Tank Lifting and Stabilization
Seminar Manual
MTS Mission Statement

To be a tank service corporation that effectively serves its clientele through:

- putting the clients’ needs first
- being cost effective
- using professional consultants, innovative and engineered technology, and trained personnel

... and to always do this with honesty, integrity and safety.
Tank Lifting and Stabilization

*Tank settlement and floor corrosion* have presented a serious challenge in refurbishing tanks that have been in operation for several years.

The industry recognizes the danger of operating tanks of questionable integrity. *Safety and contingent liability* concerns now require more attention be given to safe operation of these tanks through *good maintenance and upgrading*.

**Mix Bros. Tank Services** has been in the business of lifting and stabilizing tanks for over 35 years. We have developed the right equipment and have trained our personnel to do the job right the first time.
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INTRODUCTION

- **Catastrophic Rupture, Fire, Environmental Problems, Injury, Legal Liability**—all are contingencies which the storage tank industry has had to develop safeguards against, and strives daily to avoid. In examining ways in which to further protect your plant site from such possible occurrences, we invite your consideration of the following material, based on over twenty-eight years of experience in tank servicing. We will specifically address some proven preventative measures to counteract the effects of tank settlement. These measures comply with the recommendations in API Section 653 and will help you to prepare for increasingly specific environmental legislation affecting your tanks.

- **Steel Bulk Storage Tanks** have been in service for nearly a century. Over the last several years, it has been increasingly necessary to lift tanks for a variety of reasons—for re-leveling and stabilizing, installation of cathodic protection and secondary containment systems, floor replacement, and for relocation.

- Some of the systems currently being used to lift tanks such as air bags, or lifting using jacking lugs welded to the tank shell create the possibility for very serious contingency problems, primarily because each of these systems introduce undue stresses in the tank structure in the lifting process. These problems do not necessarily become immediately evident, but appear later when the tank is full of product and under the greatest operating stress. Additional factors such as a sudden change in temperature or an earth tremor can trigger catastrophic failure of the tank.

- Because of the capital cost of the tank itself, and the contingent liabilities resulting from failures caused by improper methods of lifting tanks, the only real insurance against tank failures is to utilize the right system and experienced personnel to lift tanks. **API Standard 653, Section B.1.3** states, “If it is decided to lift the entire tank shell and bottom at one time, it should be done by personnel with demonstrated experience in this technique.”

- There are very few contractors presently operating in the world today who have given serious thought to the very important business of lifting tanks safely without introducing undue stresses into the tank. The technology which **Mix Bros. Tank Services** utilizes is the most advanced in existence today. It ensures that neither adverse stresses nor secondary bending moments are introduced into the tank structure during the lifting process.

- This material will explain the differences between the various methods in use today and **Mix Bros. Tank Services’ “Electro-Hydraulic Equalift”** jacking technology. It will examine the various reasons for lifting tanks, and illustrate why this technology is the best insurance against tank failures and the contingent liabilities associated with such failures.
METHODS OF RAISING TANKS

1. FUNDAMENTALS

When raising a circular structure, such as a storage tank, it is extremely important to remember that unlike a rectangular structure where one side can be lifted at a time using the opposite side as a pivot point, a circular structure has no such pivot point. As illustrated in Drawing L0039, lifting pressure cannot be applied in one area of the tank without inducing adverse stresses in other areas, such as the shell and floor on the opposite side of the tank. As a result, the only way to ensure that no adverse stresses are introduced into the tank structure is to lift the tank uniformly, level and in plane, all the way around its perimeter.

2. THE RIGHT TOOL FOR THE JOB

If the tank is to be raised high enough to accommodate men and equipment working underneath it, jacks which are large and long enough to accomplish a single lift to the desired elevation are preferable. Some methods using short-stroke jacks can also attain these elevations, but only by a series of lifts, which require blocking of the tank while the jacks are re-set. A major problem using air bags or short-stroke hydraulic jacks is that the tank is seldom lifted and lowered vertically, which often rotates the tank out of alignment with the piping connections.

MTS’ Electro-Hydraulic Equalift Jacking System

a) High Lift

To accomplish this in a single lift, the “HIGH LIFT” hydraulic jacking method is utilized. When lifting a tank to build the entire foundation, to install secondary containment liners, to inspect the underside, to dismantle the tank or to install undercarriages for relocation, the Electro-Hydraulic Equalift Jacking System is used to meter large volumes of oil to our Single Stroke HIGH LIFT jacking cylinders. With each jack receiving an equal volume of oil, a smooth and perpendicular lift is ensured (Photo IM000772).

Over the last 40 years of MTS’ involvement in industrial lifting and moving of heavy and over-dimensional structures, we have led the way in developing new and better systems to handle delicate loads with a high priority to keep the vessel or tank free of unnecessary stress. Our research
Pivot Point is predictable

Pivot Point is unpredictable
Electro-Hydraulic Equalift Jacking System

Photo IM000772
and development efforts have resulted in the world’s most advanced unified lifting technology dedicated to lifting large storage tanks.

The objectives to be attained in our self-imposed mandate involved the following.

1) The system must allow for a 10 foot lift in a single stroke (Photo DM00003).

2) The oil to each jacking station must be very accurately metered to ensure an equal volume of oil to each jacking cylinder, regardless of differentials in weight carried by each cylinder. This aspect of the technology ensures a level, in-plane, perpendicular lift without jockeying the tank from side to side during the lift. The equipment must also have the option to provide equal pressure to any one or all of the jacking cylinders to accommodate the manipulating of the tank to in-plane level when the tank has settled out of level.

3) The hydraulic oil supply must meet or exceed 30 gallons per minute to ensure a lift in a matter of minutes. The lowering of the tank needs to happen in the same time frames and manner to give protection against an unexpected storm blowing in.

4) The hydraulic pressure supplied by the pump must equal the working pressure of the rest of the system, that being 3500 to 4000 pounds per square inch.

5) The design needs to ensure stability for 75 mile an hour winds when the tank is elevated 8 feet above the pad (Photo IM00089).

6) Every aspect of the system must have at least a five to one safety factor built into the equipment and procedures.

7) The system design must be “idiot proof” with automatic shut downs if mistakes are made by the operator. This helps to eliminate risks (Photo DM00002).

8) Electrical and hydraulic schematics must be clear and understandable so that any professional tradesman could trouble shoot and repair even if they have never seen the machine before.

9) The jacks must be sturdy enough to endure the stress of the lift as well as the potential of rough handling during transportation.
Ten Foot Stroke

Photo DM000003
10) A tank support safety system with a very definite means of evaluating from an engineering perspective must be in place to protect men and equipment working under the tank. This is accomplished through the placing of engineered steel columns at each jacking position. **Safety columns** stand next to the cylinder rod to carry the weight should a leak develop (Photo IM000778). The column value of the 6 x 6-W15 complete with \( \frac{1}{2} \) inch plates welded on each end is 75,000 pounds as per the advice of our P. Eng. There is always a space of 1.5 to 2 inches between the top of the column and the underside of the apron to allow for the thermal expansion and contraction of the oil in the jacking cylinder.

11) Being able to lift the tank in one stroke to full height allows for **Prefabolicated Bolted Together Cribbing** to be installed mechanically after the tank has been lifted. This allows for easy repositioning of the cribs as foundation work progresses, and since the cribs can not be handled by hand, but by a fork lift or a loader, crew fatigue and back straining from block stacking by hand is eliminated.

All of the criteria was met or exceeded in the final product that has been developed and manufactured by **Mix Bros Tank Services**.

The technology allows for a perpendicular lift, combined with proper floor and roof support. The tank is not twisted or contorted as is necessary when lifting with airbags, where the tank is teeter tottered over pivot points. The MTS single stroke high lift jacks have excellent lateral stability, unlike airbags which have none. Airbags should never be used to lift a tank of any significant size. A unified oil volume delivery system and single stroke high lift jacks is the only right way to lift tanks.

**b) Low Lift**

When addressing **out-of-plane (differential) shell settlement, or edge settlement problems**, the “**LOW LIFT**” technique is utilized. Once the tank has been lifted clear of its foundation using the same lifting equipment, but with shorter jacking cylinders, it can be brought to a level plane. As the volume of oil flow is precisely measured to each jacking station, a perpendicular lift is ensured, maintaining the tank in a **stress-free position** while re-foundationing work to correct the settlement problem is conducted around the periphery of the tank (Photo IM000228).
Safety Columns and Prefabricated Bolted Together Cribbing
Low Lift Jacking System
3. PRESSURE VERSUS VOLUME

Because lifting a tank from side to side alters the stress dynamics within the tank, it is important to ensure a perpendicular lift. Using a system which involves only equal pressure, such as a free flow of oil to hydraulic jacks or equal air pressure to airbags; does not guarantee a perpendicular lift.

Mix Bros. Tank Services’ LOW LIFT and HIGH LIFT hydraulic jacking technology is based on a central jacking unit which supplies an equal volume of oil to each jacking station. These systems ensure that each jack raises at exactly the same rate. Because it does not operate on equal pressure, which is subject to weight differentials, this system ensures a perpendicular lift of the tank.

4. LIFTING POINTS

a) The point on the tank which lifting pressure is applied is of crucial importance. Systems such as airbags, air foils, or water flotation apply lifting pressure to the floor plates, turning this thin membrane into a structural member to carry the entire weight of the shell. The tank floor is designed only as a seal to contain fluid, and is not designed to be a structural member. Any flexing of the floor plates at the shell, caused by such lifting pressures, can cause weld fractures. These fractures may not appear until months or years later when the tank is fully loaded and the floor-to-shell weldaments fail, resulting in a catastrophic rupture.

b) The attachment of jacking lugs onto the tank shell for the purpose of lifting also presents stress-related problems. First, their attachment to the tank shell necessitates welding, resulting in heat-affected zones and induced stresses. Second: When using short stroke hydraulic jacks, the lug must be designed offset from the shell enough to allow for the dimensions of the cribbing used to jack from, the eccentric nature of these lugs induces substantial direct stresses and secondary bending moments into the tank shell (see Drawing L0015). With the MTS single stroke High-Lift Jacks these Lugs, when or if necessary, are more compact in design, substantially reducing the secondary bending moments and stress.

c) The only point on which lifting pressure can be applied without any moment or detrimental stress is directly under the tank shell. The LOW LIFT and HIGH LIFT systems use specially designed lifting aprons to ensure that lifting pressure is applied only at this point and not under the floor plates inside the shell. As illustrated in Drawing L0040, neither the floor plates nor the tank shell are subjected to any induced stresses—making this the best method to ensure the tank lifting operation does not result in weld fractures and spills.
INCORRECT WELDED SHELL LUG LIFTING METHOD

TANK SHELL

LIFTING STRESS

WELDED ON LUGS CAUSE LOCALIZED HEAT STRESS

SHORT LUG CAUSES SHELL BENDING

LIFTING STRESS

ECCENTRIC LIFTING FORCE

JACK

TIMBER CRIBBING
SAFE JACK SPACING (40') WAS DETERMINED BY ENGINEERING CALCULATION. THE HIGH TANK WALL ACTS AS A LARGE I-BEAM SO THERE IS NO DEFLECTION BETWEEN JACKING POINTS.

UNIFIED HYDRAULIC JACKING UNIT SUPPLIES EQUAL PRESSURE OR EQUAL VOLUME OF OIL TO EACH JACK SIMULTANEOUSLY.

HYDRAULIC OIL SUPPLY HOSES

WOODEN SPACER - NO WELDING REQUIRED ON TANK SHELL

HYDRAULIC JACK

TANK FLOOR

LIFTING FORCE IS DIRECTLY UNDER THE SHELL
TANK LEVELING AND STABILIZATION

The leveling and stabilization of tanks is necessary due to the effects of tank settlement. Tank settlement can occur in a variety of ways, each affected by a number of factors. Because of inherent safety concerns related to tank failures caused by excessive settlement, API Standard 653 contains a number of requirements governing maximum permissible tank settlement limits. The Electro-Hydraulic Equalift tank lifting technologies are the safest and most economical way to rectify tank settlement problems, both to satisfy API requirements and more importantly, to ensure continued safe operation of tanks currently in service. This section will examine the contributing factors to tank settlement, causes and effects of settlement, and the safest and most effective solutions to these problems.

1. GEOLOGICAL CONSIDERATIONS IN SETTLEMENT

In understanding why tanks settle, it is important to consider the characteristics of the soil beneath the tank, and the ways in which various kinds of soil will react when subjected to the pressure or load of the tank on the soil. (The following information is referenced from An Introduction to Geotechnical Engineering, Robert D. Holtz & William D. Kovacs, 1981 Prentice-Hall, Inc., Chapter 8, “Consolidation and Consolidation Settlements”).

a) “When a soil deposit is loaded (for example by placement of a loaded tank upon it), deformations (of the soil) will occur. The total vertical deformation at the surface resulting from the load is called SETTLEMENT.

b) When a soil deposit is loaded, it will compress because of:

1) deformation of the soil grains
2) compression of air and water in the voids, and/or
3) squeezing out of water and air from the voids.

c) As pore fluid is squeezed out, the soil grains rearrange themselves into a more stable and denser configuration, and a decrease in volume and surface settlement results.

d) How quickly this process takes place depends on the permeability of the soil. It is therefore important to consider the qualities of the two kinds
of soil most commonly found under tanks—**granular materials such as sand or gravel**, and **clay soils**.

e) **Granular materials** (coarser-grained soils) such as sand and gravel are subject to very quick consolidation—nearly instantaneously in most cases. This is because of the relatively high permeability of granular soils. In other words, *it is very easy for the water (and air) in the voids to be squeezed out*.

f) When *clays* undergo loading, because of their relatively low permeability the compression is controlled by the rate at which water is squeezed out of the pores. This process is called **consolidation**. Deformation of clay soils under load may continue for months, years and even decades.

2. **TANK SETTLEMENT THEORY**

a) **Storage Tanks vs Flexible Structures**

It is also important to consider the differences between storage tank settlement as opposed to settlement of other flexible structures.

In predicting tank settlement, it was generally assumed that bulk storage tanks, like other flexible structures, exert a **uniform load** on the base on which they are located. The pressure distribution beneath a tank has thus been described as is illustrated in **Drawing L0019, Fig. 1**. The circular lines below the cross-section of the tank illustrated are lines along which there exists equal pressure. The top line represents a pressure of 90% of the pressure exerted at the surface, with each successive bulb representing an area of lower pressure. Tank settlement has therefore **been predicted** to occur along the lines of pressure, as illustrated in **Drawing L0019, Fig. 2**.

In *actual practice*, however, bulk storage tank settlement **does not occur in this manner**. There are fundamental differences between bulk storage tanks and other flexible structures which result in differences in settlement. **While other flexible structures may exert a uniform load on their substrate bases, bulk storage tanks do not**.

1) The **tank shell** (by way of example, 40 ft high), because of the weight of the steel in the wall and a portion of the roof, **exerts a downward force of approximately 800 to 1000 pounds per lineal foot along the circumference of the tank**.
UNIFORM LOAD

PRESSURE BULGE

FLOOR

FIG. 1

STORAGE TANK LOAD

FIG. 3

UNIFORM LOAD

SURFACE PRESSURE

SETTLEMENT

FLOOR

FIG. 2

TANK LOAD

SURFACE PRESSURE

SETTLEMENT

FLOOR

FIG. 4

UNIFORM LOAD

SUB-SURFACE PRESSURE

SETTLEMENT

FLOOR

STORAGE TANK LOAD
2) This pressure is borne on the 1.5”-2” sketch plate projection around the bottom of the tank. This results in an effective load of **6000 to 8000 pounds per square foot** (greater on higher or heavier-walled tanks) (Drawing L0021).

3) In contrast, the pressure exerted by the product in the tank and the tank floor itself (assuming 40 ft of fluid with a specific gravity of 0.8 within the tank), even when the tank is fully loaded, is just **2000 pounds per square foot** (or **3400 pounds per square foot on a 64 foot high tank**).

4) Because of this weight and pressure differential, the actual pressure bulbs beneath the tank are therefore as is illustrated in Drawing L0019, Fig. 3, with settlement thus predicted to occur as shown in Drawing L0019, Fig. 4.

To illustrate from an actual project, **Mix Bros. Tank Services** was called to analyze and alleviate a settlement problem on a 100-foot diameter tank, 40 feet high, situated in western Canada. In this tank, pressures along the sketch plate are approximately 6000 psf. Pressure on the inside tank floor is approximately 2000 psf. The tank was constructed in 1955. No settlement readings were available until 1964 (nine years later). However, from 1964 to 1975, the tank settled approximately 0.4 ft (nearly 5 inches). (Drawing L0018). Note that this settlement occurred **after** the tank had undergone its theoretical maximum rate of settlement, which occurs in the first few years after construction. Note as well that the greatest amount of settlement occurred along the tank perimeter.

b) **Settlement Components**

In addition to this weight differential between the tank shell and the rest of the tank, there are **three settlement components** which affect the way in which a tank will settle. These are outlined in API Standard 653, Section B.2.2.:

“Settlement of a tank is considered to be the result of either one or a combination of the following three settlement components.

1) **B.2.2.1. Uniform settlement**

(Drawing L0013, Fig. 1). This component often can be predicted in advance, with sufficient accuracy from soil tests. It may vary in magnitude, depending on the soil characteristics. Uniform settlement of a tank does not induce stresses in the tank structure. However, piping and attachments must be given adequate consideration to prevent problems caused by such settlement.

(MTS Note: B.2.2.1 is a reference to the consolidation of the soil in the substrate, and assumes that the wall of the tank has been
UNIFORM "FLAT FLOOR" SETTLEMENT IS UNCOMMON

SHELL AND FLOOR EDGE SETTLEMENT IS MOST COMMON
properly foundationed so that the entire structure [wall and floor] settle at the same rate.)

2) **B.2.2.2 Rigid body tilting of a tank (planar tilt)**
   This component rotates the tank in a tilted plane (Drawing L0042, Fig. 1). The tilt will cause an increase in the liquid level, and therefore, and increase in the hoop stress in the tank shell. Also, excessive tilting can cause binding of peripheral seals in a floating roof, and inhibit roof travel. This type of settlement could affect tank nozzles that have piping attached to them. Drawing L0037 shows that the settled location of the tank shell, after rigid body tilt, can be represented by either a cosine or sine wave with respect to its original position in a horizontal plane.

3) **B.2.2.3 Out-of-plane settlement (differential settlement)**
   Due to the fact that a tank is a rather flexible structure, chances are great that the tank shell will settle in a non-planar configuration, inducing additional stresses in the tank shell (Drawing L0043). The out-of-plane settlements at the bottom edge lead to a lack of circularity at the top of the tank, and in the case of a floating roof tank, the extent of the induced ovality may impede the proper functioning of the floating roof in such a way that re-leveling is required. Also, such settlements may cause flat spots to develop in the tank shell. This type of settlement could affect tank nozzles that have piping attached to them.

   While uniform settlement and rigid body tilt of a tank may cause a number of problems by themselves, as described in API Standard 653, our experience has shown that the majority of tank settlement concerns stem from differential (out-of-plane) settlement, both around the shell and near the floor to shell joint. Further, API Standard 653, Section B.2.2.4. states that “...the out-of-plane settlement is the important component to determine and evaluate, in order to ensure the structural integrity of the shell and body.” Because tanks will settle differently than other structures, as explained previously, the most prevalent form of settlement is a combination of out-of-plane and edge settlement.

   1) **Edge settlement** occurs when the tank shell settles sharply around the periphery, resulting in plate deformation near the shell-to-bottom corner junction (Drawing L0038).

It is significant to note that in actual field situations, it is almost always a combination of these three factors (as identified above) that results in a settled tank being out of specification. **In fact, in over 20 consecutive years of raising tanks to correct settlement**
Fig. 1
RIGID PLANAR TILT
WHERE FLOOR MOVES IN PLANE WITH THE SHELL, IS UNCOMMON

Fig. 2
PLANAR TILT OF SHELL
WHERE FLOOR DOES NOT MOVE IN PLANE WITH THE SHELL, IS COMMON

SEE DWG. L0013
FOR UNIFORM TANK SETTLEMENT
Out-of-plane deflection for point \( i \) is
\[
S = U - \left( \frac{1}{2} U + \frac{1}{2} U \right) \text{ for example: } S = U - \left( \frac{1}{2} U + \frac{1}{2} U \right)
\]

\( U \) = out of plane settlement of point \( i \)
\( - \) when above cos. curve;
\( + \) when below cos. curve, for example:
\( U = (+) \)
\( U = (-) \)

Note: See 10.5.1.2 for definition of "N"
FLAT SPOTS (OVALLITY) IN SHELL

WAVY ROOF PLATES

CREASING OF SHELL/ROOF JOINT

SEVERE STRESS IN SHELL, ROOF, AND FLOOR

INTERIOR FLOOR PROFILE

ORIGINAL ELEVATION

FLOOR AT SHELL PROFILE

SEE DWG. L0037 FOR GRAPHICAL REPRESENTATION
R = Radius width of settled area (in feet)
B = Settlement (in inches)

Permissible depth of B is given by this formula:

\[ B = 0.37R \]
problems, Mix Bros. Tank Services’ personnel have never observed a uniformly settled tank, or a rigid body tilt-settled tank that has not had edge settlement problems, which became evident once the tank was opened for internal inspection.

2) A major obstacle in determining the seriousness of the stress resulting from settlement is the fact that tanks are seldom taken out of service to allow for an inside inspection and inside survey of the tank. This inside inspection and survey is crucial in determining the actual nature and seriousness of the settlement problem. For example, when a survey taken around the outside perimeter of a tank shell alone indicates that the tank has tilted, but the chime is still in plane, the assumption is that the entire tank meets API 653 specifications; however, the low side of the tank invariably has a greater amount of edge settlement than the high-to-low differential of the tilt ([Drawing L0042, Fig. 2]). As well, uniform settlement may also cause problems of edge settlement which are not evident unless the interior of the tank is available for inspection ([Drawing L0013, Fig. 1 + 2]). Accurate methods of measuring and assessing tank settlement are described later in this presentation.

3. CAUSES OF SETTLEMENT

   a) Precipitation

   The roof area of a tank collects a large amount of water during rainfall. This water is deposited down the tank shell onto the pad, thoroughly saturating the edge of the pad. Saturated foundation material has a much reduced bearing capability contributing to tank shell settlement. [Drawing L0022] illustrates the results of the reduced strength of saturated foundation materials. In addition, heavier water run-off causes erosion from under the sketch plate and the edge of the tank pad, causing further settlement.

   b) Thermal Expansion and Contraction

   During the course of an average day, a tank will expand and contract due to thermal effects from the sun and temperature changes. The degree of expansion and contraction is affected by temperature differentials, as well as the amount of fluid in the tank. This expansion and contraction, coupled with the pressure of 6000-8000 psf under the sketch plate, results in the soil being shaved away, contributing to tank shell settlement. ([Drawing L0024]). This can be observed when there is a build-up of material around the bottom periphery of the tank.
Fig. 1
RIGID PLANAR TILT
WHERE FLOOR MOVES IN PLANE WITH THE SHELL, IS UNCOMMON

Fig. 2
PLANAR TILT OF SHELL
WHERE FLOOR DOES NOT MOVE IN PLANE WITH THE SHELL, IS COMMON

SEE DWG. L0013 FOR UNIFORM TANK SETTLEMENT
UNIFORM "FLAT FLOOR" SETTLEMENT IS UNCOMMON

SHELL AND FLOOR EDGE SETTLEMENT IS MOST COMMON
SATURATED FOUNDATION MATERIAL WITH REDUCED BEARING CAPACITY

ACCUMULATION OF RUN-OFF FROM TANK ROOF

2'

APPROX. 8 TO 10'

PRECIPITATION EFFECT

c) **Displacement of Foundation Material**

The foundation material under the shell is often saturated to well beyond the optimum moisture content. Bearing strength of saturated soil can only be a fraction of the same soil in a dry condition. When all the factors are acting together—the weight of the tank shell, the saturated plastic soil fines, and the thermal expansion and contraction of the tank—there is a displacement of material from under the tank shell out to the exterior of the tank perimeter *(Drawing L0023).*

d) **Insufficient Shell Support**

Inadequate foundation construction has been an important factor in tank settlement. In many cases, the entire foundation pad was designed and built for a pressure of 2000 psf, reflecting the general assumption that tanks, like other flexible structures, exert a uniform load upon their bases. However, part of the pad supports a pressure of 2000 psf, while the portion directly beneath the sketchplate supports a pressure of up to 8000 psf. In order to effectively equalize the pressure/weight differential between the tank interior and the tank shell, an annular bearing member of at least 2 feet wide, placed strategically under the shell would be required. However, in most cases, tanks are constructed with a sketch plate of only 1.5”-2”, extending outside the bottom perimeter of the shell, to bear this pressure. Therefore, *pad construction* should be designed to support this weight differential. This has not normally been the case in most tank farms in North America.

It should be noted that even if a tank is positioned on a substrate of well-compacted granular material, such as sand or gravel, the above factors will eventually contribute to shell settlement.

4. **EFFECTS AND RESULTS OF TANK SHELL SETTLEMENT**

Over a period of time, a tank shell may settle considerably, dependent on the factors outlined above. *API Standard 653* provides formulas for calculation of acceptable settlement, beyond which the stresses to which the tank structure is subjected become unacceptably high, and present a risk of rupture. **Tank ruptures happen at the point where stresses are greatest.** On a storage tank, this is typically at the floor-to-shell connection. **Ruptures create disastrous situations—environmentally, fiscally and from a safety standpoint.** There are observable effects of stress that will indicate the possibility of a problem.

a) **Adverse Stresses in the Corner Weld Area**
ORIGINAL GRANULAR FOUNDATION

DISPLACEMENT OF SATURATED MATERIAL
As a tank experiences settlement, primarily edge settlement, adverse stresses are induced in the corner weld area. This area is considered a “critical zone” as outlined in API 653 Section 7.9.1.1, which states “the critical zone for repairs to the tank bottom is within the annular ring, within 12 inches of the shell, or within 12 inches of the inside edge of the annular ring.” As the stress induced by settlement increases with continued settlement, strain results. This strain may be readily visible during an informal external tank inspection, or may be concealed from view. Typical strain patterns in the corner weld area include deformation of the bottom of the shell or elongation of bottom plates. If settlement continues unchecked, stresses will manifest themselves in a failure. Failures in the corner weld area typically occur in one of two ways—plate failure or weld failure.

The steel plate material used in tank shells and bottoms will deform elastically until stress values reach the yield point. At this point, the plate material will permanently deform. Typically, a light-walled tank shell will elastically strain and pull inwards (Drawing L0027, Fig. 1). In heavier-walled tank shells, due to increased rigidity in the shell, bottom elongation is the primary mode of failure. At the yield point of a ¼” thick bottom plate, stress can exceed 100,000 pounds per lineal foot of shell circumference. As the bottom plate thickness increases, as with corrosion allowances, this load at yield also increases. The tension developed by this stress also directly loads the shell-to-bottom weld. If the geometry of the corner weld area is such that the yield strength of the bottom plate exceeds the strength of the corner weld, a weld failure is likely. It is important to note that these high loadings will concentrate stresses at weld defects. Stress concentrations invariably lead to premature failures both in weldament and material (Drawing L0026).

b) Other External Indicators of Deformation and Settlement

External evidences of tank shell deformation and settlement also include dimpling of the tank shell at the rafter-to-shell connection of fixed-roof tanks, flat spots in the shell, and deflection of piping leading to the tank. Also, when the tank is empty, and the weight of the fluid is off the floor, the floor plates will often rebound, raising the shell slightly off the pad (Drawing L0020).

Other forms of tank shell deformation include out-of-roundness at the top of open-top tanks, as a result of differential settlement. The resulting ovality of the tank can cause binding of the peripheral seals in a floating roof and inhibit roof travel, resulting in the need to re-level the tank.
FIG. 1
LIGHT WALLED TANK

FIG. 2
HEAVY WALLED TANK
FIG. 1
BEFORE SETTLEMENT

FIG. 2
AFTER SETTLEMENT
FIG. 1

IN SETTLEMENT, THE FLOOR PLATE BECOMES A STRUCTURAL MEMBER

SKETCH PLATE LIFTS SLIGHTLY

LOW PRODUCT LEVEL ~ 1' - 0"

FIG. 2

~ 6'

DIMPLING AT RAFTER CONNECTION

FIG. 3

STRESS AT PIPE CONNECTION

LONGITUDINAL MOMENT INDUCED IN TANK SHELL
5. MEASURING SETTLEMENT

API Standard 653, Section B.1.2. indicates that “a decision to level a tank . . . relies very much on the proper interpretation and evaluation of the monitored settlement data.”

Section B.2.1. further identifies an absolutely crucial procedure in measuring tank settlement: “The principal types of tank settlement consist of settlements which relate to the tank shell and bottom plate. These settlements can be recorded by taking elevation measurements around the tank circumference AND across the tank floor. (MTS NOTE: From the highest elevation to the lowest, as per the circumferential survey) . . . Data obtained from such measurements should be used to evaluate the tank structure. Drawing L0036 Figs. B-1 and B-2 (from API Standard 653, Section B) illustrate the correct method for surveying a tank in order to obtain these two sets of measurements. It is only when these measurements are used together that an accurate picture of actual tank settlement can be achieved. Please note as well that although it is important to have the perimeter of a tank level, it is even more important to correct the out-of-spec edge settlement to relieve the stress between the floor and the wall.

Once an accurate survey of the tank has been obtained, API Standard 653 supplies the following formula to calculate maximum permissible edge settlement (Section B.3.3.):  

\[
B = 0.37R
\]

Where:
B = settlement, in inches
R = radius width of settled area, in feet

A simple explanation of this formula when applied to edge settlement is that the maximum permissible edge settlement is 3/8” per foot of settled area (Drawing L0038).

The formula for calculation of allowable out-of-plane settlement is as follows (Section B.3.2.):

\[
S < (L \times Y \times 11) \ [2(E \times H)]
\]

Where:
S = deflection in feet (out of plane distortion)
L = arc length between measurement points, in feet
Y = yield strength, in pounds per square inch
E = Young’s modulus, in pounds per square inch
H = tank height, in feet
Notes:
1. There must be at least 8 settlement points. The maximum spacing of settlement points is 32 feet around the circumference.
2. Points shall be equally spaced around the tank shell. API 653 10.5.1.2 gives the following method of determining the number of settlement points:
   Divide the tank diameter (in feet) by ten and round up fractions to the next higher number. Minimum is 8 survey points.
   Eg. 100ft dia. div. by 10 = 10 survey points minimum.

3. API 653 asks for at least 8 settlement points. The maximum spacing of settlement points is 32 feet around the circumference.
4. Points shall be equally spaced around the tank shell. API 653 10.5.1.2 gives the following method of determining the number of settlement points:
   Divide the tank diameter (in feet) by ten and round up fractions to the next higher number. Minimum is 8 survey points.
   Eg. 100ft dia. div. by 10 = 10 survey points minimum.

Measurements of Shell Settlement (External)

Measurements of Internal Floor Settlement- Tank Out of Service
R = Radius width of settled area (in feet)
B = Settlement (in inches)

Permissible depth of B is given by this formula:

\[ B = 0.37R \]
Should the measurements reveal that the tank is outside the maximum limits, **Section B.3.1.** indicates that “experience has shown that if settlements exceed the . . . requirements, then further assessment or repair is required.” **Section B.1.2.** further indicates that “if at any time settlement is deemed excessive, the tanks should be emptied and re-leveled.”

### 6. CORRECTING SETTLEMENT

When a settled tank is determined to be outside recommended API requirements, a decision must be made on whether or not to relevel the tank. In this regard, **API Standard 653, Section B.1.3.** states:

“Approaches used to correct tank shell and bottom settlement include techniques such as localized repairs of the bottom plates, partial re-leveling of the tank periphery, and major re-leveling of the entire tank bottom. Major re-leveling of the tank, involving total lifting of the tank shell and bottom at one time, can introduce high localized stresses in the structure and impair its integrity. . . . If it is decided to lift the entire tank shell and bottom at one time, it should be done by personnel with demonstrated experience in this technique. ”

**Mix Bros. Tank Services** has the technology and expertise to respond to both kinds of lifting requirements, as outlined in the API recommendation above, to address tank shell settlement needs. While it used to be a major concern to tank owners facing the prospect of having to lift a tank, the methods and technology used by **Mix Bros. Tank Services** ensure that no adverse stresses are induced into the tank shell, making even the total lifting of the shell and bottom at one time a safe and economical operation.

The safest method for the total lifting of the tank shell and bottom at one time is the **HIGH LIFT** method. This method uses hydraulic jacks with a 10-foot-plus stroke. The interior floor and columns are first suspended using an interior cabling system, to ensure that no structural damage occurs during the lifting process. The entire tank is then lifted off the old pad with the **Electro-Hydraulic Equalift Jacking System.** The pad and foundation are then repaired or reconstructed to provide a stable foundation.

Total lifting of the shell and bottom at one time may not always be required, depending on the repair needed. The alternative to total lifting of the tank shell and bottom is the **LOW LIFT Repair** method. This method involves lifting the tank shell with the **Electro-Hydraulic Equalift Jacking System**, to a height consistent with the undisturbed interior of the tank, to its original design elevation, conducting the necessary repairs to the foundation, and thus re-leveling and stabilizing the tank on its new foundation.
It should also be noted that although some advocate methods (for correcting tank settlement) using localized lifting techniques to lift one portion of the tank while the rest remains in place, **Mix Bros. Tank Services** does not utilize localized lifting techniques. **In fact, localized lifting often introduces more stress into the tank than it removes.** It is not at all uncommon to raise a tank because a survey would indicate shell differential elevations (out-of-plane), only to find that when the tank is suspended on our hydraulic system with near-equal pressure at each jacking station, that the out-of-plane, high/low spot was actually built into the tank. To attempt to correct the elevation differential in this situation will only induce severe stress in the tank. For this reason, a circumferential survey which may indicate an out-of-plane shell can only be verified when the entire shell has been uniformly lifted off the pad, and the pressures of each jacking station are taken into account.

Recognizing the causes and associated problems with tank settlement, **Mix Bros. Tank Services** provides a number of recommended methods for foundationing and stabilizing settled tanks. If a tank is to be successfully stabilized, an adequate foundation must be installed under the tank shell. In extreme cases, reconstruction of the entire pad and foundation may be necessary. *This must be done using sound engineering principles that follow normally accepted construction standards regarding soil-bearing designs.*

The effect of each repair method outlined below, in its proper setting and circumstances, is to safely and effectively equalize the excessive downward pressure directly beneath the tank shell, to ensure that the pounds per square foot of load are consistent beneath the entire tank.

**a) Factors which determine the method of repair include:**

1) Substrate soil composition—sand, silt, clay or combinations of these.
2) Soil moisture content
3) Distance to the bedrock
4) Weight of tank shell

**b) Repair methods provided by Mix Bros. Tank Services include:**

1) Reinforced Concrete Ring with Fillcrete ring footing
2) Reinforced Concrete Ring with Annular Aggregate
3) Fillcrete ring footing
4) Aggregate Ring with Geotextile
5) Piling
6) Lift and Fill Voids with Fine Crushed Aggregate or Sand

These methods are outlined in detail in the following pages.
24" x 24" Concrete Ringwall
On Gravel Foundation

Tank Wall

7/16" x 24" Fibreboard
(Asphalt-impregnated)
Above Concrete Ring

25 MPa (3500 psi) Concrete Ring
Reinforced with
6-25M (#8) Horizontal Bars &
10M (#4) Stirrups @ 18"
Min. Bar Spacing from forms
Top & Outside 1.5"
Bottom & Inside 3"

Tank Floor
Restored to Design Elevation

14" 10"

Native Material
Slope H2 for 3'
Then Slope H to
Existing Grade

Void Space Filled
With
Conveyed Sand or
1/4" minus Aggregate

Clean Crushed Gravel
Compacted to 95% Std.
Proctor Density

1 1/2" to 2" Clean Rock
To Permit Drainage
During Construction

Geotextile Liner
Prevents Gravel
From Migrating

6'-0"
7. REPAIR METHODS

a) **Reinforced Concrete Ring with Fillcrete Annular Footing**

Fillcrete is a flow-able fill material consisting of a sand and cement mix to produce about 400psi in strength. It replaces crushed stone or compacted granular type foundation support footings. It interfaces well where there is poor muddy soil that makes it impossible to compact a granular foundation over. It can be excavated when cured for addition of or changes to electrical or underground piping to tank (Drawing D00012).

This configuration is the optimum choice for several reasons:

1) It lowers the bearing pressure of the shell on the underlying soil by increasing the bearing surface.

2) Fillcrete is waterproof so it shields the foundation base from excessive water and run off and erosion, and prevents saturation of bearing soil.

3) Fillcrete keys into the contour of the trench, increasing foundation stabilization and effective bearing area of soil.

4) Faster to install, since no compaction time is required, reducing turnaround time.

b) **Reinforced Concrete Ring with Annular Aggregate Ring**

The *Reinforced Concrete Ring with Annular Aggregate Ring* method involves the construction of a reinforced concrete foundation complete with an annular sub-base of well-graded and compacted crushed material (Drawing L0007). This configuration has several advantages:

1) It lowers the bearing pressure of the shell on the underlying soil by increasing the bearing surface.

2) The reinforced concrete ring also acts as a splash pad for rain water run-off, preventing erosion of material from under the tank.
Ring Wall Construction:

compacted fill

Existing soil

Fillcrete interlocks with irregularities of trench and increases stability of foundation

MTS

Fillcrete footing and concrete ring wall foundation

D00012
GOAL TAR SEALANT,
2 1/2' ASPHALT, SLOPE 1:12 FOR 3'
1' OF 1/2" MINUS GRAVEL
WATER RESISTANT PLASTIC MEMBRANE

NATIVE MATERIAL
SLOPE 1:1 TO EXISTING GRADE

TANK SHELL

3/4" WASHED ROCK
SELF-COMPACTING

CLEAN CRUSHED 3" MINUS
GRAVEL COMPACTED TO
95% STD. PROCTOR

1-1/2" to 2" CLEAN ROCK
6" DEEP TO PERMIT TRENCH
DRAINAGE DURING
CONSTRUCTION

GEOTEXTILE LINER

GEOGRID
PREVENTS GRAVEL
FROM MIGRATING

TANK FLOOR
RESTORED TO DESIGN ELEVATION

PREVIOUS TANK FLOOR ELEVATION

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GEOGRID
PREVENTS GRAVEL
FROM MIGRATING
3) It acts as a soil retainer, keeping the foundation material under the tank.

4) The concrete acts as a “rub-plate” for thermal expansion and contraction of the tank.

For these reasons, the reinforced concrete ring is an excellent method of stabilizing your tank.

NOTE: When using the High Lift method in conjunction with the reinforced concrete ring, the tank can be lowered onto the newly reconstructed pad, and the concrete poured to match the existing contours of the bottom of the tank. Experience has proven that this method works well to ensure a proper “fit” between the existing tank and new concrete.

c) Fillcrete Ring

The Fillcrete Ring method involves the excavation of a 42” deep by 60” wide trench under the perimeter of the tank, that is filled with Fillcrete similar to the Fillcrete ring under the concrete foundation mentioned above(a) (Drawing D00018). It is a fast and economical foundation that performs very well. It sheds water and keeps bearing soils from becoming saturated, however, fillcrete should not be used in situations where the tanks is desired to be raised above grade. It performs best at or below grade, for above grade concrete reinforced ring wall should be used.

d) Crushed Aggregate Ring with Geotextile

The Crushed Aggregate Ring method involves the construction of a compacted crushed aggregate foundation to broaden the base and reduce the bearing requirement under the shell. The existing contaminated soil around the periphery of the tank is removed and replaced with new well graded crushed aggregate. Geotextile fabric can be utilized to maintain the stability and confinement of the new compacted material (Drawing L0006).

NOTE: While this method will ensure stability of your tank for several years, it misses some of the advantages of the concrete ring foundation.

e) Piling
Ring Wall Construction: Tank is lifted to correct settlement issues before Fillcrete is installed

Fillcrete

Existing soil

Fillcrete interlocks with irregularities of trench and increases stability of foundation

Load

MTS

Fillcrete Footing

D00018

ns
e) **Piling**

In situations where the tank has settled severely on soils that have very low shear and bearing capacity, it may be necessary to install added support by pressing piles around the perimeter of the tank.

*It is very important to note that this procedure is meant only to add stability and not to be the prime-bearing member.* For this reason MTS promotes the pressing of the piles to a depth that will carry only half of the projected weight of the tank shell and the fluid that is stored directly above the ring wall and piles. The other half of the load is carried on the ringwall. If the ringwall settles because of consolidation the piling will settle along with it avoiding the problem of point loading that would result if the piles were pressed deep enough to carry the whole load.

MTS uses a hydraulic cylinder with a 20 foot stroke to press the piles to the desired resistance to equal 50% of the projected load.

The weight of the tank supplies the ballast for the pile pressing unit to push against when installing each pile.

The piles are pressed immediately against the edge of the tank and utilize an offset pile cap to transfer the load *(Drawing L0007K).*

Accurate analysis and pre-engineering are performed in advance to determine the approximate depth of the piles as it relates to the bore test results and the desired resistance to maintain the portion of the load allocated to the piling.

**NOTE:** This option is seldom used but is a good remedy in poor conditions.

f) **Edge Settlement Correction**

The *Edge Settlement Correction* method involves lifting the tank to its original floor to shell elevation and filling the void with a fine, clean, crushed, non-corrosive aggregate. This method returns the tank to a planar state, but unless the pad around the tank is adequately sealed and the tank compound properly drained, the new foundation will also be subject to erosion over time, possibly requiring future repair *(Drawing L0004).*

**NOTE:** While this is a temporary, make-safe repair, it will restore your tank to original elevations, but will be subject to the same settlement problems over time.
Air injection procedure

TANK WALL

Native material sloped to grade

Tank floor restored to design elevation

Previous tank floor elevation

VOD space filled with pneumatically conveyed 1/4" minus aggregate or coarse sand

Fill granular fill against tank shell

Blow pipe & hose from air compressor

INJECTED SAND FOUNDATION
Secondary Containment and Environmental Upgrading

Over the past few years, an issue of increasing concern to legislators responsible for environmental protection has been the issue of preventing the hazardous effects on the environment of product loss from hydrocarbon storage tanks. As a result, governments at the state and provincial level have increasingly been implementing legislation which will eventually require all such storage tanks to have built-in systems to safely contain such spills. The most common of these spills is as a result of cracked welds in floor plates, as well as the effects of corrosion; occasionally there is a catastrophic rupture that empties the tank into the compound and beyond.

There are a number of alternatives to explore when considering secondary containment options. Some are prohibitively expensive, while others simply provide warnings of spills without addressing the problem of product spilled into the compound and beyond. For example, one method of secondary containment currently in use is the installation of second bottoms in the tank. Problems with this method include a high cost for installation, and the fact that it offers no protection or containment in the event of a catastrophic rupture.

The most cost-effective and reliable method of secondary containment is an early warning system including the installation of an oil-resistant liner beneath the entire tank, extending far enough outside the perimeter of the tank to allow for the liner to be extended (if desired) to contain the entire compound. The result is an impermeable barrier which has the capability to contain any product loss that may occur, provided that the dyke walls are of sufficient strength and volume to contain the spill.

The use of permeable liners for secondary containment is a relatively new concept, and has produced many claims and failures. In considering what to use in secondary containment, it is imperative to use the highest quality and most appropriate liner designed to contain the product in the tank.

The main factor which has served to dissuade tank owners from choosing this option has been a hesitancy to lift the entire tank shell and bottom in order to install a liner. That concern can now be alleviated using Mix Bros. Tank Services’ Electro-Hydraulic Equalift tank lifting technology. API Standard 653, Section B.1.3. states:
“If it is decided to lift the entire tank shell and bottom at one time, it should be done by personnel with demonstrated experience in this technique.”

The safest method for total lifting of the tank shell and bottom at one time is the **HIGH LIFT** method. This method uses 16 to 24 ft hydraulic jacks, to which an equal volume of oil is metered using the **Electro-Hydraulic Equalift Jacking System**. This system guarantees a continuous perpendicular lift to a height at which the installation of the liner can take place. No undue stresses are introduced into the tank shell during this process. The interior floor is first suspended using an interior cabling system, to ensure that no structural damage occurs during the lifting process. There is an added advantage to having the tanks at this height—it allows for inspection of the underside of the floor, and any repairs that may be necessary to the foundation or pad. Once all work beneath the tank is complete, the tank is lowered back onto its foundation.
TANK RELOCATION AND
DISMANTLING—RE-ERECTION

There are many tanks in existence today that are either in the wrong location or are no longer needed. Product is being trucked for miles on a regular basis because existing tanks are not where they are needed.

Because of the capital cost of building new tanks the inconveniences are tolerated. MTS offers two options for the relocation of good existing tanks in answer to this problem.

1. MOVING AS A SINGLE UNIT

Conventional Method:
To move the tank as a single unit, it is first raised by the use of the Electro-Hydraulic Equalift Jacking System. A custom-designed steel beam sub-structure is then fastened to the bottom of the tank to evenly support the weight of the tank during relocation. Under this beam assembly are a number of 16-wheel bogies with hydraulically charged levelers (designed by Mix Bros. Tank Services) which automatically compensate for uneven terrain, thus ensuring uniform load distribution throughout the moving process. Each of the bogies is capable of being steered independently, as required, or all can be maneuvered as a single unit (Drawing L0031).

At other times larger tanks situated on the water can be relocated (even over thousands of miles) economically by barge.

Mix Bros. Tank Services can also supply any site preparation requirements for the tank’s new location, including foundations and dykes.

When the tank has arrived at its new location, and is maneuvered into the correct position above the foundation, the High Lift jacks are utilized to raise the tank, and the steel sub-structure removed. Upon its removal, the jacks are then lowered until the tank is resting safely on the new foundation.

Tank Turtles
MTS developed the Tank Turtle tank relocation system after applying years of experience gained knowledge in the relocation of large oversized structures and specifically applied it to tank moving. No large beam structures or wheeled bogies are used. Instead the Tank Turtles are basically a walking beam, self propelled
HYDRAULICALLY OPERATED BOGIE WHEEL ASSEMBLIES

ELEVATION VIEW

TANK SHELL

CROSS BEAMS

PLAN VIEW

TANK RELOCATION
BEAM & BOGIE SYSTEM

EDMONTON
and are capable of crawling over unprepared ground and soil. It is a **Stackable System**, meaning the larger the tank; the more **Tank Turtles** are used, so any size tank can be moved. Ninety percent of tank moves are in plant, or less than 1000 feet, and this is what the **Tank Turtles** were designed for. Their maneuverability allows for precise tank locating, and they can even rotate a tank in place. For longer moves, wheeled bogies can be used to do the travelling, and the Tank Turtle can be used to precisely position the tank into the tightest of locations.

2. DISMANTLING AND RE-ERECTION

The viability of relocating a tank in this manner (as described above) depends on the integrity and design of the tank to be moved. Some situations allow us to relocate a tank, setting it up to meet all the **API 650 and 653** requirements, at a significant saving to the client. Each tank and the circumstances related to it must be examined to determine the advisability of the move. In some situations, however, it is simply not viable. Dismantling and re-erection then become an option. **MTS** has used different methods, depending on the size and location of the tank.

In some situations a tank can be cut in half vertically and transported in two pieces.

Tanks can be cut horizontally and refitted after a lengthy move. This allows for passage under overhead structures that could not be negotiated otherwise.

Larger tanks can be dismantled in sections and moved by flat deck or rail to almost anywhere in the country.

The specifics of any of these options can be discussed to determine how best **MTS** might serve our clients.
VI. UNDER-FLOOR GROUTING

There are thousands of tanks located along the Mississippi and in the Gulf Coast area that have a serious problem with floors that have settled significantly over the years that they have been in service. In the past few years MTS has developed a system to inject a non-corrosive, flowable–fill, that will quickly and efficiently raise the entire floor, columns and roof system back to the original floor to shell elevation design.

Tanks with sunken floors inherently have developed other serious problems:

- Stresses develop at the floor to shell connection.
- Stresses develop at the top of the shell to the roof connection
- The columns, girders and rafters are adversely affected and at times will rotate because the rafters are not snug against the roof.
- Water flows under the floor when the tank is not loaded. This adversely affects the pad and encourages corrosion on the underside of the floor.
- Floor welds under stress may fracture and cause leaks and associated environmental problems.
- The floor design relative to the sump is no longer operating as designed.
- Gauging readings are no longer accurate.

MTS has the right answers to these serious problems by utilizing the right equipment, the right procedures and the right grout mix design of self leveling flowable-fill to correct your floor elevation to original design and free your tank of stresses in the process.

1) THE RIGHT EQUIPMENT

MTS uses 70 cubic yard per hour grout pumps that will allow the flowable-fill to be installed quickly, avoiding the creation of under-floor voids. The material is pumped through 4-inch grout nozzles welded to the floor on a pre-determined grid to ensure final elevations are correct.

2) THE RIGHT PROCEDURES

Safety and efficiency are the major considerations in getting the project done right. Flexible flow lines mounted on castered dollies make moving the grout
supply lines from nozzle to nozzle within the tank possible without compromising our personnel’s safety. Laser levels and string lines are used to ensure correct final elevations. Two-way communications between the controller in the tank and the pump operator outside the tank ensure both safety and controlled amounts of grout injected at any one grout nozzle. Specially designed jacks and lifting bars are used to raise columns to allow the grout to flow under the columns and prevent depression and irregularities often associated with mud pumping. All flow lines and attachments are engineered relative to the operating pressure subjected to them by the pump.

3. THE RIGHT GROUT MIX DESIGN

When pumping a grout mixture under the floor of a tank, it is important to ensure that the product used does not create other contingency problems. The major considerations include: cathodic protection, corrosion and bearing capacity. The grout mix design that MTS has developed addresses all of these concerns. Our design and the rationale for the material and additives that are used are revealed only to our clients on a confidential basis. Using the wrong grout mix design may result in impaired effectiveness of a cathodic protection system or cause underside floor corrosion. One of the special additives in the design creates an additional 20% of entrained air which in turns adds dramatically to its pumpability and its self-leveling. MTS has experienced good success with this mix design.

4. THE RIGHT RESULTS

The placement of the grout under the floor is very carefully monitored and controlled to ensure that desired elevations are achieved and the floor brought back to original design.

5. THE RIGHT PRICE

Re-leveling sunken floors using alternative methods such as removing and replacing the floor plates or high lifting the whole tank can take the tank out of service for extended periods and cost much more to accomplish. In the interest of serving you better, MTS has introduced the underfloor grout injection system for re-leveling sunken floors. This is our endeavor to save you money over alternative methods. The speed and efficiency at which we perform this service will always ensure you get the right price.
VII. CONCLUSION

Mix Bros. Tank Services has the technology and extensive experience in all aspects of lifting tanks—the Right Way—for the purposes of correcting settlement problems, secondary containment, underfloor grouting, relocation or dismantling for re-erection. The cost-effectiveness and success of our technology has been proven repeatedly among our many clients in North America. We would be pleased to conduct site visits and prepare proposals or quotations on any tank servicing requirements.

Our engineering and marketing staff are available to respond to any questions or concerns. Contact MIX BROS. TANK SERVICES in Norco, Louisiana at (985) 764-3300, or our Canadian office at (780) 471-1386. We also recommend you visit www.howtolifttanks.com and www.mixbros.com for more information.