mixer pumps will heat the tank at rates exceeding that of the authorization basis when the tank is partially full and their power must be turned down. The lower powered Flygt pumps could still operate at full power even at reduced tank levels.

Another advantage of Flygt mixer is that one directional thrust imparts net momentum to the waste which, given time, can result in substantial circulating velocities. Full scale testing of Flygts at SRS has used them in what they call "racetrack mode" where the entire tank circulates and ends up sweeping all the solids to the middle where the transfer pump could be located. This "racetrack mode" has real potential for tanks not cluttered with ALCs and other fragile items.

My personal opinion is a Flygt mixer attached to a sturdy mast that can move up and down, swivel, and rotate should be built and tested. There are so many unknowns as to how well the baseline mixer pumps might work for mobilization that we need a ready alternative if they come up short.

end

A-3000-723 (01/98)

CORRESPONDENCE DISTRIBUTION COVERSHEET

Author	Addressee	Correspondence No.
D. M. Squier, 376-4346	Mr. E. A. Pacquet, NHC	FH-0002672

Subject: PREDICTED FLYGT MIXER PERFORMANCE ASSESSMENT FOR DOUBLE-SHELL TANKS

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May 19, 2000

FH-0002672
Reissue

Mr. Eric A. Pacquet, Manager
Retrieval System Development
Numatec Hanford Corporation
Post Office Box 1300
Richland, Washington 99352

Dear Mr. Pacquet:

PREDICTED FLYGT MIXER PERFORMANCE ASSESSMENT FOR DOUBLE-SHELL TANKS

References:

1. Letter from D. W. Day and H. Gladki, ITT Industries Flygt Corp., to G. Leshikar, COGEMA Engineering Corp., dated April 12, 2000.

2. Letter from D. W. Day, ITT Industries Flygt Corp., to G. Leshikar, COGEMA Engineering Corp., dated March 17, 1000, with attachment, "Mobilization of Cohesive Sludge in Storage Tanks Using Jet Mixers," authors, M. R. Poirier, H. Gladki, M .R. Powell, P. O. Rodwell, PNNL.

3. EDT 628093 for RPP-5664, Rev. 0, "Derived Requirements for Double-Shell Tank High Level Waste Auxiliary Solids Mobilization," dated February 28, 2000.

4. Work Plan Rev. 0, Engineering Study,"Evaluation of Flygt Mixers for Double-Shell Tank High Level Waste Auxillary Solids Mobilization," dated December 2, 1999.

5. Table 9 - 3 , "Applied Fluid Dynamics Handbook," author, Robert D. Blevins, publisher, Krieger Publishing Company, Malabar, Florida, applied copyright date, 1984.

NOTE: This letter is a reissue of a letter dated April 15, 2000; please dispose of copies so dated.

High-level radioactive waste tanks contain solids that have settled into sludge on the tank bottoms. This sludge must be mobilized to aid the retrieval process for ultimate disposal. Flygt mixers are being considered as an auxiliary means to mobilize waste tank sludge. These mixers utilize a submerged motor to drive a ducted propeller blade.

The engineering study (Reference 4), "Evaluation of FLYGT Mixers for Double Shell Tank High Level Waste Auxiliary Solids Mobilization," Revision 0, Section 3.1.3, identified a subtask to assess the mixer's predicted performance. This letter presents the Engineering Laboratories independent evaluation of the data available for predicting Flygt mixer performance documented in the test report paper (Reference 2), "Mobilization of Cohesive Sludge in Storage Tanks Using Jet Mixers."

Mr. Eric A. Pacquet
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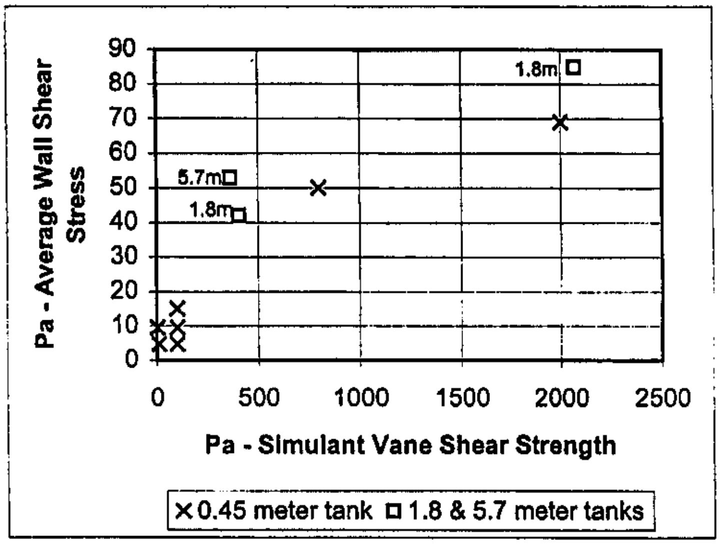

These small-scale tests were conducted in 0.45 m, 1.8 m and 5.7 m diameter tanks. The tests draw a relationship between measurements of sludge shear strength, tank-wetted area and mixer thrust to the percentage of sludge mobilized.

A motor speed controller varies the mixer thrust. The mixer thrust divided by the tank-wetted area gives an Average Wall Shear Stress (AWSS) value. The tests incremented the AWSS to determine a value that mobilized 80 percent of the sludge simulant.

Figure 1 is a reproduction of the AWSS versus the sludge shear strength plot presented in the paper. Seven of the data points were collected in the 0.45 m tank, two points were measured in the 1.8 m tank and one point was measured in the 5.7 m tank. Data points collected using similar sludge shear strengths in different sized tanks vary by as much as 20 percent.

Figure 1 Average Wall Shear Stress vs. Shear Strength

The tests are based on sludge simulants with a shear strength of 0.010 kPa to 2 kPa. Five of the data points used a simulant with shear strength of 0.1 kPa or less. The Hanford waste tank solids handling equipment must mobilize sludge with a minimum shear strength of 3.38 kPa as detailed in the requirements document (Reference 3), "Derived Requirements for Double-Shell Tank High-Level Waste Auxiliary Solids Mobilization," RPP-5664, Rev.0.

The tests produced a very limited number of data points. The tests used simulants with a shear strength that is two-thirds of the minimum shear strength stated in the requirements document. The required AWWS varies between the different tank sizes for a given sludge shear strength. This small data set does not contribute to a high level of confidence in the ability to extrapolate mixer performance in a full sized tank.

The ability to mobilize settled sludge requires a shearing force to erode the exposed sludge surface. These shearing forces are developed by fluid flowing over the sludge surface. The greater the fluid velocity, the greater the shearing force. Analytical methods permit the calculation of submerged jet velocities at distances from the source nozzle. These calculated velocities represent idealized conditions, but they can be used as a basis for performance comparisons between types of equipment. Equation 1 details the calculation of the jet stream centerline velocities at distances from the nozzle.

$$V_x = \frac{12 \times (\textit{Nozzle Exit Velocity}) \times (\textit{Nozzle Radius})}{\textit{Distance From Nozzle}}$$

$$\textit{where:} \quad V_x = \textit{Velecity At Distance } X \textit{ from Nozzle}$$

(From Reference 5: Table 9-3 Submerged Turbulent Jets, "Applied Fluid Dynamics Handbook")

Equation 1 - Jet Stream Centerline Velocity

Figure 2 is a plot of the calculated submerged jet centerline velocities produced by a mixer pump nozzle and a Flygt mixer at distances from the jet source. The plot represents a mixer pump with a 0.15 m (0.5 foot) diameter nozzle and a 20,751 liters per minute (5,482 GPM) flow rate. These specifications match those of a single nozzle in the 223 kW (300 horsepower) dual nozzle pump installed in tank 241-AZ101. The Flygt mixer velocities represent a model 4680 with a 0.77 m (2.51 foot) diameter "nozzle" and a 116,628 liters per minute (30,810 GPM) flow rate.

A constant velocity flow region, termed the initial region, extends 10 nozzle radii downstream from

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the nozzle. A transition region bridges the area between the initial region and the fully developed flow region. Equation 1 provides values for the fully developed flow region and this is the only region plotted on Figure 2.

Two traces are shown for the Flygt mixer to bound the range of predicted fluid velocities. This mixer will have a swirl component that may reduce the fluid velocity. One trace is the idealized velocity without the swirl component. It is assumed that the swirl component will reduce the initial region by one half so the "swirled" trace is offset along the X-axis by that amount. The plot suggests that the Flygt mixer will have a performance similar to the jet mixer pump at the waste tank's outer reaches.

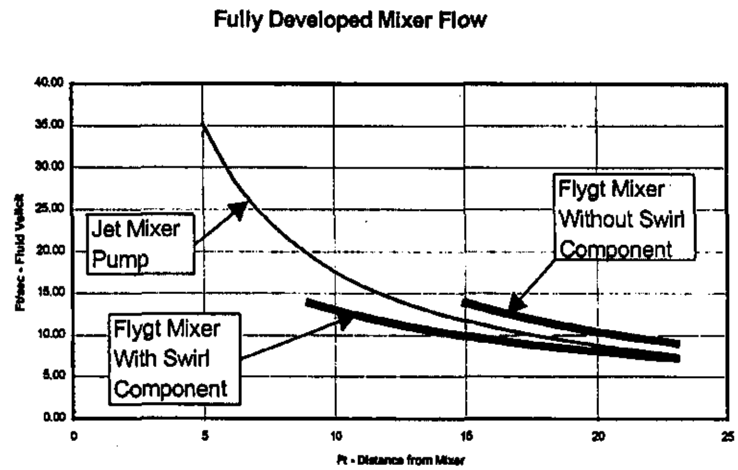

Figure 2 Centerline Mixer Flow Velocities

ITT Corporation letter (Reference 1), "Flygt Mixer Evaluation for Hanford Waste Tank AY-102", dated April 12, 2000, describes the application of the auxiliary mixers in a waste tank. The two oscillating jet mixer pumps are installed in diametrically opposed risers. ITT's letter assumes the jet mixer pumps are effective over 64% of the tank bottom. The remaining 36% of the tank bottom would be agitated by two oscillating Flygt mixers installed in individual risers, 90° from each jet mixer. All the mixers are installed in risers 4.9 meters (16 ft) from the tank wall. Given that the two mixer types produce similar velocities at 4.9 or more meters, they can be expected to have similar effectiveness in sludge mobilization.

The reviewed experimental data is too limited to predict Flygt mixer performance in a full sized Hanford waste tank. The independent assessment provided by the analytical results indicates the Flygt mixer may perform similar to the installed jet mixer pumps over the effective cleaning radius (23 feet) quoted in reference 1. Well-conceived experimental measurements will provide the greatest assurance that a piece of equipment will work correctly. A better judgment on the suitability of Flygt mixers could be made with limited tests using simulants having characteristics

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similar to the Hanford tank contents.

As a minimum, it is necessary to determine a flow velocity that will erode the sludge surface. This can be accomplished by a small-scale test in a flow trough. A sludge simulant would be placed in the trough and recirculated flow would be directed over the simulant. The trough flow velocity is monitored and incremented until erosion is observed.

Large tank Flygt mixer tests are underway to support Savannah River's installation. This test facility could be used to take measurements of the Flygt mixer flow velocities at increasing distances from the mixer. Possibly, analytical adjustments to the velocity measurements would be necessary to account for differences in density and viscosity. If the sludge erosion velocity is known, then the effective mixer-cleaning radius can be determined by these measurements.

This independent analytical assessment indicates that the jet mixer pumps and Flygt mixers are expected to produce similar fluid velocities over the cleaning radius required in the waste tank geometry. This suggests that the sludge mobilization effectiveness of the two mixer types will be similar.

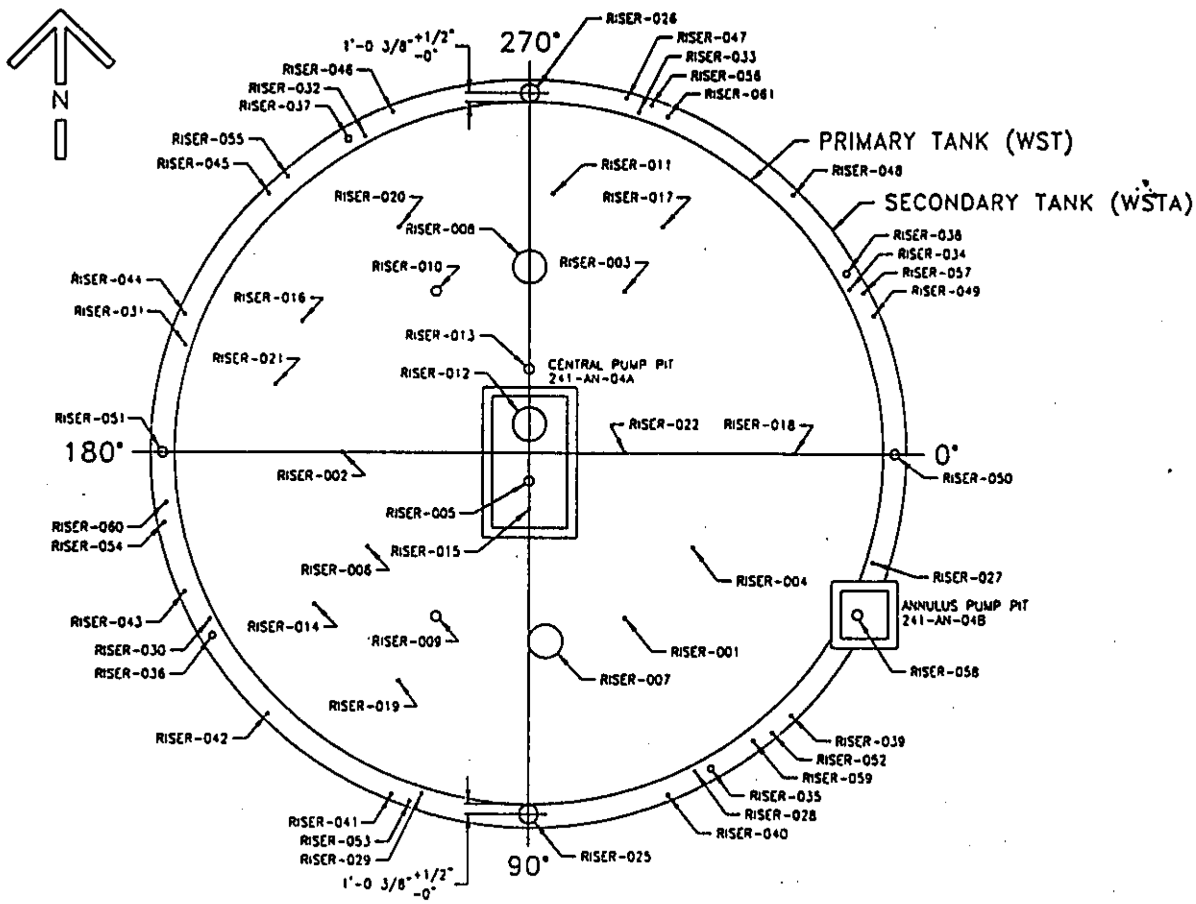
Very truly yours,

D. M. Squier, Engineer
Engineering Laboratories
Site Services

ljg

Appendix E

TANK LARGE RISER SURVEY

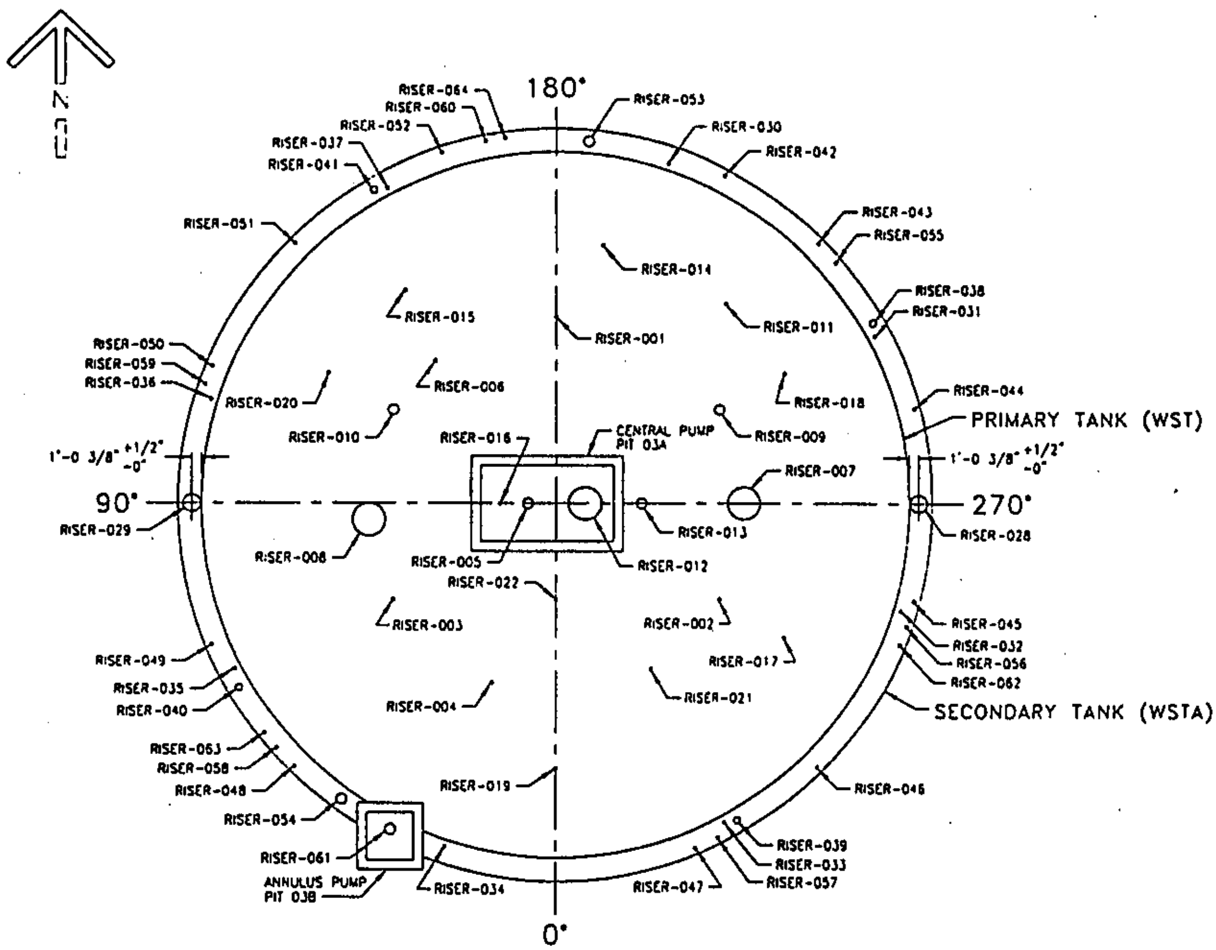


PLAN VIEW TANK 241-AN-104

H-14-010501, REV 2, SH 4

PROJECT W-211 AN-104 PROJECTED LARGE RISER UTILIZATION			
RISER NO	DIAMETER	EQUIPMENT INSTALLED	AVAILABILITY
005	12"	TRANSFER PUMP	NO
007	42"	MIXER PUMP	NO
008	42"	MIXER PUMP	NO
012	42"	CAMERA	YES
013	12"	TEMPERATURE PROBE	YES

UTILIZATION BASED ON HNF-1507 AND DISCUSSION WITH PROJECT W-211 PERSONNEL. WHERE EQUIPMENT LISTED AS INSTALLED, BUT "AVAILABILITY" IS "YES", INDICATES MOVEMENT OF PROJECT EQUIPMENT TO ANOTHER RISER IS POSSIBLE.

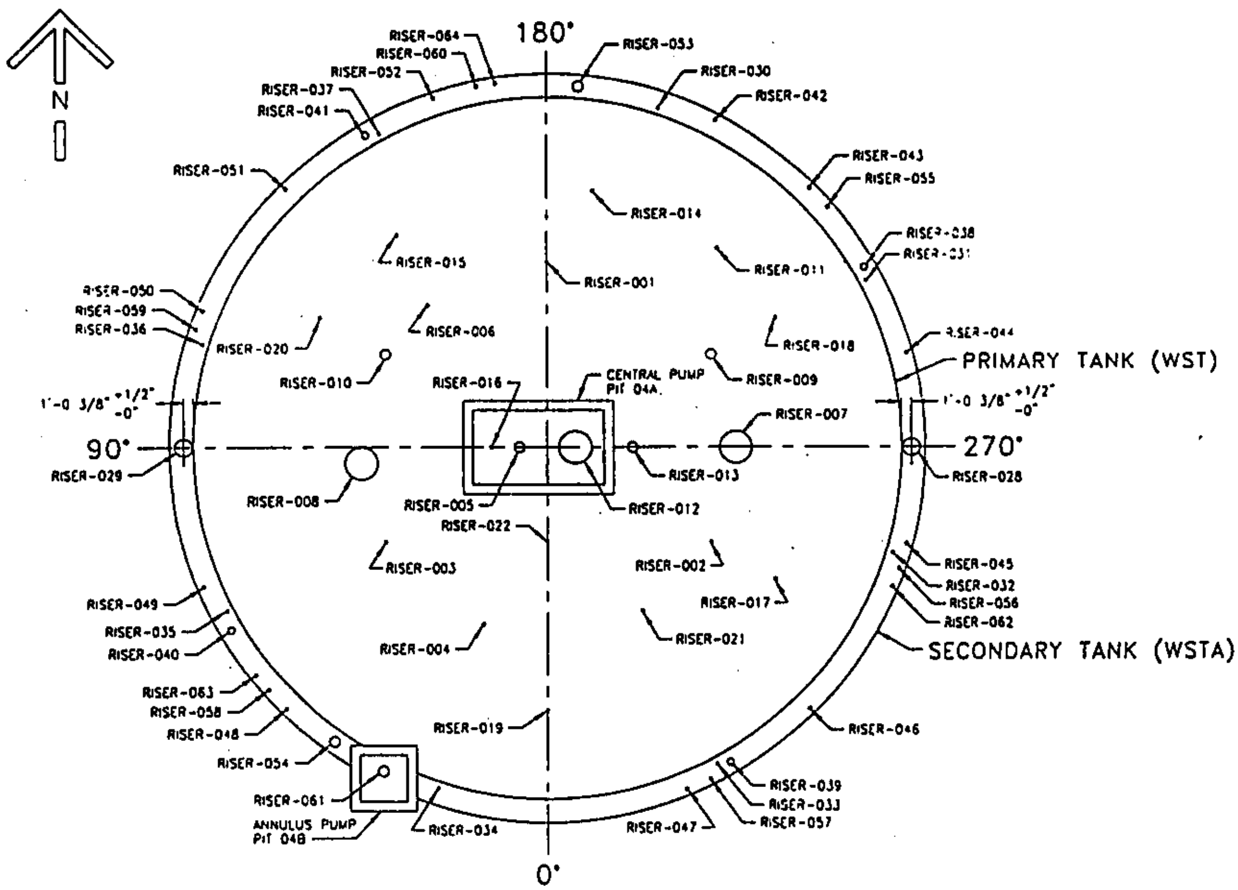


PLAN VIEW TANK 241-AW-103

H-14-010502, REV 1, SH 3

PROJECT W-521 AW-103 PROJECTED LARGE RISER UTILIZATION			
RISER NO	DIAMETER	EQUIPMENT INSTALLED	AVAILABILITY
005	12"	NONE	YES
007	42"	MIXER PUMP	NO
008	42"	MIXER PUMP	NO
012	42"	TRANSFER PUMP	NO
013	12"	CAMERA	YES

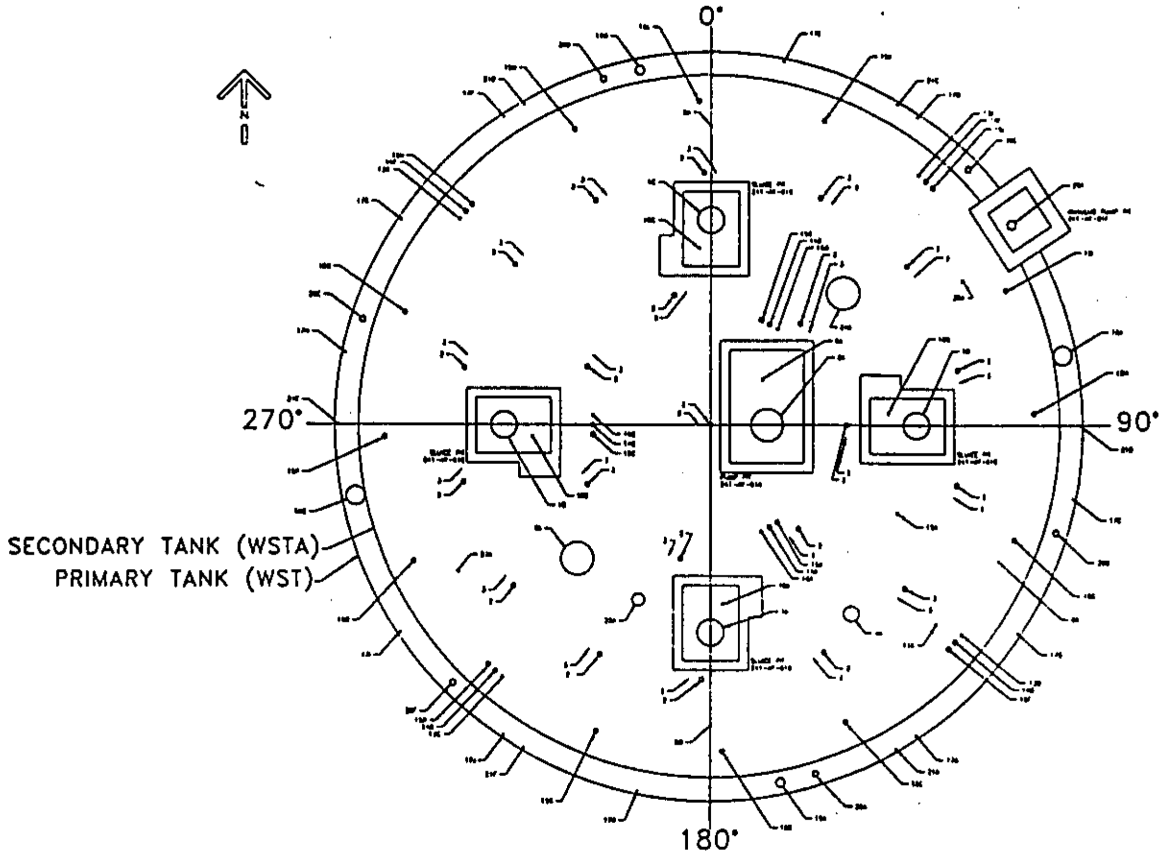
UTILIZATION BASED ON HNF-4408 AND DISCUSSION WITH PROJECT W-521 PERSONNEL. WHERE EQUIPMENT LISTED AS INSTALLED, BUT "AVAILABILITY" IS "YES", INDICATES MOVEMENT OF PROJECT EQUIPMENT TO ANOTHER RISER IS POSSIBLE.



PLAN VIEW TANK 241-AW-104

H-14-010502, REV 1, SH 4

NEITHER PROJECT W-211 NOR W-521 BASELINE PLANNING INSTALLS PRIMARY MIXER PUMPS IN AW-104. IT IS ASSUMED RISERS -007 AND -008 ARE AVAILABLE FOR THE PROPELLER MIXER AT THIS TIME.



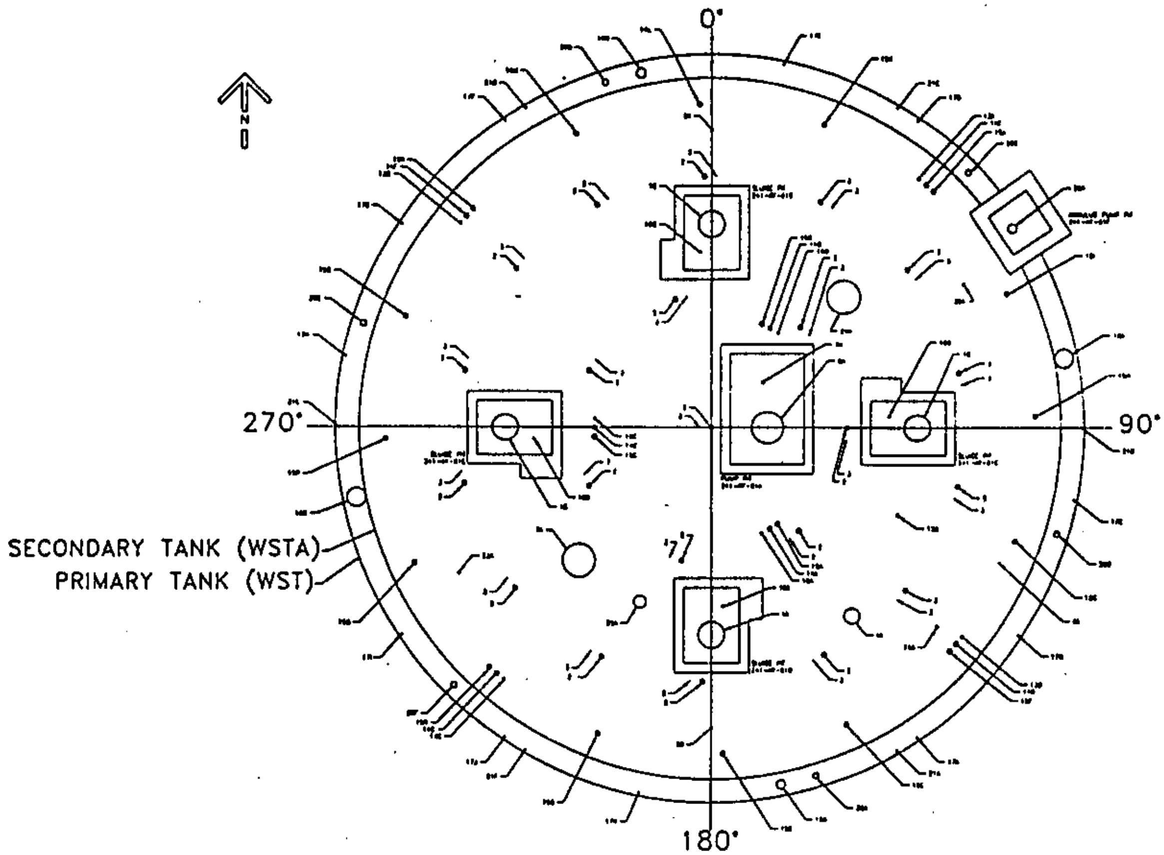
PLAN VIEW TANK 241-AY-101

H-2-64447, REV 7, SH 1

PROJECT W-521 AY-101 PROJECTED LARGE RISER UTILIZATION			
RISER NO	DIAMETER	EQUIPMENT INSTALLED	AVAILABILITY
1A	34"	MIXER PUMP	NO
1B	34"	SEE NOTE BELOW	SEE NOTE
1C	34"	MIXER PUMP	NO
1D	34"	SEE NOTE BELOW	SEE NOTE
6	42"	TRANSFER PUMP	NO
7	42"	STEAM COIL (INACTIVE)	NO
22	16"	OPEN	YES
24	42"	CAMERA	YES

UTILIZATION BASED ON HNF-4408 AND DISCUSSION WITH PROJECT W-521 PERSONNEL. WHERE EQUIPMENT LISTED AS INSTALLED, BUT "AVAILABILITY" IS "YES", INDICATES MOVEMENT OF PROJECT EQUIPMENT TO ANOTHER RISER IS POSSIBLE.

PROJECT BASELINE IS EXPECTED TO BE REVISED FROM (4) 150 HP PRIMARY JET MIXER PUMPS TO (2) 300 HP MIXER PUMPS. IF THIS DOES NOT OCCUR, THEN THEN THIS RISER IS NOT AVAILABLE.



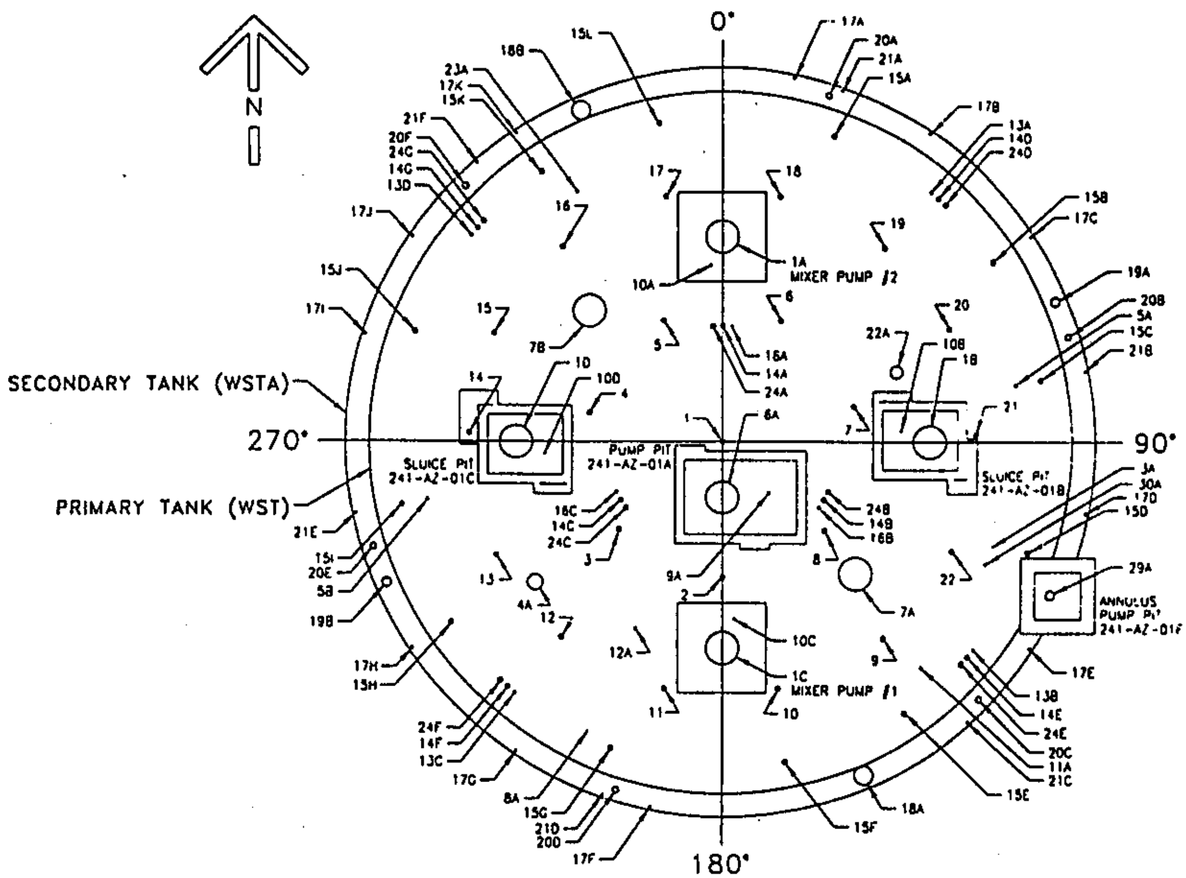
PLAN VIEW TANK 241-AY-102

H-2-64447, REV 7, SH 1

PROJECT W-211 AY-102 PROJECTED LARGE RISER UTILIZATION			
RISER NO	DIAMETER	EQUIPMENT INSTALLED	AVAILABILITY
1A	34"	MIXER PUMP	NO
1B	34"	SEE NOTE BELOW	SEE NOTE
1C	34"	MIXER PUMP	NO
1D	34"	SEE NOTE BELOW	SEE NOTE
6	42"	TRANSFER PUMP	NO
7	42"	STEAM COIL (INACTIVE)	NO
22	16"	OPEN	YES
24	42"	CAMERA	YES

UTILIZATION BASED ON HNF-1507 AND DISCUSSION WITH PROJECT W-211 PERSONNEL. WHERE EQUIPMENT LISTED AS INSTALLED, BUT "AVAILABILITY" IS "YES", INDICATES MOVEMENT OF PROJECT EQUIPMENT TO ANOTHER RISER IS POSSIBLE.

PROJECT BASELINE IS EXPECTED TO BE REVISED FROM (4) 150 HP PRIMARY JET MIXER PUMPS TO (2) 300 HP MIXER PUMPS. IF THIS DOES NOT OCCUR, THEN THIS RISER IS NOT AVAILABLE.



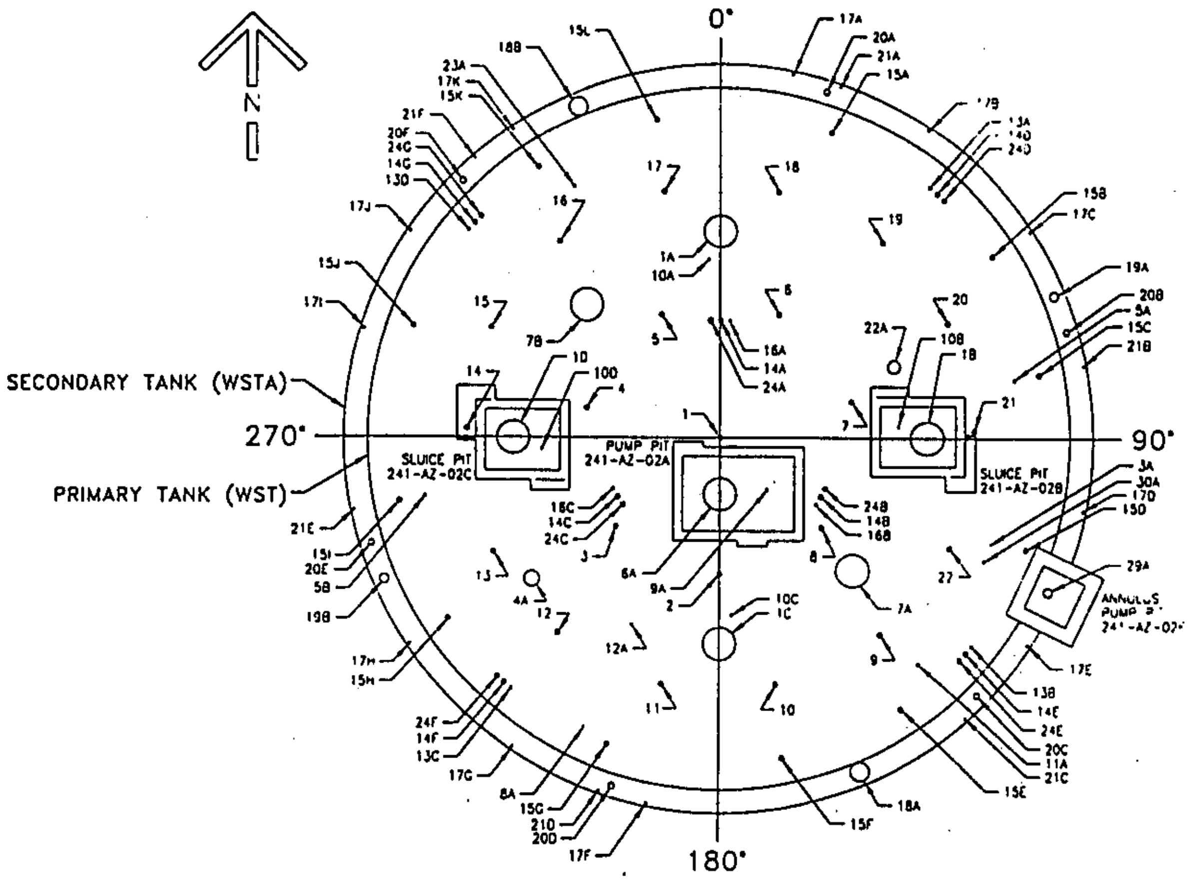
PLAN VIEW TANK 241-AZ-101

H-14-010507, REV 0, SH 1

PROJECT W-151 AND W-211 AZ-102 PROJECTED LARGE RISER UTILIZATION

RISER NO	DIAMETER	EQUIPMENT INSTALLED	AVAILABILITY
1A	42"	MIXER PUMP	NO
1B	42"	NONE	YES
1C	42"	MIXER PUMP	NO
1D	42"	NONE	YES
6A	42"	TRANSFER PUMP	NO
7A	42"	STEAM COIL (INACTIVE)	NO
7B	42"	PRIMARY VENT INLET	NO
22A	16"	"ENRAF" LIQUID LEVEL GAUGE	NO

UTILIZATION BASED ON HNF-1507 AND DISCUSSION WITH PROJECT W-151 AND W-211 PERSONNEL. WHERE EQUIPMENT LISTED AS INSTALLED, BUT "AVAILABILITY" IS "YES", INDICATES MOVEMENT OF PROJECT EQUIPMENT TO ANOTHER RISER IS POSSIBLE.

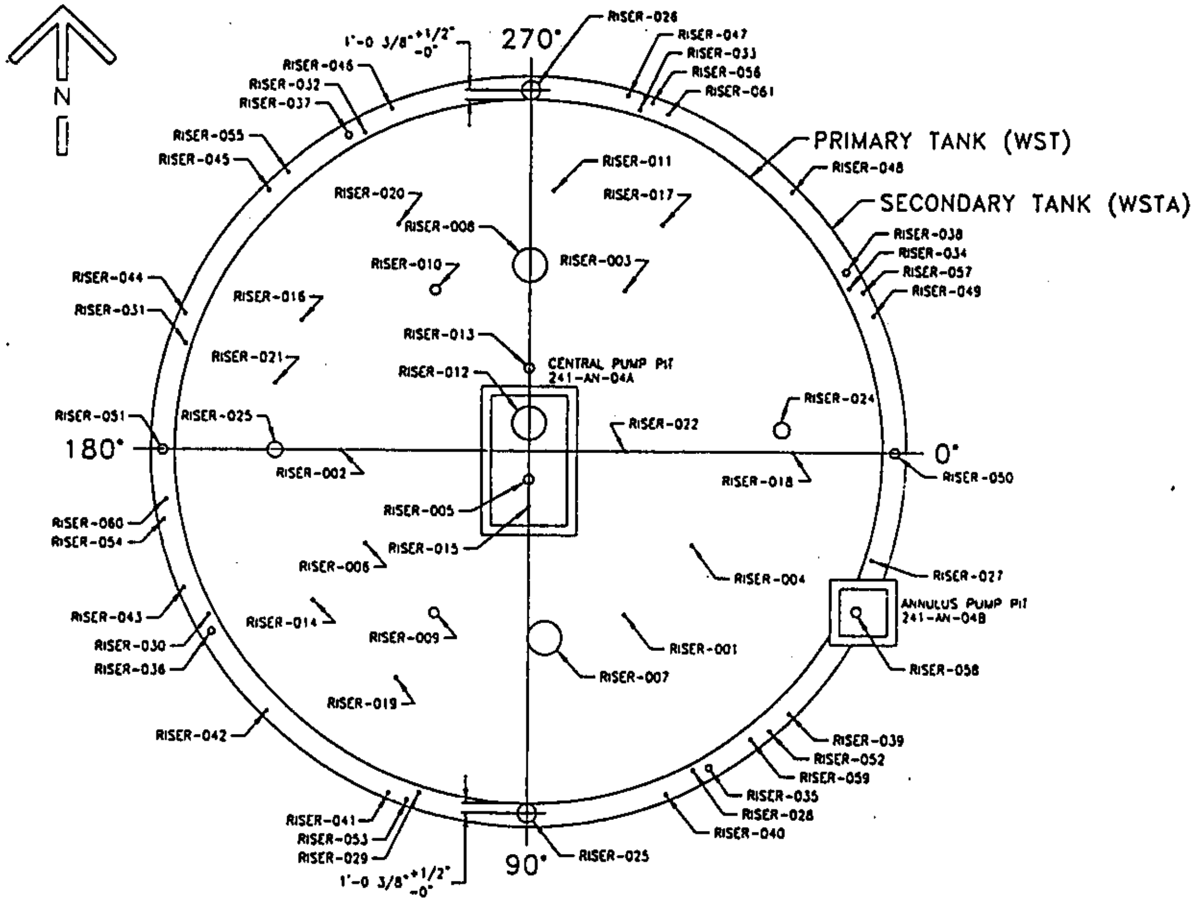


PLAN VIEW TANK 241-AZ-102

H-14-010507, REV 0, SH 2

PROJECT W-211 AZ-102 PROJECTED LARGE RISER UTILIZATION			
RISER NO	DIAMETER	EQUIPMENT INSTALLED	AVAILABILITY
1A	42"	MIXER PUMP	NO
1B	42"	NONE	YES
1C	42"	MIXER PUMP	NO
1D	42"	NONE	YES
6A	42"	TRANSFER PUMP	NO
7A	42"	STEAM COIL (INACTIVE)	NO
7B	42"	PRIMARY TANK VENT INLET	NO
22A	16"	LIQUID LEVEL GAUGE	NO

UTILIZATION BASED ON HNF-1507 AND DISCUSSION WITH PROJECT W-211 PERSONNEL. WHERE EQUIPMENT LISTED AS INSTALLED, BUT "AVAILABILITY" IS "YES", INDICATES MOVEMENT OF PROJECT EQUIPMENT TO ANOTHER RISER IS POSSIBLE.

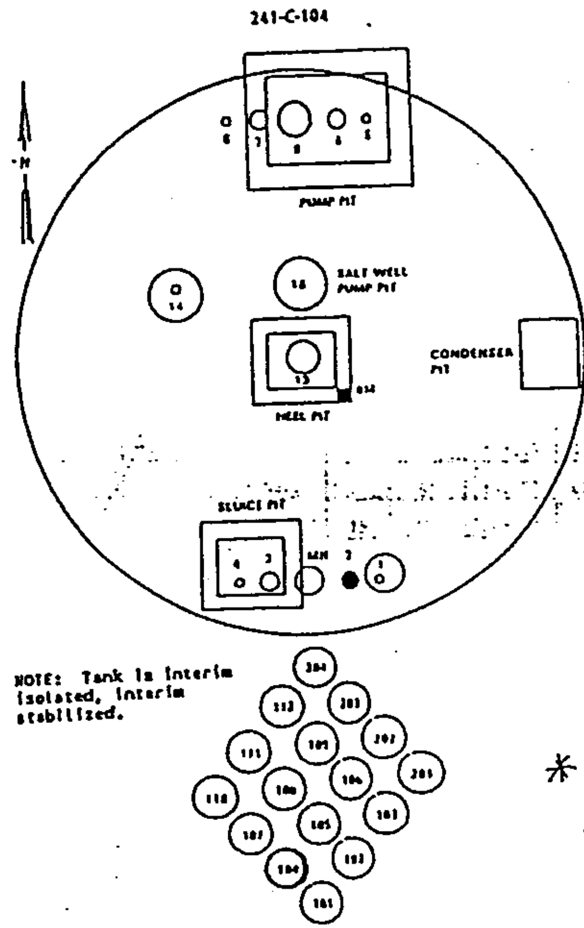


PLAN VIEW TANK 241-SY-102

H-14-010531, REV 2, SH 2

PROJECT W-211 SY-102 PROJECTED LARGE RISER UTILIZATION			
RISER NO	DIAMETER	EQUIPMENT INSTALLED	AVAILABILITY
005	12"	TRANSFER PUMP	NO
007	42"	MIXER PUMP	NO
008	42"	MIXER PUMP	NO
013	42"	TEMPERATURE PROBE	YES
014	12"	OPEN	YES
023	12"	EVAPORATOR FEED TRANSFER PUMP	YES
024	20"	NON-FUNCTIONAL	YES
025	20"	NON-FUNCTIONAL	YES

UTILIZATION BASED ON HNF-1507 AND DISCUSSION WITH PROJECT W-211 PERSONNEL. WHERE EQUIPMENT LISTED AS INSTALLED, BUT "AVAILABILITY" IS "YES", INDICATES MOVEMENT OF PROJECT EQUIPMENT TO ANOTHER RISER IS POSSIBLE.
RISERS -024 AND -025 ARE CONSTRUCTION RISERS CAPPED BELOW GRADE. MODIFICATION IS REQUIRED TO MAKE THESE USEFUL RISERS.



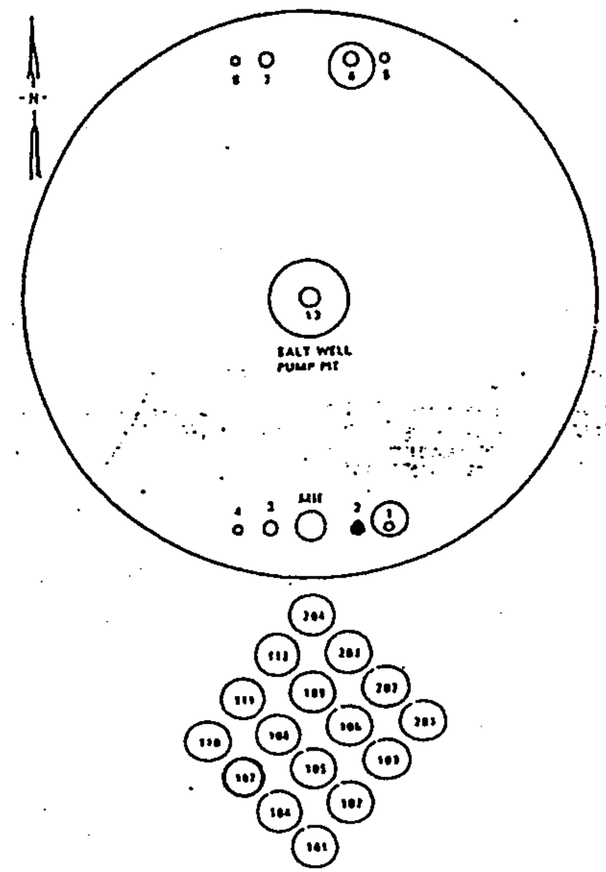
241-C-104

NO.	DIA.	ELEV.	DESCRIPTION AND COMMENTS
1	4"	648.22	LIQUID LEVEL WELL "B"
2	12"	648.11	BN, BREATHER FILTER
3	12"	649.22	OBSV PORT
4	4"	640.21	RECIRCULATING DIP TUBES VC
5	4"	639.63	RECIRCULATING DIP LEG VC
6	12"	640.33	SLUICING ACCESS VC
7	12"	648.50	TEMPERATURE PROBE
8	4"	647.68	FIC
9	42"	640.33	SLUDGE PUMP VC
13	26"	645.09	SALTWELL RISER
14	4"	643.50	LIQUID LEVEL WELL "A"
15	12"	645.30	SALTWELL SCREEN AND PUMP

C_L INSIDE TANK BOTTOM = 609.00

REF DWGS DOME PLAN/AS BLT H-2-37004
RISER ELEV. H-2-1744, H-2-37912, H-W-72743
ISOLATION H-2-73344
VERIFIED 6/30/88

* Location and number of primary mixer pumps projected for this tank is unknown.



241-C-107

NO.	DIA.	ELEV.	DESCRIPTION AND COMMENTS
1	4"	648.15	LIQUID LEVEL WELL "B"
2	12"	648.20	FLANGE, SPARE, BM
3	12"	648.20	FLANGE
4	4"	648.16	BREATHER FILTER
5	4"	648.19	TEMPERATURE PROBE
6	12"	641.00	LIQUID LEVEL WELL "A"
7	12"	647.71	B-222 OBSV PORT
8	4"	648.18	FIC
13	12"	644.08	SALTWELL SCREEN AND PUMP

C_L INSIDE TANK BOTTOM = 609.00

REF DWGS DOME PLAN/AS BLT H-2-37007
RISER ELEV H-2-1744, H-2-37912, H-V-72743
ISOLATION H-2-73347
VERIFIED 6/30/88

* Location and number of primary mixer pumps projected for this tank is unknown.

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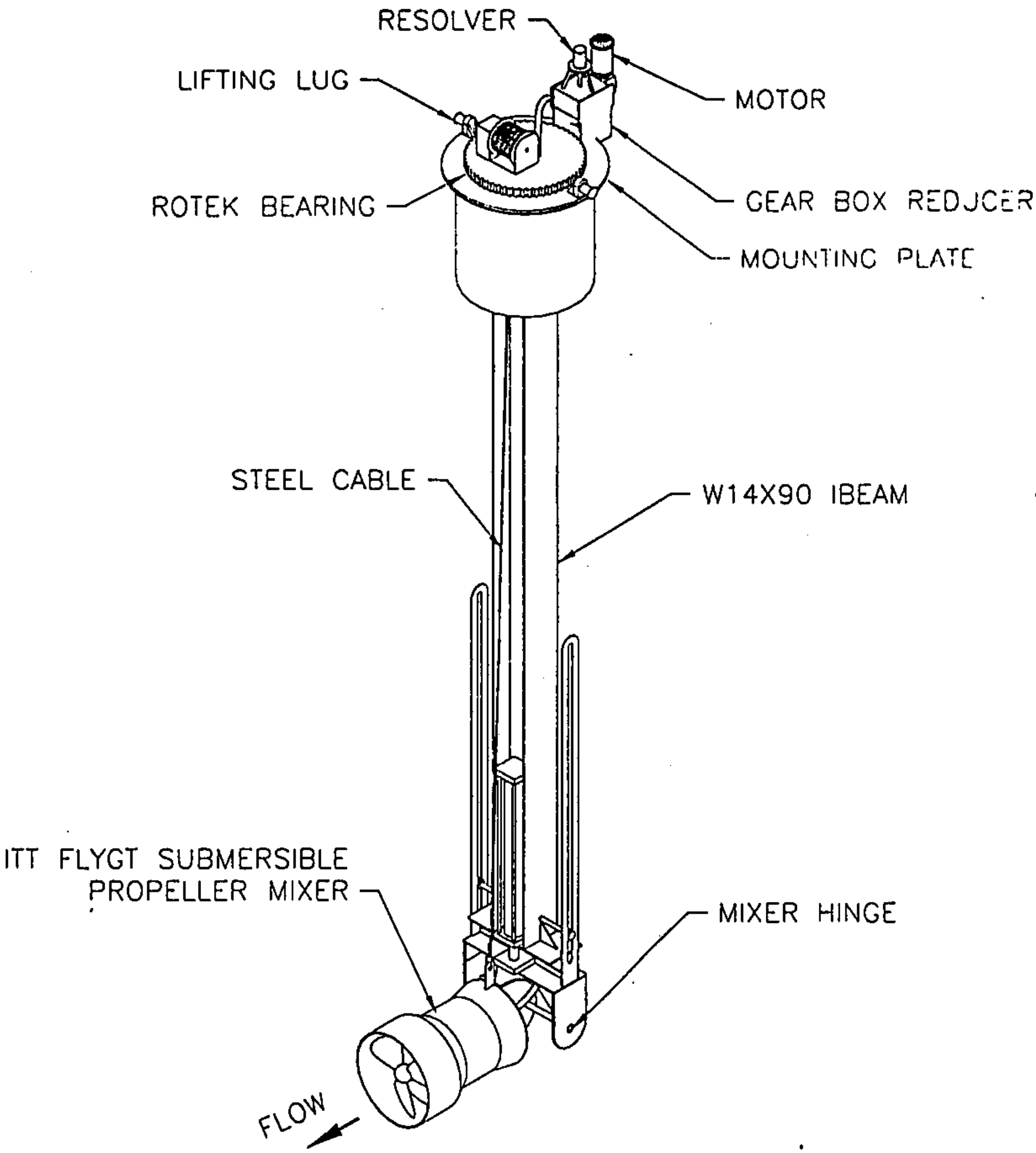
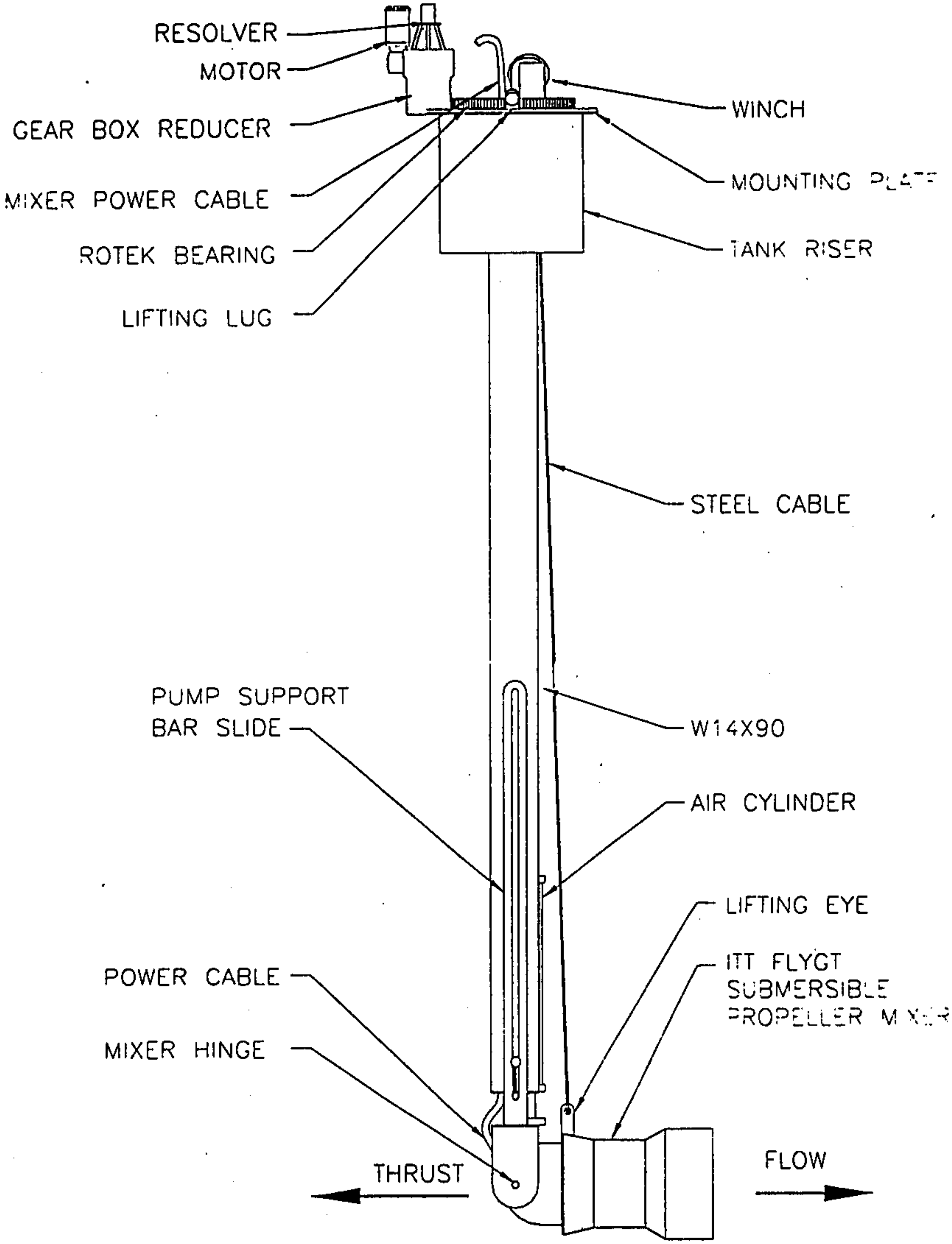
Appendix F

DEPLOYMENT MAST CONCEPTUAL DESIGN

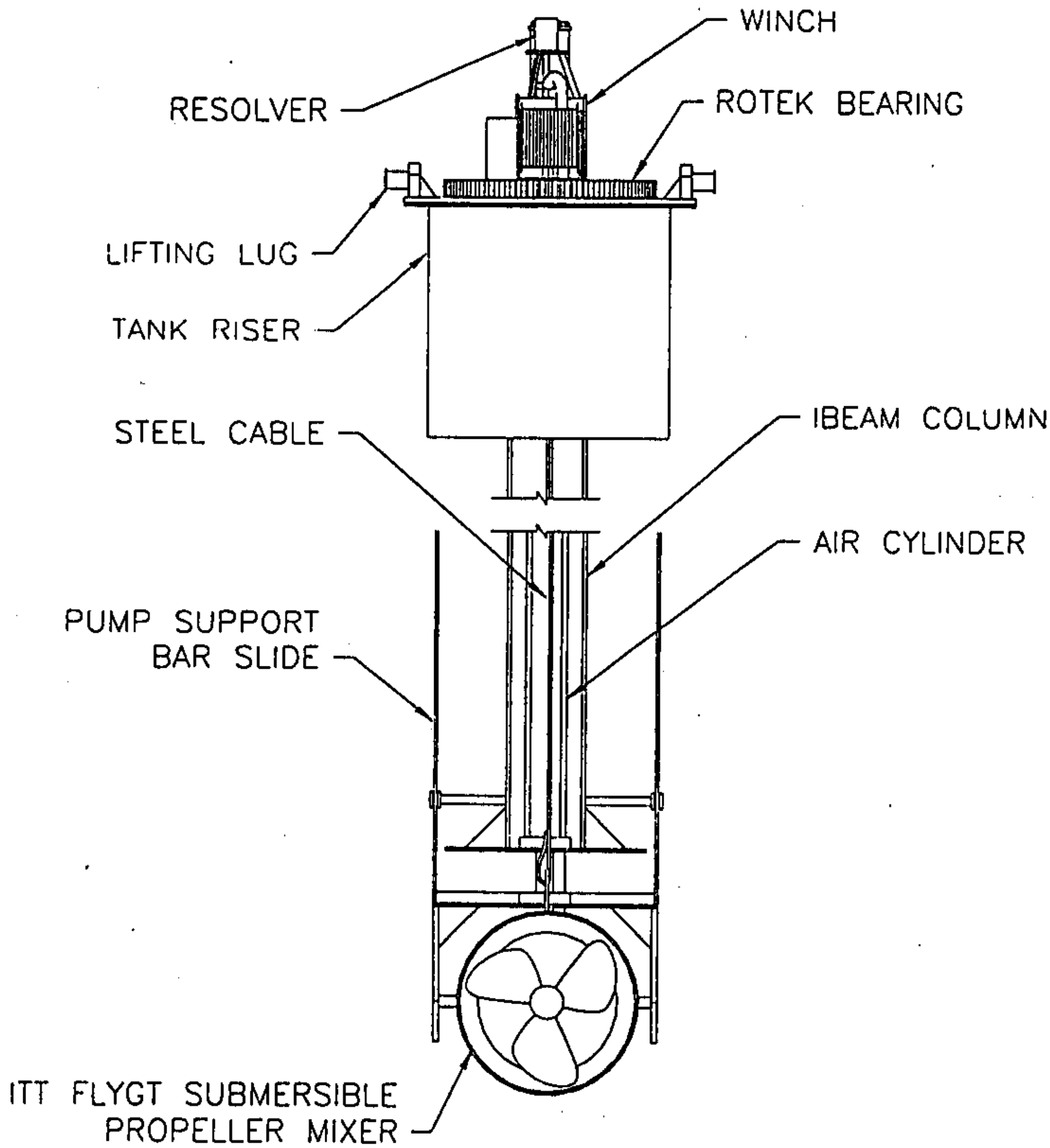
Weights Worksheet for Flygt Mixer and Conceptual Cantilever Deployment Mast Design					6/4/00
No.	Item	Wt/unit	Unit	Description	Weight (lb)
1	Flygt Propeller Mixer from Vendor				1000
2	Mast, W 14 x 90	90	40	lb/ft x ft length	3600
3	Mounting plate/Rotek bearing	490	1.14	steel density * volume of 50" dia. x 1" thick	557
4	Power cable				50
5	Winch, with remote actuator				500
6	Air cylinder				300
7	Gearbox			AN-107 mixer pump gearbox = 250 lb	300
8	Misc. pieces/parts				500
	Total Weight on Tank				6807



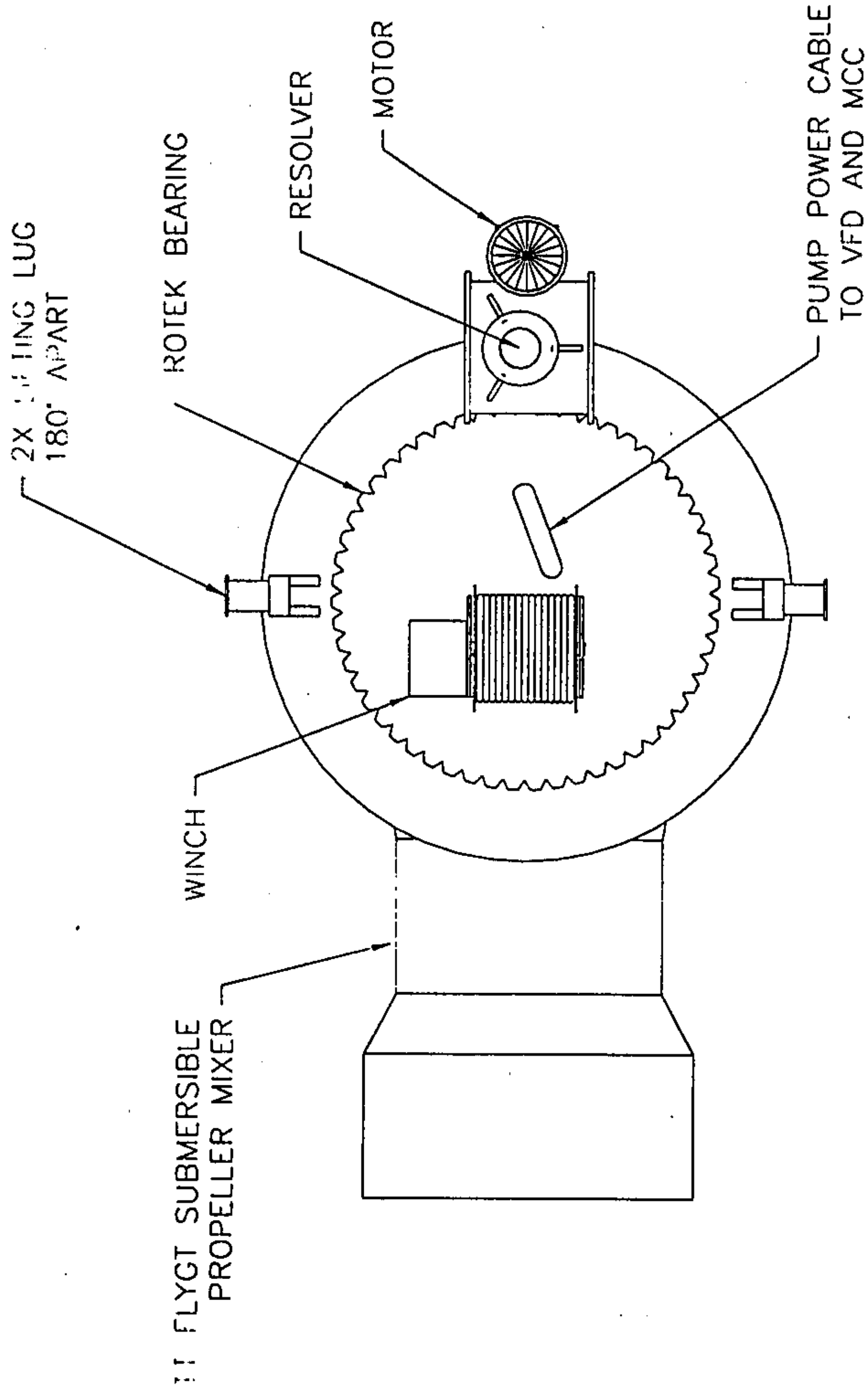
CONCEPTUAL ADJUSTIBLE LENGTH FLYGT MIXER ASSEMBLY



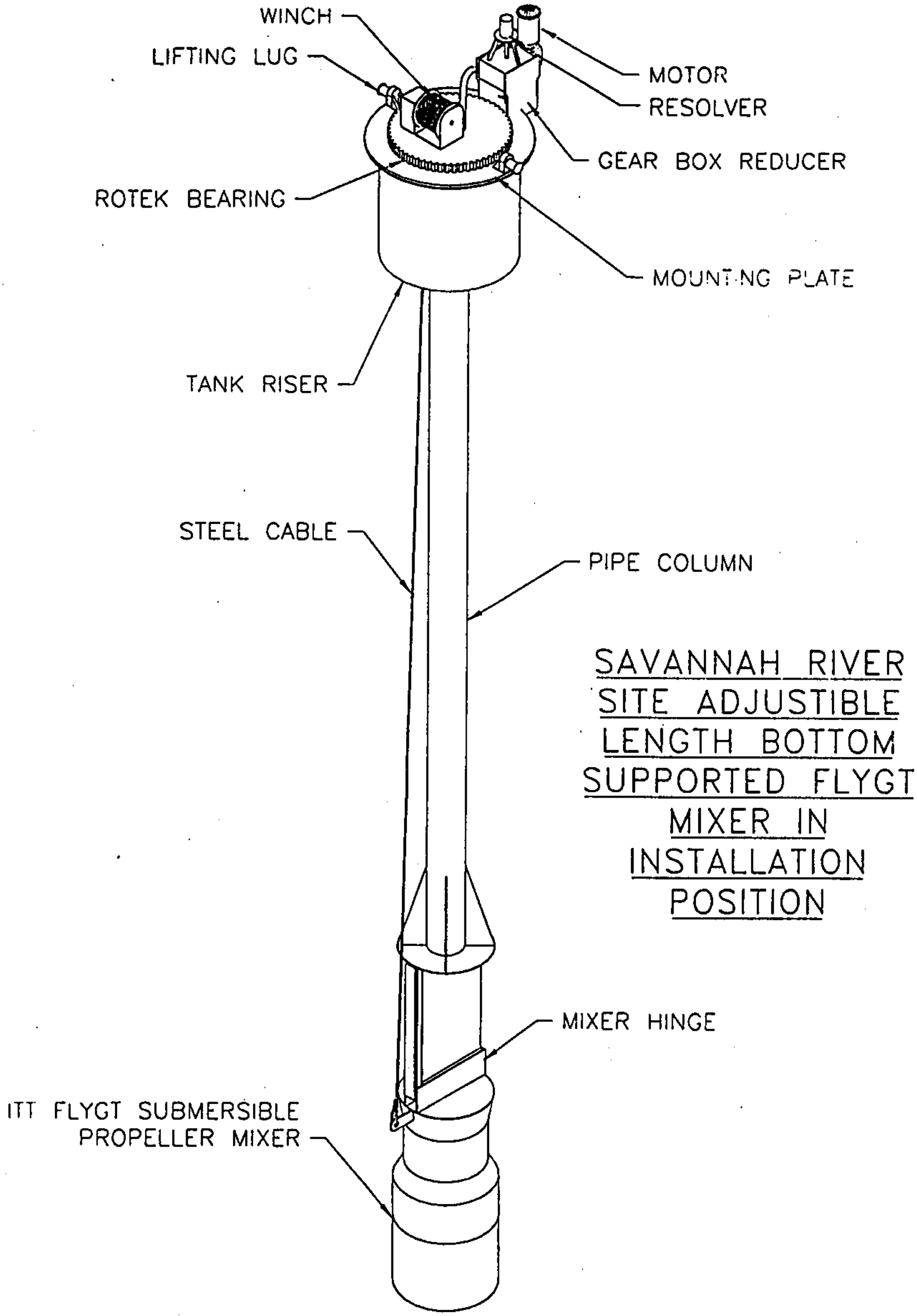
ADJUSTABLE LENGTH MIXER ASSEMBLY SIDE VIEW



ADJUSTABLE LENGTH FLYGT MIXER
ASSEMBLY END VIEW



FLYGT MIXER ASSEMBLY TOP VIEW


WINCH
LIFTING LUG
MOTOR
RESOLVER
GEAR BOX REDUCER
ROTEK BEARING
MOUNTING PLATE
TANK RISER
STEEL CABLE
PIPE COLUMN
SAVANNAH RIVER SITE ADJUSTIBLE LENGTH BOTTOM SUPPORTED FLYGT MIXER IN INSTALLATION POSITION
MIXER HINGE
ITT FLYGT SUBMERSIBLE PROPELLER MIXER

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RPP-6421, REV 0

APPENDIX G. COST ESTIMATE FOR FLYGT® MIXER DEPLOYMENT

06/08/00
Project Title: Evaluation Of Flygt Mixers For High Level Waste For Mobilization
Job No. 4848-156 (Final Estimate R3)
COGEMA ENGINEERING CORP.

ESTIMATE BASIS

1. Estimate Purpose

The purpose of the estimate basis is to provide an explanation for the Rough Order Of Magnitude Estimate for the Engineering Case Study to evaluate the deployment of two Flygt Mixers in one tank as a potential technology for auxiliary mobilization of DST high level waste solids.

2. Estimate Technical Basis

A. This estimate is prepared for COGEMA Engineering, as requested by the Statement of Work for Engineering Study Contract Number 4848, Release Number 156.

B. The technical scope of work description is in the following reference documents:
   1. H-14-010531, Rev.2, H-2-64447, H-14-010501, Rev. 7, H-2-37732, Rev. 10
   2. Sketch's showing Worm Gear, Motor, Mast, Rotation Plate, and Mixer assembly with Submersible Propeller Mixer.
   3. Document RPP-5664, Rev. 0, "Derived Requirements for DST HL Waste Aux. Solids Mobilization.
   4. Historical information from previous projects at the Hanford and Savannah River sites.

C. The estimate is consistent with the cost/schedule work breakdown structure.

D. This estimate utilizes the Industry Standard Construction Specification Institute (CSI) System. The CSI format is used to accumulate all costs on the project. The CSI format is separated into the following categories:
   01 – General
   02 – Excavation and Civil
   03 – Concrete
   04 – Masonry
   05 – Metals
   06 – Wood and Plastics
   07 – Thermal and Moisture Protection
   08 – Doors and Windows
   09 – Finishes
   10 – Specialties
   11 – Equipment
   15 – Mechanical
   16 – Electrical and Instrumentation/Controls

06/08/00
Project Title: Evaluation Of Flygt Mixers For High Level Waste For Mobilization
Job No. 4848-156 (Final Estimate R3)
COGEMA ENGINEERING CORP.

ESTIMATE BASIS

3. Estimate Methodology

A. **Direct Costs:** A detailed takeoff of material quantities is utilized in the preparation of this estimate.

(1) Construction labor, material, and equipment units are estimated based upon Industry Standard Commercial Estimating Manuals and Databases.

(2) Historical Hanford data and construction experience is utilized in developing the method of performance and productivity units.

B. **General Direct Cost Adjustments:**

(1) The direct cost can be adjusted by the estimator, as appropriate; to reflect influences by work site or other identified project or special conditions.

(2) A Special Work Procedure (SWP) adjustment is applied to the estimate to account for Hanford tank farm work requirements. The SWP adjusts direct labor upward to account for daily pre-job safety meetings; gaining access authorization to the tank farm(s) from Operations; dressing and undressing personal protective equipment (PPE); clearing or releasing work areas of contaminated materials; and moving materials, tools, and equipment in and out of the farm. The SWP adjustments are applied as follows:

a. Labor hours are adjusted upward 78% for work in the tank farms with PPE.
b. Labor hours are adjusted upward 100% for work in the tank farms with PPE and respirator

(3) Premium Pay:
Overtime requirements and shift differential pay for craft labor are union-negotiated under the Hanford Site Stabilization Agreement (HSSA). The cost estimate includes overtime allowances for alternative shifts due to extreme weather conditions and safety concerns. The estimate basis is based on working one shift five days a week. Also, overtime allowances are made for pit work rotation through lunch.

(4) Sales tax is applied to all materials and procured equipment purchases at 8%.

(5) Construction consumable items, such as small tools, weld rod, tape, caulking, plastics, gloves, paper, are estimated at 3.2% of direct construction labor dollars. This is an allowance based on the estimator's experience and the requirements of these items to be used during construction.

(6) Equipment usage of government-owned equipment, controlled by Dyncorp, is included in the estimate at 8% of direct construction labor dollars. This is an allowance based on similar projects previously estimated at the Hanford Site.

ESTIMATE BASIS

(7) General Conditions: This is an allowance based on similar projects previously estimated at the Hanford Site (W-151, W-030, W-058, W-320, and W-314 Phase I).This is 15% of direct construction labor hours and includes the following:

a. All project personnel are required to attend four hours of safety meetings each month. The estimate includes the cost for conducting and attending these meetings. The meeting dates are coordinated with the Project Hanford Management Contract (PHMC) mandatory safety meetings to minimize impacts to construction.
b. Detailed daily construction work planning is conducted outside normal shift hours.
c. Haul men and materials
d. Step-off pad support
e. Clean-up support
f. Non-project materials
g. Training
h. General condition materials

(8) Construction support staffing is a percentage of direct construction labor hours at 23%. Staffing is based on recent projects (Projects W-151, W-030, W-058, W-320, and W-314 Phase I) for tank farm construction work. These items include Project Management, Construction Department Management, Construction Superintendents/Supervision, Project Controls, Construction Engineering, Contract Management, Safety/Industrial Hygiene Support, Construction Document Control, and other miscellaneous Construction Support Personnel.

(9) Construction foreman costs is included at 5% of direct construction labor hours This is an allowance based on similar projects previously estimated at the Hanford Site (W-151, W-030, W-058, W-320, and W-314 Phase I).

(10) The cost estimate includes cost anticipated due to historically documented delays from inclement weather. Construction work inside the tank farm and occasionally outside the tank farm is constrained due to weather conditions by operations procedure or health and safety concerns. Based on historical data, weather delay impact will idle 20 personnel (construction related) for each day of delay. This assumption applies to construction forces working in or around the tank farm.

C. **Direct Cost Adjustments:**

D. **Rates:**

(1) Construction craft labor rates are those listed in Appendix A of the Hanford Site Stabilization Agreement (HSSA). The HSSA rates include base wage, fringe benefits, and other compensation as negotiated between Fluor Daniel Hanford, Inc. (FDH) and the National Building and Construction Trades Department AFL-CIO. COGEMA Engineering incorporates costs for workmen compensation, FICA, State and Federal Unemployment Insurance, and fee to develop a fully burdened rate by craft.
(2) Engineering rates are based on the approved Architect/Engineer (A/E) Contractor Pools Rate Sheet.
(3) PHMC rates are provided by LMHC and include Overhead and Profit (OH&P), General and Administrative (G&A), fee, and Essential Site Services (ESS). The rates used for the estimate are FY2000 rates.

06/08/00
Project Title: Evaluation Of Flygt Mixers For High Level Waste For Mobilization
Job No. 4848-156 (Final Estimate R3)
COGEMA ENGINEERING CORP.

ESTIMATE BASIS

E. **Site Allocations Adjustments:**

FDH G&A/ESS and Government Furnished Services (GFS) rates are applied to Enterprise Contractor costs that provide engineering, construction, and procurement services. Work is performed by PHMC contractors, and provided by COGEMA Engineering with labor and material rates, which included site allocations.

Site allocation adjustments for labor, materials, and procured equipment for Enterprise Contractors are developed and provided by FDH for cost estimating use as follows:

(1) FDH GFS = 3% (FY 00) 5% (FY 01 through FY 06)
(2) FDH G&A/ESS = 19.1% (FY 00) 19.9% (FY 01 through FY 06)
(3) Compounded rate for GFS & G&A/ESS for FY 2000 = 22.7% & FY 01 through FY06 = 25.9%.

The compounded rate is applied to engineering labor, construction labor and material, and procurement.

4. Escalation

Escalation percentages are based upon the latest budget guidance from the U. S. Department Of Energy as referenced in the escalation assumptions, "UNICALL", dated March 1999.

5. Contingency Analysis:

10 Engineering	- 25%
11 Project Management	- 25%
2 Procurement	- 20%
3 Construction	- 35%
4 Development	- 25%
5 Startup/Testing	- 25%

6. ASSUMPTIONS:

A. No weather delays are included in the estimate.
B. Existing riser will be available for pumps.
C. Greenhouse is needed for entry into risers.
D. Masks are not required for work; Whites only.
E. No demolition required.
F. Power is available in the ICE building to feed power rack.
G. Developmental costs covers on-site, and Sub-Contractor personnel.

06/08/00
Project Title: Evaluation Of Flygt Mixers For High Level Waste For Mobilization
Job No. 4848-156 (Final Estimate R3)
COGEMA ENGINEERING CORP.

ESTIMATE BASIS

H. DOE readiness review not required. Standards startup review Checklist only.
I. Underground feeders to rack, above ground from rack to pump.
J. No cameras are required.
K. Water source is not required.
L. A Pump supporting structure/foundation is required at each riser.
M. A Test Facility is available on-site to test the full length deployment mast and mixer prior to installation. No such facility curently exists.
N. Safety Assessment uncovers no critical issues involving costly resolution.

Evaluation Of Flygt Mixers For HL Waste For Mobilization
Contract L01560-156
blt
J.J. Zimmer

Success Estimating and Cost Management System

Rough-Order-Magnitude
WORK BREAKDOWN STRUCTURE SUMMARY

WBS Description	Estimate Subtotal	Escalation %	Escalation Total	Subtotal	Contingency %	Contingency Total	Total Dollars
Flygt Mixers For HL Waste Mobilization	$6,873,059	2.25%	$154,931	$7,027,990	27.06%	$1,901,483	$8,929,473
-- 1 Engineering	$1,462,584	2.30%	$33,639	$1,496,223	25.00%	$374,056	$1,870,279
-- 11 Project Management	$790,928	2.30%	$18,191	$809,119	25.00%	$202,280	$1,011,399
-- 2 Procurement	$212,795	2.30%	$4,894	$217,689	20.00%	$43,538	$261,227
-- 3 Construction	$1,518,770	2.30%	$34,932	$1,553,702	35.00%	$543,796	$2,097,497
-- 4 Development	$1,313,550	2.30%	$30,212	$1,343,762	25.00%	$335,940	$1,679,702
-- 5 Startup/Testing	$1,574,431	2.10%	$33,063	$1,607,494	25.00%	$401,874	$2,009,368

COGEMA Engineering Corp.
By: blt
06/08/2000

Evaluation Of Flygt Mixers For HL Waste For Mobilization
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Rough-Order-Magnitude
WORK BREAKDOWN STRUCTURE SUMMARY

WBS Description	Estimate Subtotal	Escalation %	Escalation Total	Subtotal	Contingency %	Contingency Total	Total Dollars
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-- 1 Engineering	$1,462,584	2.30%	$33,639	$1,496,223	25.00%	$374,056	$1,870,279
--- 10 Engineering	$1,462,584	2.30%	$33,639	$1,496,223	25.00%	$374,056	$1,870,279
---- 101000 Title I/Title II/Title III Design Engineering	$1,462,584	2.30%	$33,639	$1,496,223	25.00%	$374,056	$1,870,279
-- 11 Project Management	$790,928	2.30%	$18,191	$809,119	25.00%	$202,280	$1,011,399
--- 110 Project Management	$790,928	2.30%	$18,191	$809,119	25.00%	$202,280	$1,011,399
---- 111000 Project Management	$790,928	2.30%	$18,191	$809,119	25.00%	$202,280	$1,011,399
-- 2 Procurement	$212,795	2.30%	$4,894	$217,689	20.00%	$43,538	$261,227
--- 20 Flygt Mixer & Deployment Mast	$212,795	2.30%	$4,894	$217,689	20.00%	$43,538	$261,227
---- 201000 Flygt Mixer & Mast Procurement	$212,795	2.30%	$4,894	$217,689	20.00%	$43,538	$261,227
-- 3 Construction	$1,518,770	2.30%	$34,932	$1,553,702	35.00%	$543,796	$2,097,497
--- 30 Civil/Structural	$169,318	2.30%	$3,894	$173,212	35.00%	$60,624	$233,837
---- 301000 Riser Preparation	$169,318	2.30%	$3,894	$173,212	35.00%	$60,624	$233,837
--- 31 Mechanical	$300,133	2.30%	$6,903	$307,036	35.00%	$107,463	$414,499
---- 310000 Pump Installation	$194,914	2.30%	$4,483	$199,397	35.00%	$69,789	$269,185
---- 311000 Above Ground Mechanical Equipment Installation	$97,319	2.30%	$2,238	$99,557	35.00%	$34,845	$134,402
---- 312000 Greenhouse	$7,901	2.30%	$182	$8,083	35.00%	$2,829	$10,912
--- 32 Electrical/Instrumentation & Controls	$607,186	2.30%	$13,965	$621,151	35.00%	$217,403	$838,554
---- 320000 Instrumentation & Controls	$302,004	2.30%	$6,946	$308,950	35.00%	$108,133	$417,083
---- 321000 Power & Control Feeders (Contr. Rm. Bldg. to	$123,476	2.30%	$2,840	$126,316	35.00%	$44,210	$170,526
---- 322000 Excavation/Backfill	$181,706	2.30%	$4,179	$185,885	35.00%	$65,060	$250,945
--- 330000 Construction Management	$327,352	2.30%	$7,529	$334,881	35.00%	$117,208	$452,089
--- 340000 Construction Equipment	$15,244	2.30%	$351	$15,595	35.00%	$5,458	$21,053
--- 36 HPT Support	$99,537	2.30%	$2,289	$101,826	35.00%	$35,639	$137,466
---- 360000 HPT Support	$99,537	2.30%	$2,289	$101,826	35.00%	$35,639	$137,466
-- 4 Development	$1,313,550	2.30%	$30,212	$1,343,762	25.00%	$335,940	$1,679,702

COGEMA Engineering Corp.
By: blt
06/08/2000

Evaluation Of Flygt Mixers For HL Waste For Mobilization
Contract L01560-156
blt
J.J. Zimmer

Success Estimating and Cost Management System

Rough-Order-Magnitude
WORK BREAKDOWN STRUCTURE SUMMARY

WBS Description	Estimate Subtotal	Escalation %	Escalation Total	Subtotal	Contingency %	Contingency Total	Total Dollars
— 400000 Flygt Mixer & Deployment Mast Development	$1,313,550	2.30%	$30,212	$1,343,762	25.00%	$335,940	$1,679,702
-- 5 Startup/Testing	$1,574,431	2.10%	$33,063	$1,607,494	25.00%	$401,874	$2,009,368
---- 50 O/C Licensing & Turnover	$351,406	2.10%	$7,380	$358,785	25.00%	$89,696	$448,482
------ 501000 Safety Assessment/Auth. Basis	$180,000	2.10%	$3,780	$183,780	25.00%	$45,945	$229,725
------ 502000 Permitting	$57,120	2.10%	$1,200	$58,320	25.00%	$14,580	$72,899
------ 503000 ABU Process	$114,286	2.10%	$2,400	$116,686	25.00%	$29,171	$145,857
---- 51 Mockup/Operability Testing	$941,671	2.10%	$19,775	$961,446	25.00%	$240,361	$1,201,807
------ 511000 Mockup Testing	$256,871	2.10%	$5,394	$262,265	25.00%	$65,566	$327,831
------ 512000 Operability Testing	$684,800	2.10%	$14,381	$699,181	25.00%	$174,795	$873,976
---- 52 Operations	$281,355	2.10%	$5,908	$287,263	25.00%	$71,816	$359,079
------ 520000 Operation Preparation	$150,000	2.10%	$3,150	$153,150	25.00%	$38,288	$191,438
------ 521000 Safety Meetings/Training	$131,355	2.10%	$2,758	$134,113	25.00%	$33,528	$167,642

Evaluation Of Flygt Mixers For HL Waste For Mobilization
Contract L01560-156
blt
J.J. Zimmer

Success Estimating and Cost Management System

Flygt Mixers For HL Waste Mobilization
1 Engineering
10 Engineering

Rough-Order-Magnitude

Flygt Mixers For HL Waste Mobilization
ESTIMATE DETAIL BY WBS / COST CODE

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
WBS 101000 Title I/Title II/Title III Design Engineering													
Note :	Drawings, Research, Calc's, Reviews, Design Support during construction, installation, field testing, and Inspections.												
Cost Code: 900	**Other Project Costs**												
990000000	TITLE I/II/III DESIGNS	1	LS	12000		960000	0	0	0	0	0	217920	1177920
AVERENG	Note : Based upon approximately 40% of Direct Construction.												
990000000	CREATE PROCEDURES/SPECIFICATIONS	1	LS	2900		232000	0	0	0	0	0	52664	284664
AVERENG	Note : Based upon AZ-101 Mixer Pump Testing estimate. Includes allowances for Transfer pump, Alarm response procedures, Data Acquisition sys, gamma cart, panel meter, pmp cooling, switches & gauges.												
Subtotal 99 Other Project Cost				14900			$0		$0		$0		$1,462,584
	Total Hours:			14900		$1,192,000		$0		$0		$270,584	
Total Cost Code: 900				14,900	0		$0		$0		$0		$1,462,584
	Total Hours:			14,900		$1,192,000		$0		$0		$270,584	
TOTAL WBS 101000				14,900	0		$0		$0		$0		$1,462,584
	Total Hours:			14,900		$1,192,000		$0		$0		$270,584	
WBS 111000 Project Management													
Cost Code: 060	**Project Management**												
990000001	PROJECT MANAGEMENT - ALLOWANCE	1	LS	11200		752528	0	0	0	0	0	0	752528
LE00E	Note : Based on 4 people full time for 1 year. 168MH's per month X 12 Months = 2016MH's per year X 4 people = 8064MH's												

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Evaluation Of Flygt Mixers For HL Waste For Mobilization
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Flygt Mixers For HL Waste Mobilization
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Rough-Order-Magnitude
Flygt Mixers For HL Waste Mobilization
ESTIMATE DETAIL BY WBS / COST CODE

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
990000003 AVERENG	PROJECT CONTROLS/SCHEDULING/ESTIMATING	1	LS	480		38400	0	0	0	0	0	0	38400
Subtotal 99 Other Project Cost				11680			$0		$0		$0		$790,928
	Total Hours:			11680		$790,928		$0		$0		$0	
Total Cost Code: 060				11,680	0		$0		$0		$0		$790,928
	Total Hours:			11,680		$790,928		$0		$0		$0	
TOTAL WBS 111000				11,680	0		$0		$0		$0		$790,928
	Total Hours:			11,680		$790,928		$0		$0		$0	

WBS 201000 Flygt Mixer & Mast Procurement

Note : Costs of production units of Flygt mixer assembly. Cost based on discussion with SRS site. SRS bid mast fabrication assembly off-site. Flygt mixer cost from vendor off-the-shelf is approximately $25K. Need 2 mixers for one DST.

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
Cost Code: 550	Other Structures												
900000000	FLYGT MIXER PROCUREMENT	1	LOT	0		0	0	0	0	162000	0	50795	212795
Subtotal 9				0			$0		$0		$0		$212,795
	Total Hours:			0		$0		$0		$162,000		$50,795	
Total Cost Code: 550				0	0		$0		$0		$0		$212,795
	Total Hours:			0		$0		$0		$162,000		$50,795	
TOTAL WBS 201000				0	0		$0		$0		$0		$212,795
	Total Hours:			0		$0		$0		$162,000		$50,795	

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Flygt Mixers For HL Waste Mobilization
ESTIMATE DETAIL BY WBS / COST CODE

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
WBS 301000 Riser Preparation													
Cost Code: 550W	**Other Structures**												
020000004 CLABW	MOBILIZATION & SETUP Note.: Includes allowances for Mob & Setup, Mob/Demob crane. Preparing entry for pump. It is assumed that the risers are currently empty. Any previously installed equipment has been removed.	1	LS	180	140	9219	0	1750	0	0	2412	2862	16243
Subtotal 02 Site Work				180	140		$0		$0		$2,412		$16,243
050000000 CLABW	ASBESTOS ABATEMENT Note.: If riser is not in pit and rarely used, it is likely that it has an asbestos gasket around mounting flange that must be removed per applicable regulations.	1	LS	0		0	0	21600	0	0	1572	6773	29944
Subtotal 05 Metals				0			$0		$0		$1,572		$29,944
060000000 CCARPW	INSTALL GREENHOUSE Note.: This activity includes setting up the greenhouse, preparing the floor covering, ante room, allowance for lights, fans, htg & cooling equipment and hauling and setting anchor blocks. Composite Crew: Electrician, Sheet Metal, Labor, Carpenter, Iron Worker, Operator Avg. $35.01 Say $36.57	1	LS	0		0	0	2419	0	0	176	759	3354

Rough-Order-Magnitude

Flygt Mixers For HL Waste Mobilization
ESTIMATE DETAIL BY WBS / COST CODE

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
060000002 CPFW	INSTALL PUMP SUPPORT STRUCT./FOUNDATION Note : Install pump supporting structure/foundation for 2 pumps.	1	LS	0		0	0	86400	0	0	6286	27091	119777
Subtotal 06 Wood & Plastics				0			$0		$0		$6,462		$123,131
	Total Hours:			0		$0		$88,819		$0		$27,849	
Total Cost Code: 550W				180	140		$0		$0		$10,446		$169,318
	Total Hours:			320		$9,219		$112,169		$0		$37,484	
TOTAL WBS 301000				180	140		$0		$0		$10,446		$169,318
	Total Hours:			320		$9,219		$112,169		$0		$37,484	

WBS 310000 Pump Installation
Note : Same costs were used on W-320 Project. Includes setting 2 pumps.

Cost Code: 700W Special Equipment/Process Systems

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
110000002 CPFW	PUMP INSTALLATION Note : Used same installation costs as W-320 transfer pump.	1	LS	1600	1248	120051	0	10800	0	0	30544	33519	194914
Subtotal 11 Equipment				1600	1248		$0		$0		$30,544		$194,914
	Total Hours:			2848		$120,051		$10,800		$0		$33,519	
Total Cost Code: 700W				1,600	1,248		$0		$0		$30,544		$194,914
	Total Hours:			2,848		$120,051		$10,800		$0		$33,519	
TOTAL WBS 310000				1,600	1,248		$0		$0		$30,544		$194,914
	Total Hours:			2,848		$120,051		$10,800		$0		$33,519	

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Flygt Mixers For HL Waste Mobilization
ESTIMATE DETAIL BY WBS / COST CODE

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
WBS 311000 Above Ground Mechanical Equipment Installation													
Cost Code: 700W	**Special Equipment/Process Systems**												
150000051 CPFW	AIR CYLINDER & CONTROLLERS Note : Includes fabrication, installation, hookup of air hoses, compressed air bottle station, and valving. Air hoses are assumed to run above ground from air station near risers.	1	LS	0		0	0	64800	0	0	4715	20318	89833
150000053 CPFW	GEARBOX/MOTOR INSTALLATION(ROTEK) Note : Includes the bearing locking device removal.	1	LS	0		0	0	5400	0	0	393	1693	7486
Subtotal 15 Mechanical				0			$0		$0		$5,108		$97,319
	Total Hours:			0		$0		$70,200		$0		$22,011	
Total Cost Code: 700W				0	0		$0		$0		$5,108		$97,319
	Total Hours:			0		$0		$70,200		$0		$22,011	
TOTAL WBS 311000				0	0		$0		$0		$5,108		$97,319
	Total Hours:			0		$0		$70,200		$0		$22,011	
WBS 312000 Greenhouse													
Cost Code: 550W	**Other Structures**												
150000048 CCARPW	GREENHOUSE PLACE IN FARM Note : Based upon W-314 Phase II cost estimate.	1	LOT	16	12	924	0	0	0	0	229	232	1385

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Flygt Mixers For HL Waste Mobilization
ESTIMATE DETAIL BY WBS / COST CODE

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
150000050 CCARPW	REMOVE GREENHOUSE	1	LOT	75	59	4347	0	0	0	0	1078	1091	6516
Subtotal 15 Mechanical				91	71		$0		$0		$1,307		$7,901
	Total Hours:			162		$5,271		$0		$0		$1,323	
Total Cost Code: 550W				91	71		$0		$0		$1,307		$7,901
	Total Hours:			162		$5,271		$0		$0		$1,323	
TOTAL WBS 312000				91	71		$0		$0		$1,307		$7,901
	Total Hours:			162		$5,271		$0		$0		$1,323	

WBS 320000 Instrumentation & Controls

Note : This activity includes Calibration and Testing.

Cost Code: 7065W Instrumentation/Controls

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
160000002 CELECW	INSTRUMENTATION & CONTROLS	1	LOT	2400	1872	171520	0	32400	0	0	44874	53211	302004
Subtotal 16 Electrical				2400	1872		$0		$0		$44,874		$302,004
	Total Hours:			4272		$171,520		$32,400		$0		$53,211	
Total Cost Code: 7065W				2,400	1,872		$0		$0		$44,874		$302,004
	Total Hours:			4,272		$171,520		$32,400		$0		$53,211	
TOTAL WBS 320000				2,400	1,872		$0		$0		$44,874		$302,004
	Total Hours:			4,272		$171,520		$32,400		$0		$53,211	

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Flygt Mixers For HL Waste Mobilization
ESTIMATE DETAIL BY WBS / COST CODE

WBS 321000 Power & Control Feeders (Contr. Rm. Bldg. to Switch Rack)

Cost Code: 7060W Electrical

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
160000000 CELECW	3#4 AWG W/#8 GND MC CABLE	1	LS	0		0	0	5400	0	0	393	1693	7486
	Note : Material costs from Richardson. Cables are run above ground from the Power Rack to the pump. Conduit and cable from the MCC Bldg. and is assumed to be not more than 200 feet from the Tank area.												
160000001 CELECW	DIST. PNL. 3PH 4W NEMA 12, 120/208V	1	EA	2	2	141	0	1793	0	0	165	597	2696
160000002 CELECW	15KVA TRANSFORMER	1	EA	4	3	281	0	1071	0	0	148	406	1906
160000003 CELECW	TERMINATIONS	32	EA	2	2	154	0	27	0	0	40	47	268
160000005 CELECW	400 AMP CB	1	EA	2	2	141	0	1104	0	0	115	381	1741
160000007 CELECW	DISCONNECTS/ RACK/CONTROLLERS	1	LS	31	25	2248	0	75600	0	0	6058	24269	108175
	Note : This includes the procurement, fabrication, and hookup for disconnects, switch rack, vfd controller, winch controller.												
160000012 CELECW	LOCK & TAG FOR ELECTRICAL	1	LS	11	9	803	0	0	0	0	199	202	1204
	Note : Allow 2 men 10 mh's each. This info is from the W-314 Phase II cost estimate.												
Subtotal 16 Electrical				53	41		$0		$0		$7,118		$123,476
	Total Hours:			94		$3,768		$84,995		$0		$27,596	
Total Cost Code: 7060W				53	41		$0		$0		$7,118		$123,476
	Total Hours:			94		$3,768		$84,995		$0		$27,596	
TOTAL WBS 321000				53	41		$0		$0		$7,118		$123,476
	Total Hours:			94		$3,768		$84,995		$0		$27,596	

WBS 322000 Excavation/Backfill

Cost Code: 7060W Electrical

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
160000000 CLABW	EXCAVATE/BACKFILL	30	CY	2250	1755	115234	0	6480	0	0	29036	30956	181706
	Note : Dig and backfill from the Instrument House to the rack located near the tank risers.												
Subtotal 16 Electrical				2250	1755		$0		$0		$29,036		$181,706

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Flygt Mixers For HL Waste Mobilization
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Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
	Total Hours:			4005		$115,234		$6,480		$0		$30,956	
Total Cost Code: 7060W				2,250	1,755		$0		$0		$29,036		$181,706
	Total Hours:			4,005		$115,234		$6,480		$0		$30,956	
TOTAL WBS 322000				2,250	1,755		$0		$0		$29,036		$181,706
	Total Hours:			4,005		$115,234		$6,480		$0		$30,956	
WBS 330000 Construction Management													
Cost Code: 050	Construction Management												
920000002	Construction Management	1	LS	0		261672	0	0	0	0	0	65680	327352
Subtotal 92 Construction Management				0			$0		$0		$0		$327,352
	Total Hours:			0		$261,672		$0		$0		$65,680	
Total Cost Code: 050				0	0		$0		$0		$0		$327,352
	Total Hours:			0		$261,672		$0		$0		$65,680	
TOTAL WBS 330000				0	0		$0		$0		$0		$327,352
	Total Hours:			0		$261,672		$0		$0		$65,680	
WBS 340000 Construction Equipment													
Cost Code: 050	Construction Management												
910000008	DynCorp Equipment	1	LS	0		0	15244	0	0	0	0	0	15244
Subtotal 91				0			$15,244		$0		$0		$15,244
	Total Hours:			0		$0		$0		$0		$0	
Total Cost Code: 050				0	0		$15,244		$0		$0		$15,244
	Total Hours:			0		$0		$0		$0		$0	

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ESTIMATE DETAIL BY WBS / COST CODE

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
TOTAL WBS 340000				0	0		$15,244		$0		$0		$15,244
	Total Hours:			0		$0		$0		$0		$0	
WBS 360000 HPT Support													
Cost Code: 900	**Other Project Costs**												
990000000	Health Physics Technician	1	EA	1597		83076	0	0	0	0	16461	0	99537
LT05B	Note : This is calculated on a 1:4 Ratio of total manhours.												
Subtotal 99 Other Project Cost				1597			$0		$0		$16,461		$99,537
	Total Hours:			1597		$83,076		$0		$0		$0	
Total Cost Code: 900				1,597	0		$0		$0		$16,461		$99,537
	Total Hours:			1,597		$83,076		$0		$0		$0	
TOTAL WBS 360000				1,597	0		$0		$0		$16,461		$99,537
	Total Hours:			1,597		$83,076		$0		$0		$0	

WBS 400000 Flygt Mixer & Deployment Mast Development

Note : Test development cost, remaining testing scope equivalant to joint test cost to date. Includes additional simulant mobilization tests on the Flygt Mixers: computational mixing analysis, procurement of pumps for test,and fabrication/qualification of a new deployment mast.

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
Cost Code: 550	**Other Structures**												
900000000	PROPELLER/PT. MAST/DEVELOPMENT	1	LOT	0		0	0	0	1000000	0	0	313550	13[illegible]550
Subtotal 90 Home Office Labor				0			$0		$1,000,000		$0		$1,3[illegible]550

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Flygt Mixers For HL Waste Mobilization
ESTIMATE DETAIL BY WBS / COST CODE

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
	Total Hours:			0		$0		$0		$0		$313,550	
Total Cost Code: 550				0	0		$0		$1,000,000		$0		$1,313,550
	Total Hours:			0		$0		$0		$0		$313,550	
TOTAL WBS 400000				0	0		$0		$1,000,000		$0		$1,313,550
	Total Hours:			0		$0		$0		$0		$313,550	

WBS 501000 Safety Assessment/Auth. Basis

Cost Code: 900 Other Project Costs

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
900000002 AVERENG	SAFETY ASSESSMENTS - ALLOWANCE	1	LS	0		0	0	0	30000	0	0	0	30000
900000002 AVERENG	AUTHORITY BASIS - ALLOWANCE Note : Provided by engineering; only needed if Safety Assessment indicates AB amendment required for conservatism.	1	LS	0		0	0	0	150000	0	0	0	150000
Subtotal 90 Home Office Labor				0			$0		$180,000		$0		$180,000
	Total Hours:			0		$0		$0		$0		$0	
Total Cost Code: 900				0	0		$0		$180,000		$0		$180,000
	Total Hours:			0		$0		$0		$0		$0	
TOTAL WBS 501000				0	0		$0		$180,000		$0		$180,000
	Total Hours:			0		$0		$0		$0		$0	

WBS 502000 Permitting

Cost Code: 900 Other Project Costs

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
900000002 AVERENG	PERMITTING Note : Provided by engineering.	1	LS	714		57120	0	0	0	0	0	0	57120
Subtotal 90 Home Office Labor				714			$0		$0		$0		$57,120

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Flygt Mixers For HL Waste Mobilization
5 Startup/Testing
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Flygt Mixers For HL Waste Mobilization
ESTIMATE DETAIL BY WBS / COST CODE

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
	Total Hours:			714		$57,120		$0		$0		$0	
Total Cost Code: 900				714	0		$0		$0		$0		$57,120
	Total Hours:			714		$57,120		$0		$0		$0	
TOTAL WBS 502000				714	0		$0		$0		$0		$57,120
	Total Hours:			714		$57,120		$0		$0		$0	

WBS 503000 ABU Process

Cost Code: 900 Other Project Costs

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
900000002 AVERENG	Signoffs and processing paperwork & documents Note.: For turnover documentation.	1	LOT	1429		114286	0	0	0	0	0	0	114286
Subtotal 90 Home Office Labor				1429			$0		$0		$0		$114,286
	Total Hours:			1429		$114,286		$0		$0		$0	
Total Cost Code: 900				1,429	0		$0		$0		$0		$114,286
	Total Hours:			1,429		$114,286		$0		$0		$0	
TOTAL WBS 503000				1,429	0		$0		$0		$0		$114,286
	Total Hours:			1,429		$114,286		$0		$0		$0	

WBS 511000 Mockup Testing

Cost Code: 900 Other Project Costs

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
920000002	MOCKUP TESTING Note.: Demonstrates functionality of assembled system(mixer, deployment mast, and controls) prior to field installation. Test assumed to be performed in an outside facility that doesn't currently exist.	1	LS	0		0	0	25920	226000	0	0	4951	256871
Subtotal 92 Construction Management				0			$0		$226,000		$0		$256,871

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ESTIMATE DETAIL BY WBS / COST CODE

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
	Total Hours:			0		$0		$25,920		$0		$4,951	
Total Cost Code: 900				0	0		$0		$226,000		$0		$256,871
	Total Hours:			0		$0		$25,920		$0		$4,951	
TOTAL WBS 511000				0	0		$0		$226,000		$0		$256,871
	Total Hours:			0		$0		$25,920		$0		$4,951	
WBS 512000 Operability Testing													
Cost Code: 900	Other Project Costs												
900000002 AVERENG	OPERABILITY TESTING Note : OTP assumed to be less extensive than the recent Project W-151 Mixer Pump Test.	1	LS	8560		684800	0	0	0	0	0	0	684800
Subtotal 90 Home Office Labor				8560			$0		$0		$0		$684,800
	Total Hours:			8560		$684,800		$0		$0		$0	
Total Cost Code: 900				8,560	0		$0		$0		$0		$684,800
	Total Hours:			8,560		$684,800		$0		$0		$0	
TOTAL WBS 512000				8,560	0		$0		$0		$0		$684,800
	Total Hours:			8,560		$684,800		$0		$0		$0	
WBS 520000 Operation Preparation													
Cost Code: 900	Other Project Costs												
900000002 AVERENG	OTHER PROJECT COSTS - ALLOWANCE Note : It includes Work Package Preparation/ Procedure Preparation support.	1	LS	0		0	0	0	150000	0	0	0	150000
Subtotal 90 Home Office Labor				0			$0		$150,000		$0		$150,000

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Evaluation Of Flygt Mixers For HL Waste For Mobilization
Contract L01560-156
blt
J.J. Zimmer

Success Estimating and Cost Management System

Flygt Mixers For HL Waste Mobilization
5 Startup/Testing
52 Operations

Rough-Order-Magnitude
Flygt Mixers For HL Waste Mobilization
ESTIMATE DETAIL BY WBS / COST CODE

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
	Total Hours:			0		$0		$0		$0		$0	
Total Cost Code: 900				0	0		$0		$150,000		$0		$150,000
	Total Hours:			0		$0		$0		$0		$0	
TOTAL WBS 520000				0	0		$0		$150,000		$0		$150,000
	Total Hours:			0		$0		$0		$0		$0	

WBS 521000 Safety Meetings/Training
Note : Allowance for safety meeting and training.

Acct # Craft ID	Description	Quantity	Unit	Manhours Baseline	Manhours SWP-Adj	Labor	Const Equip	Material	S/C	Procured Equip	General Cond	OH&P &SiteAlloc	Estimate Subtotal
Cost Code: 900	Other Project Costs												
920000000	SAFETY MEETINGS/TRAINING	1	LS	0		0	0	0	100000	0	0	31355	131355
Subtotal 92 Construction Management				0			$0		$100,000		$0		$131,355
	Total Hours:			0		$0		$0		$0		$31,355	
Total Cost Code: 900				0	0		$0		$100,000		$0		$131,355
	Total Hours:			0		$0		$0		$0		$31,355	
TOTAL WBS 521000				0	0		$0		$100,000		$0		$131,355
	Total Hours:			0		$0		$0		$0		$31,355	
TOTAL Flygt Mixers For HL Waste Mobilization				45,454	5,128		$15,244		$1,656,000		$144,893		$6,873,058
	Total Hours:			50,581		$3,608,944		$342,963		$162,000		$943,014	

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