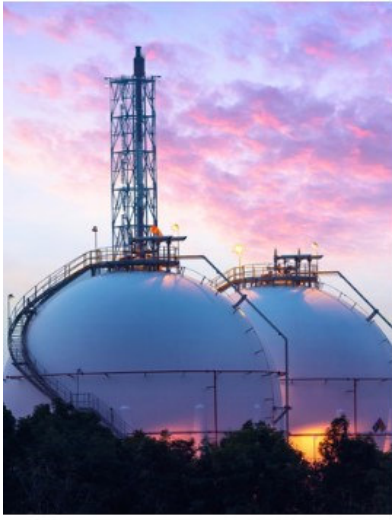




Storage tank - maintenance:

Tank base corrosion

Bonding Applications

Corrosion protection External Internal

API 653: Tank lifting as an
option to repair

Prepared by: DSc Dževad Hadžihafizović (DEng)

Sarajevo 2023

MONTHLY ABOVEGROUND STORAGE TANK INSPECTION CHECKLIST

Location: _____ Date: _____ Completed by: _____

	Tank:	Tank:	Tank:
Is there any deterioration on the tank, tank coating, piping, foundation, drainage, supports, ladder, platform, or safety equipment? For molded plastic tanks, check for evidence of cracked and worn areas and delamination. If yes, specify below.	Yes No	Yes No	Yes No
Is there any water at the lowest possible point within the primary tank (fuel tanks only)? Remove any water found. For tanks containing other products, is there any evidence of chemical degradation?	Yes No N/A	Yes No N/A	Yes No N/A
Is there any evidence of liquid (product or water) in the interstitial space (double-walled tanks) or containment area?	Yes No N/A	Yes No N/A	Yes No N/A
Are all drain valves secured in the closed position when not in use and all tank openings properly sealed? Are the piping connections tight and aligned?	Yes No N/A	Yes No N/A	Yes No N/A
Is the spill basket clean and functional?	Yes No N/A	Yes No N/A	Yes No N/A
Is the liquid level gauge readable and in good condition?	Yes No	Yes No	Yes No
Are there any obstructions or restrictions to the normal and emergency vents that prevent normal function? Ensure that the emergency vent moves freely.	Yes No	Yes No	Yes No
Are there any operational malfunctions of ancillary equipment (pumps, gauges, etc.)?	Yes No	Yes No	Yes No
Is there any evidence of a release from the tank – this includes visible signs of leakage around the tank, concrete pad, containment area, ringwall, or ground?	Yes No	Yes No	Yes No
Is there a clear path to the tank and containment area, and are gates/doors to the containment area operable and in good condition?	Yes No	Yes No	Yes No
Is a complete spill kit available?	Yes No	Yes No	Yes No
Are there any conditions that may be a fire or safety hazard, or pose an environmental hazard? If yes, specify below.	Yes No	Yes No	Yes No

Any deficiencies noted during the inspection must be corrected as soon as possible. **Facility personnel must contact EHS to review all tank maintenance and needed repairs with the exception of replacing hoses and fuel filters.** If there are any questions, call the Department of Environmental Health and Safety at 814/865-6391. Comments/Clarifications and Corrections: _____



Belzona Solutions Storage Tanks

Outline



- **Overview of a Storage Tank**
- **Storage Tank Problem Areas**
- **Belzona Solutions for Storage Tanks**
 - Overview
 - Tank base corrosion
 - Bonding Applications
 - Corrosion protection
 - External
 - Internal



Overview of a Storage Tank

What is a Storage Tank?



- A storage tank is a bulk storage container, usually for holding liquids, sometimes for compressed gases
- Storage tanks are available in many shapes
- Some of the largest can be found in Zirku island in the UAE. They can hold 1.25m barrels of oil...



One of the



every car in

What is a Storage Tank?



- One of the most common types of storage tank in industry are cylindrical storage tanks
- These can be used to store a variety of materials



Storage Tank Types



Five main types of cylindrical storage tank:

1. Fixed Roof Tank
 2. Internal Floating Roof Tank
 3. External Floating Roof Tank
 4. Open Top Tank
 5. Pressurized Tank
- } Variable Vapor Space Tank

Fixed Roof Tank

Overview



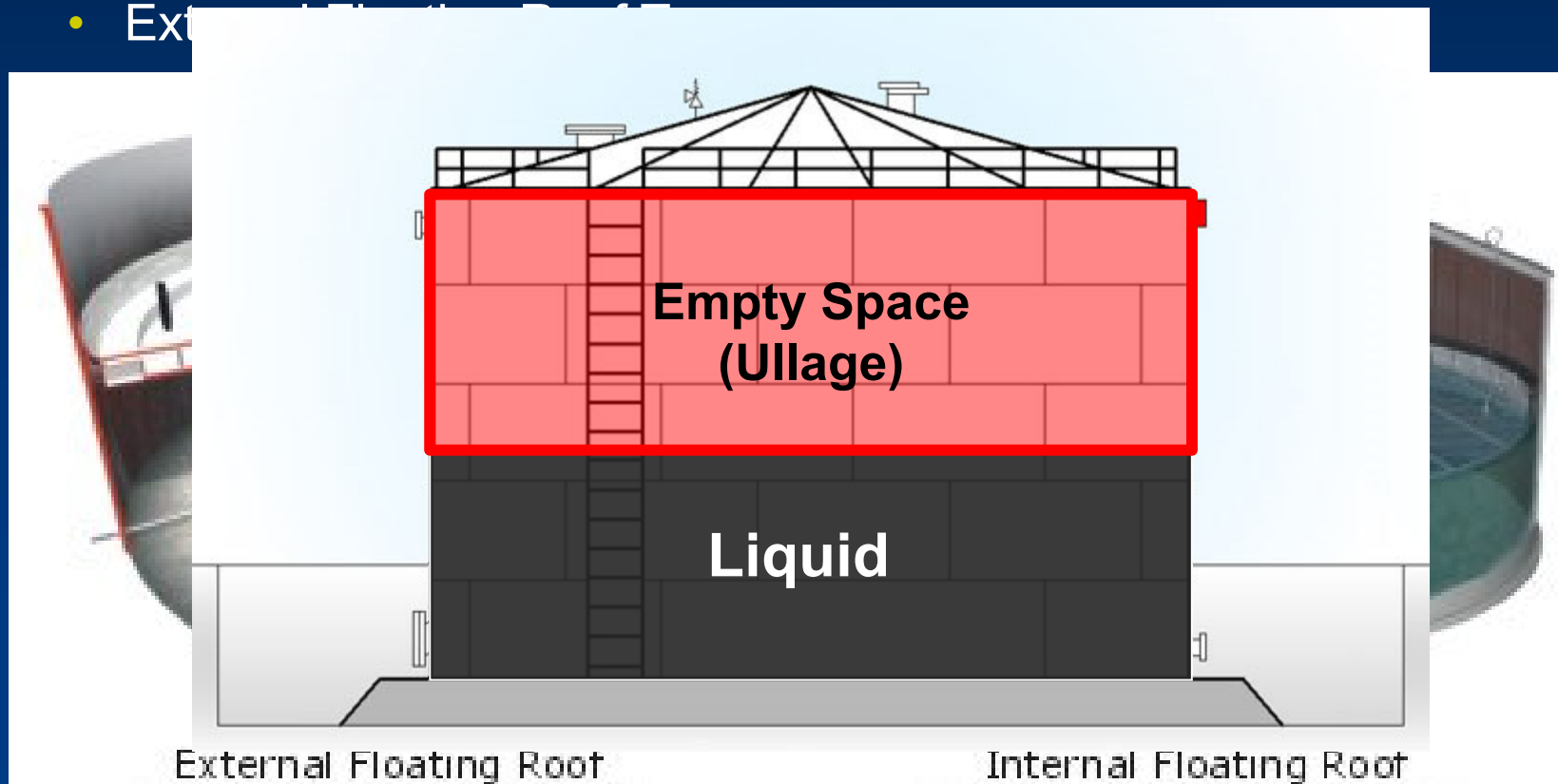
- For storing harmless liquids involving little or no pressure , and very high flash points. (e.g. fuel oil, water, bitumen etc.)
- Simple, mild steel, rectangular or cylindrical tanks fitted with a flat, dome or conical roof .



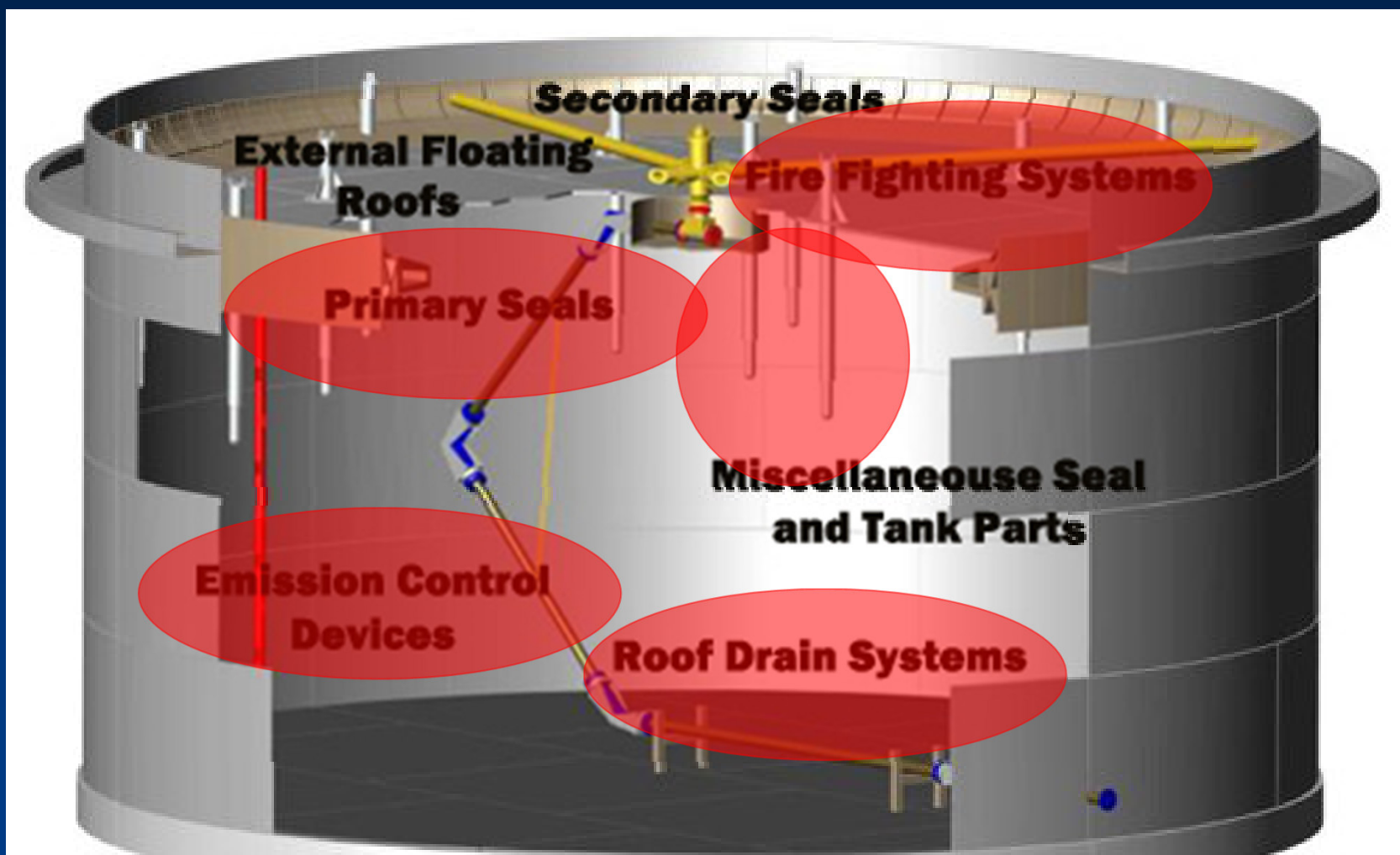
Floating Roof Tank

Overview

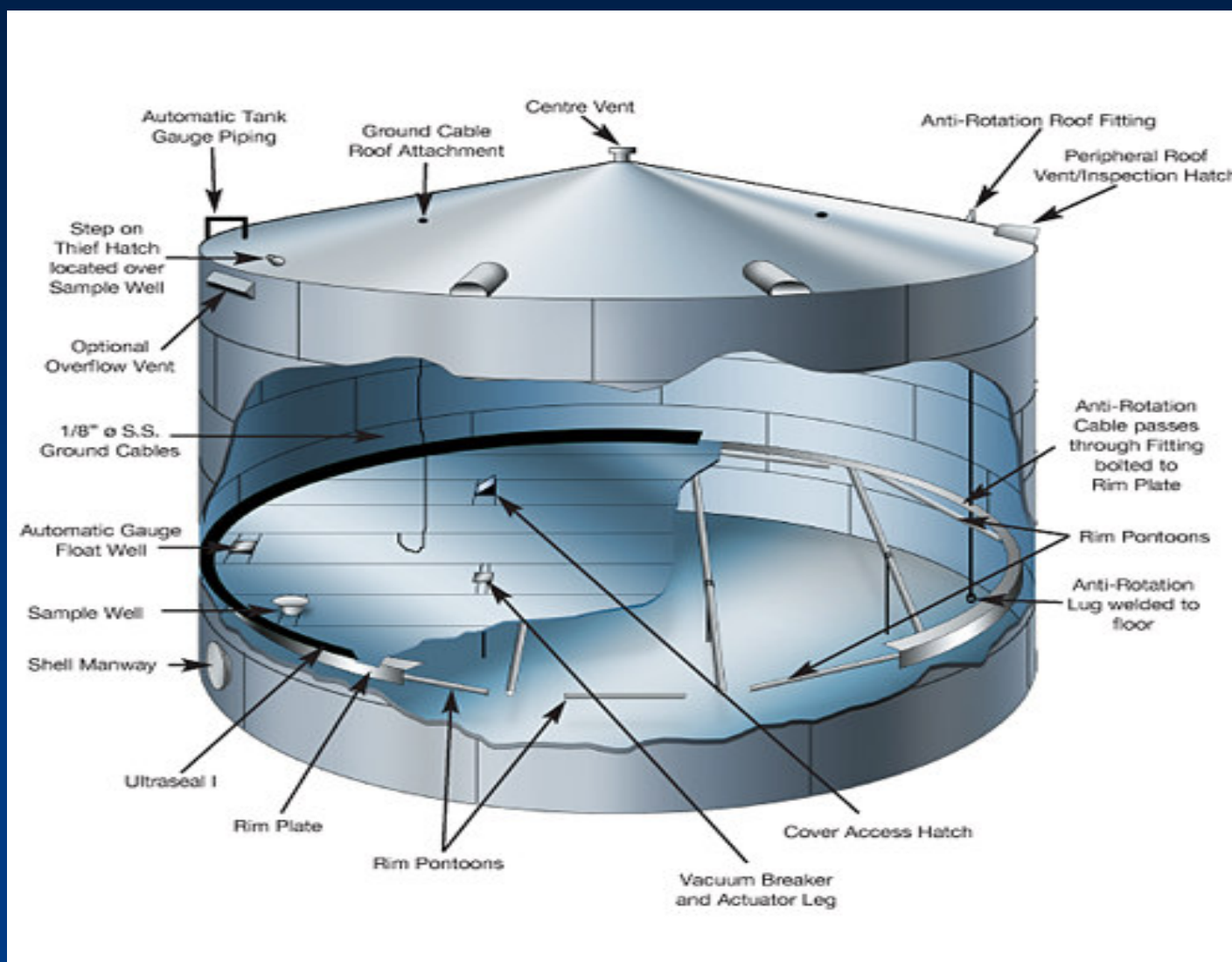
- Variable Volume Tanks
 - Internal Floating Roof Type
 - External Floating Roof Type



External Floating Roof Tank (FRT)



Internal Floating Roof Tank (IFRT)



Other Tank Types

Open top tank →



Pressurised Tanks ↘





Storage Tank Problem Areas

What is the Problem?



Leaks leading to

- Wastage
- Lost resources
- Environmental damage
- Potential disaster



“Statistics indicate as many as 25% of all Underground storage tanks (USTs) may now be leaking”

Maryland Real Estate Agency

“Almost 10,000 gasoline and oil spills, some of them more than a decade old, are contaminating the underground aquifers that supply drinking water”

Scientific Journal

What is the Problem?



Corrosion is the main cause of these leaks



Other causes could be environmental damage or damage due to impact

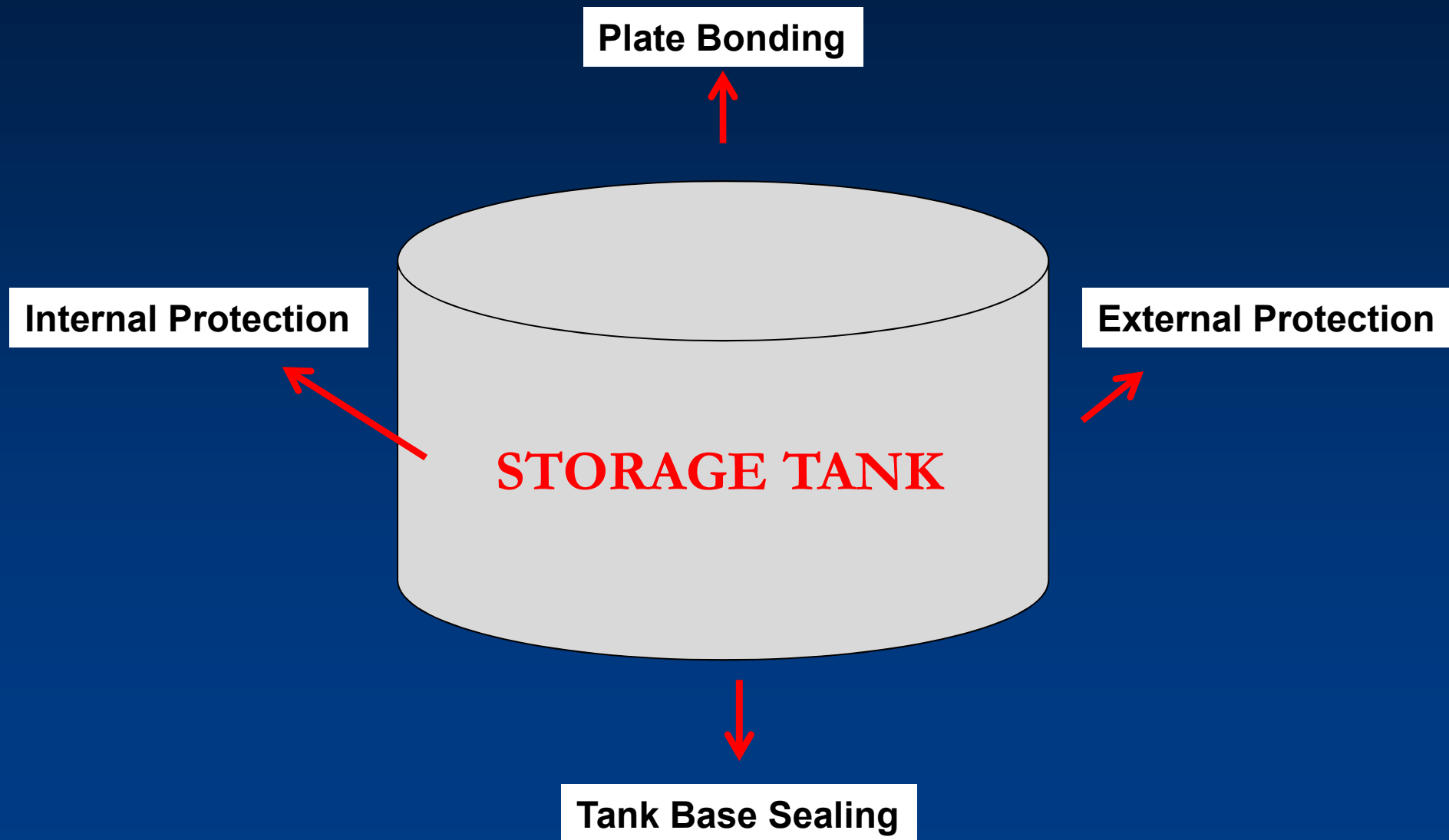




Belzona Solutions For Storage Tanks

Belzona Solutions

Overview



Belzona Solutions

Overview



STORAGE TANK

A 3D perspective drawing of a light gray cylindrical storage tank. A red arrow points from the bottom center of the tank to a white rectangular box containing the text "Tank Base Sealing".

Tank Base Sealing

Problem Areas

Tank Base



Corrosion of tank wall and 90 degree angle

Water / moisture ingress
under the tank base through
degradation of seal
moves the capillary action
squeezes the water under
corrosion of tank base
the base

Tank Base Traditional Repairs



- Mastics
- Asphalt & Bitumen

Problem Areas

Tank Base



- Steel Skirts

Problem Areas

Tank Base



- Bonded Rubber

Problem Areas

Tank Base



Corrosion at the Chine Angle

- Tank needs to be cut open for plate entry
- New base needs to be built
- Base welded into position
- Hydro Test needs to be conducted

Approx. Costs (30 Metre tank)

- £20,000 for cutting and entry / base removal
- £4,000 for sand-bit floor screed replacement
- £5,000 for flexible liner
- £20,000 for new bottom plates
- £50,000 for inspection and Hydro Test

£99,000

Plus :

- Tank cleaning / waste disposal costs
- Tank out of service for 3 months



Tank Base Sealing using Belzona

Belzona System

Advantages



What makes the Belzona system better?

- Breathable
- Flexible
- Weather resistant
- Excellent adhesion...

Weatherproof
Prevents water penetration



Microporous
Allows moisture to escape



Seamless
Seals around irregular contours



High adhesion
Ensures long service life onto a variety of surfaces



Durable
Withstands industrial environments



Environmentally friendly
Low VOCs



Surface tolerant
Good adhesion to a variety of surfaces



Longevity
Stands the test of time



Flexible
Moves in sympathy with the substrate



UV resistant
Resists climatic variations



Cold applied
Safe



Tank skirt refurbishment & protection



1. Surface Preparation by grit blasting
2. Conditioning using Belzona Surface Conditioners
3. First layer of Belzona 3111 Flexible Membrane and Belzona 9311 Reinforcement Sheet
4. Final Layer of Belzona 3111 for full system.



Tank skirt refurbishment & protection

1. Surface Preparation by grit blasting



- Grit blasting to 75 micron profile on the steel tank wall & tank base
- Pit filling using a Paste grade product or plate bonding if necessary on the tank outside walls
- Rebuilding of the concrete base with a Belzona 4000 series product if heavily damaged



Tank skirt refurbishment & protection

2. Conditioning using Belzona 3921 General Surface Conditioner (GSC)



Belzona 3921 GSC is applied on all the areas where the system is to be applied

Bond breaker tape is applied between the metal surface and the base

Masking tapes keep the application neat and tidy



Tank skirt refurbishment & protection

3. First Layer of Belzona 3111 and Reinforcement sheet



- Application of the first Belzona 3111 layer can commence when the Belzona 3921 has cured (at least 4 hours, no more than 2 days)
- Reinforcement sheet is used to control application thickness and provide strength and flexibility



Tank skirt refurbishment & protection

4. Application of final layer of Belzona 3111



- Application of the final second layer of Belzona 3111
- The complete system fully seals the tank base



Belzona Solutions

Overview

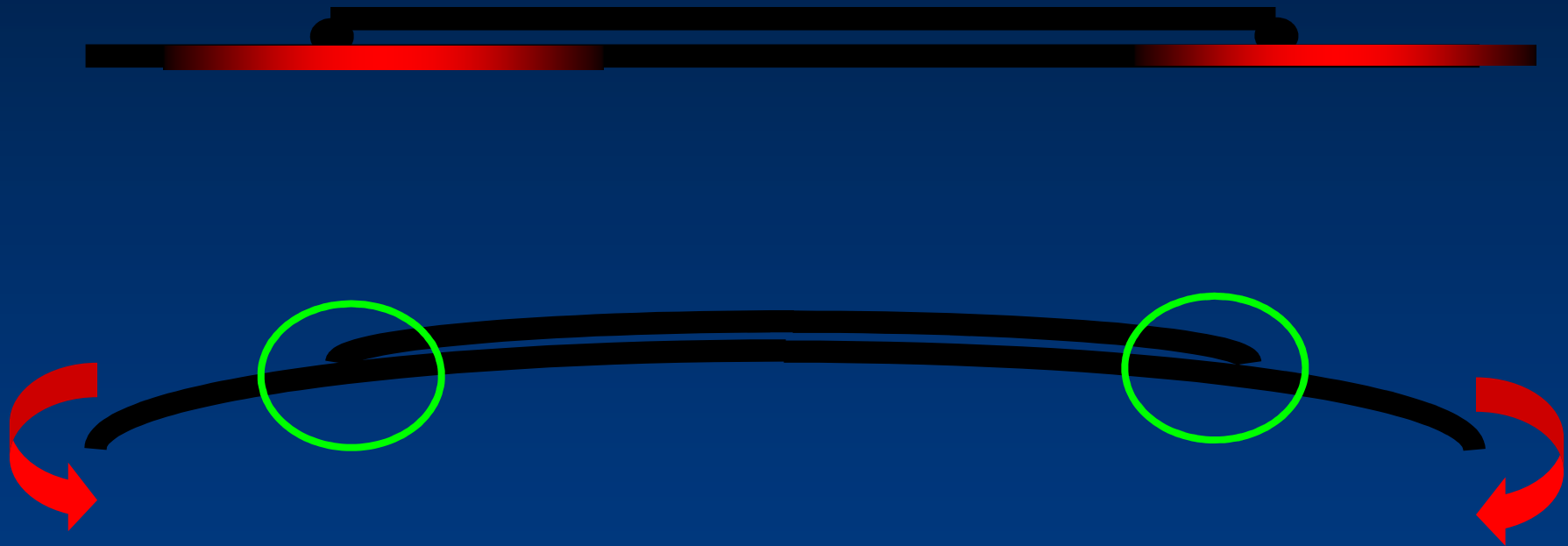


Plate Bonding



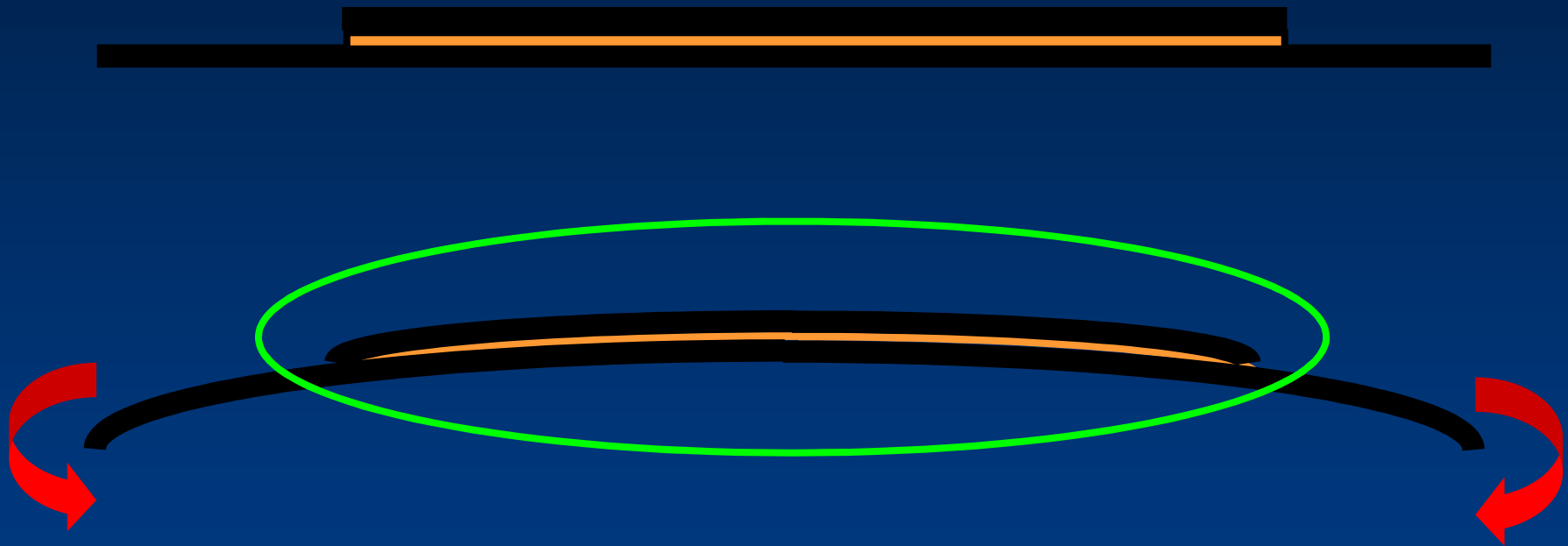
STORAGE TANK

Welding or Bonding?



Forces are transferred through
the **HEAT AFFECTED** zones only

Welding or Bonding?



100% contact so, forces are
transferred through the **ENTIRE**
BONDED AREA

Plate Bonding

Advantages



- Very High Adhesion
- Impressive Impact Resistance
- Easy to do on site - technology developed for use offshore
- No welding or similar problems
- Tried and tested solution...

- Compared to original 8mm deck, the composite plate can withstand greater static loading and higher impact loads before failure
- In shear the composite sandwich is comparable to an equivalent weld
- The composite sandwich provides the most reasonable compromise between cost and performance. It is considered robust enough to withstand the rigours of laydown area operations



Bonding Applications



- A versatile and effective solution to many common problems
- Not limited to plate bonding for leak sealing...



Bonding Applications



Leak sealing is one of the main reasons for carrying out plate bonding operations



Bonding Applications



Bonding Applications



- Bonding applications are not just confined to leak sealing and corrosion protection
- Supports, walkways, stairs and lifting equipment can also be bonded using the same technique



Other Bonding Applications



Bonding can also be used to attach many other pieces of equipment such as...



Stairways and walkways...



Wind Girders...



Deluge systems...

Other Leak Sealing Applications



Leak sealing of a floating roof - just like any equipment which floats, if a leak occurs in a floating roof, it could sink!





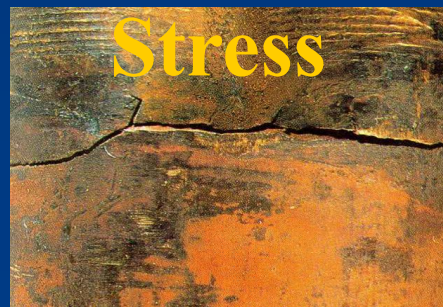
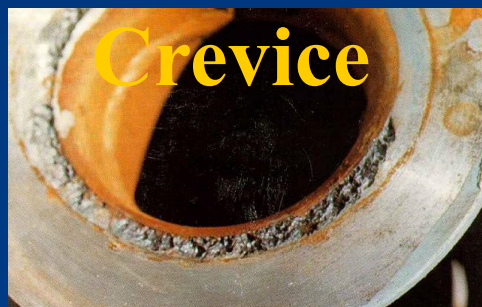
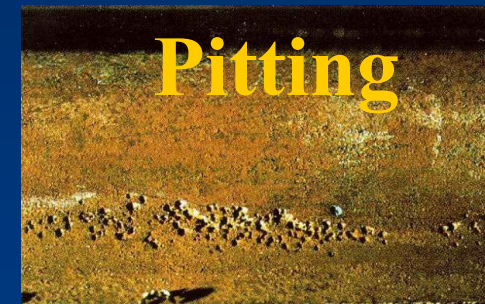
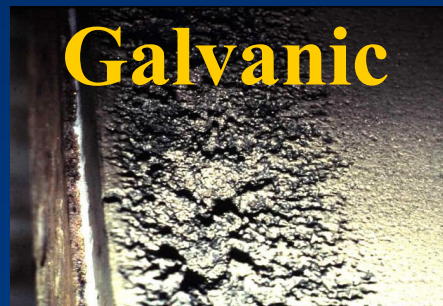
Internal and External Tank Linings

Why Think About Lining Any Tank?



Limitations of Conventional Materials of Construction

- Carbon Steel
- Overlaid Carbon Steel
- Stainless Steel
- Duplex Steels

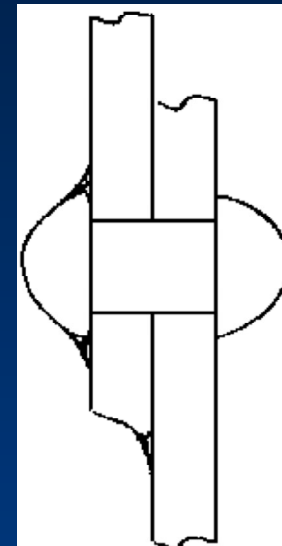


Tank Construction Considerations



Riveted or Welded seams?

- Check radii prior to application
- Grind smooth any irregularities
- Use a paste grade product to smooth and fair surface irregularities



Internal and External Linings

Application Method



Application Method:

- Grit Blast steel
- Check for contamination
- Pit filling
- Stripe coating
- First coat application
- Second coat application
- Final inspection



Belzona Solutions

Overview



External Protection



External Protection

Belzona 6111/5111



External corrosion can lead to thinning of the tank walls and potential leaks

- Grit blast steel
- Fill in pitting if necessary
- Apply Belzona 6111 Liquid Anode for steel protection
- Apply two coats of Belzona 5111 Ceramic cladding



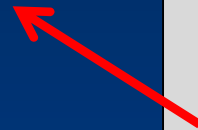
Result is not only corrosion protected but is also stain and UV resistant and aesthetically pleasing

Belzona Solutions

Overview



Internal Protection



STORAGE TANK

Product Range

Internal Lining Products



Product Reference	Operating temperature	Sprayable	Spark & thickness resistance	Chemical resistance	Erosion resistant
Belzona produce a large range of Internal Lining solutions. The choice of product depends on the application situation. Do you require...					
5811	50°C (122°F)	Yes	Yes	limited	No
• Chemical resistance?		No	No	excellent	Yes
• A spray applied coating?		Yes	Yes	limited	Yes
• High Temperature resistance?		Yes	Yes	excellent	No
• Erosion Resistance...					
5891	90°C (194°F)	Yes	Yes	good	No
1391S	110°C (230°C)	Yes	Yes	excellent	No
1391	120°C (248°F)	No	No	good	Yes
1391T	120°C (248°F)	No	Yes	excellent	Yes
1392	120°C (248°F)	No	No	excellent	Yes
1521	150°C (302°F)	Yes	Yes	excellent	No
1591	180°C (365°C)	No	Yes	excellent	Yes

Product Range

Internal Linings for Service Below 90°C



- Belzona 1321 (Ceramic S-Metal)
- Belzona 1341 (Super metal Glide)
- Belzona 4311 (CR-1)
- Belzona 5811 (Immersion Grade)
- Belzona 5891 (High Temperature Immersion Grade)
- Belzona 5892 (High Temperature Immersion Grade 2)



Application

Internal Linings for Service Below 90°C



Crude oil storage tanks in Brazil.



Product Range

Internal Linings for Service Above 90°C



- Belzona 1391 (Ceramic High Temperature)
- Belzona 1391T (Trowel able grade)
- Belzona 1391S (Spray applied version of Belzona 1391)
- Belzona 1392 (Ceramic High Temperature 2)
- Belzona 1521 (High Temperature Spray Applied Coating)
- Belzona 1591 (Ceramic Extreme High Temperature Coating)



Application

Internal Linings for Service Above 90°C



- Corrosion in the tank base
- Only the problem areas were coated saving time and money
- Belzona 1521 was chosen for it's resistance to hydrocarbons, spray capabilities and performance in hot water/hydrocarbon situations



Belzona Solution

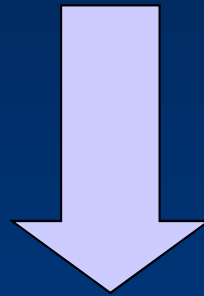
Corrosion Protection of small bore nozzles



Small bore nozzles are difficult to blast properly, difficult to apply coating and cannot inspect properly. A cost effective alternative to used to form flange face is to insert corrosion inert sleeve and bond into place using suitable Belzona material



Major Opportunity Worldwide



TANKS A LOT!



Ivor Wildin
Director, WTS



API 653: TANK INSPECTION CODE: TANK LIFTING AS AN OPTION TO REPAIR



Introduction

General



Annex B of API 653 lays out prescriptive limits to bottom settlement, planar tilt and differential settlement. If the settlement is found to be outside the stated limits what options do we have to correct it?

OPTIONS FOR LIFTING TANKS

1. AIR BAGS
2. CLIMBING JACKS
3. HYDRAULIC JACKING



Are the most common forms of lifting storage tanks however both Option 2 & 3 require the welding on of lifting frames or pad eye to connect the jacks to. If a tank has leaked and washed out the basecourse then it would not be prudent to weld in the vicinity.

AIR BAG LIFTING

Within the past five - ten years the environmental impact on the operation of petro-chemical product storage tanks containing hydrocarbon or other dangerous goods, constructed to standards such as API 650, has taken on critical implications for refineries, distribution centres and other storers of Dangerous Goods.

Pollution of the supporting foundation and possible widespread effects on ground water has resulted in moves to require the installation of secondary containment. That is not to say, necessarily, a tank with two steel bottoms, but alternative means of reducing the failure probability to an acceptable public or statutory level. Compliance with statutory codes such as Dangerous Goods Regulations 2010 and AS 1940 dictate that ‘impervious’ secondary containment is now required throughout the bunded area.

In the USA, Europe, and other western countries it has long been required to also place a secondary containment liner or double bottom under storage tanks.

The ongoing quest by engineers is to establish corrosion trends in tanks through inspection by various means however the underfloor has always provided a challenge to ascertain a clear evaluation of deterioration hence, assurance of the integrity of the primary containment.

Clearly, increased inspection of the tank bottom has merit and visual examination of the bottom from inside the tank can be supplemented by ultrasonic methods, acoustic leak detection and magnetic flux scanning.

Tank lifting now offers a very cost-effective method for underfloor inspection, combined with the opportunity to undertake repairs to the bottom and underside painting, together with improvements and repairs to the Bit-sand surface of the tank pad.

An impervious membrane can also be installed with a leak detection trough formed around the tank edge so rendering the tank compliant and extending its useful life.







In fact, tank lifting using discrete airbags offers the most cost-effective method for lifting tanks off their foundations. When compared with the more conventional system of hydraulic jacking, the airbag method results in some very distinct advantages, apart from a most significant reduction in cost.

It is not necessary to weld any attachments to the shell or dig deep pits beneath the annular plate. Site preparation is an absolute minimum, and only requires excavations extending 400mm, under the tank shell by 800mm wide and 30mm deep, at a number of discrete locations. In the case of smaller tanks, say up to 46M (150 feet) diameter, the annular plate can be well clear of the pad within six hours of the lifting crew arriving at site.

Summary

The application of the airbag method for lifting bulk liquid storage tanks has been described, together with some of the background theory and experimental measurements that have been made to develop a safe and very economical means of raising tanks so that their bottom underside can be examined or foundation pad repaired or complete secondary containment inserted under the tank.

NDT methods are always a ‘compromise’ and address the evaluation of a defect but not the ‘root cause’ or seek to remediate the cause, this can lead to defects caused by foundation debris continuing to manifest themselves in the corrosion of repaired plates on a floor.

Other considerations are those causing settlement problems in storage tanks where the ground bearing capacities have not resisted the forces applied by the tank. Planar tilt and differential settlement render the tank unusable if this exceeds the limitations in Appendix B of API 653. The lifting of the tank either partially or wholly to insert a ring beam (FIG 1) is required to remediate the settlement.





Size Limits?

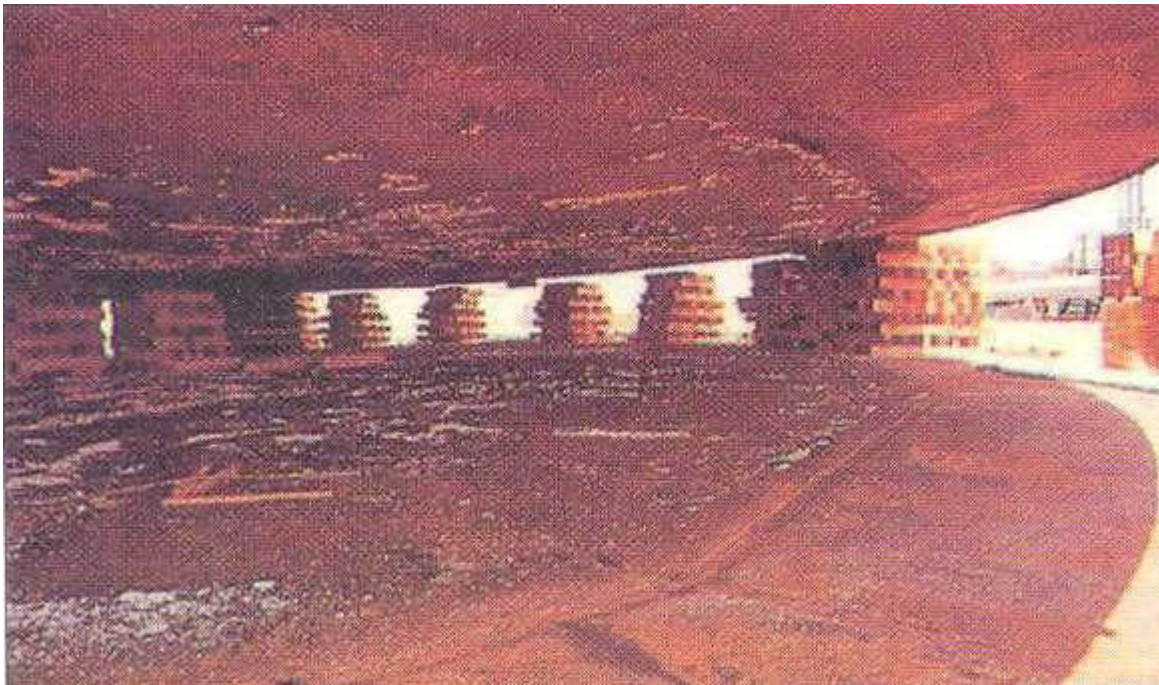


53 X 19M
SRC Singapore

Other touches we can do:



This tank had leaked twice at SRC Singapore and the floor was to be replaced. After lifting it was found that the MFL Scan was in error and there was only two holes in the floor due to stones the rest of the floor had the heat numbers still visible in perfect condition!



25M X 15M
SRC Singapore

The finishing touches.....



HMAS Stirling WA



**FLOOR CHANGE
AUSTRALIAN LUBRICATION MANUFACTURERS
FREMANTLE, WESTERN AUSTRALIA
A JOINT CALTEX/BP FACILITY**

Tank 21 at ALMC had suffered planar tilt outside the limits stated in API 653 Appendix B. The tank was built in 1938 and had leaked through external floor corrosion.

The job was to correct the differential settlement, install a secondary containment liner under the tank and change the floor in the tank.



The tank was lifted from the ground using airbags inserted under the tank



As the tank rises pushed up by the airbags the height gain is consolidated by inserting timber gluts under the tank. The number and support and lifting positions is dictated by a computer program which ensures the stability of the tank and that the compressive loads do not exceed the bottom strake buckling (API 650) of the tank.





The lifting continues around the tank until the whole periphery of the tank is supported on the cribs of timber





As the tank rises the airbags are placed on cribs of timber which then allows the tank to be lifted increasingly higher. The height gain is constantly consolidated by inserting further timber gluts on the support cribs. The tank always remains LEVEL +/- 6 inches side to side minimising any stresses imposed in the lifting.

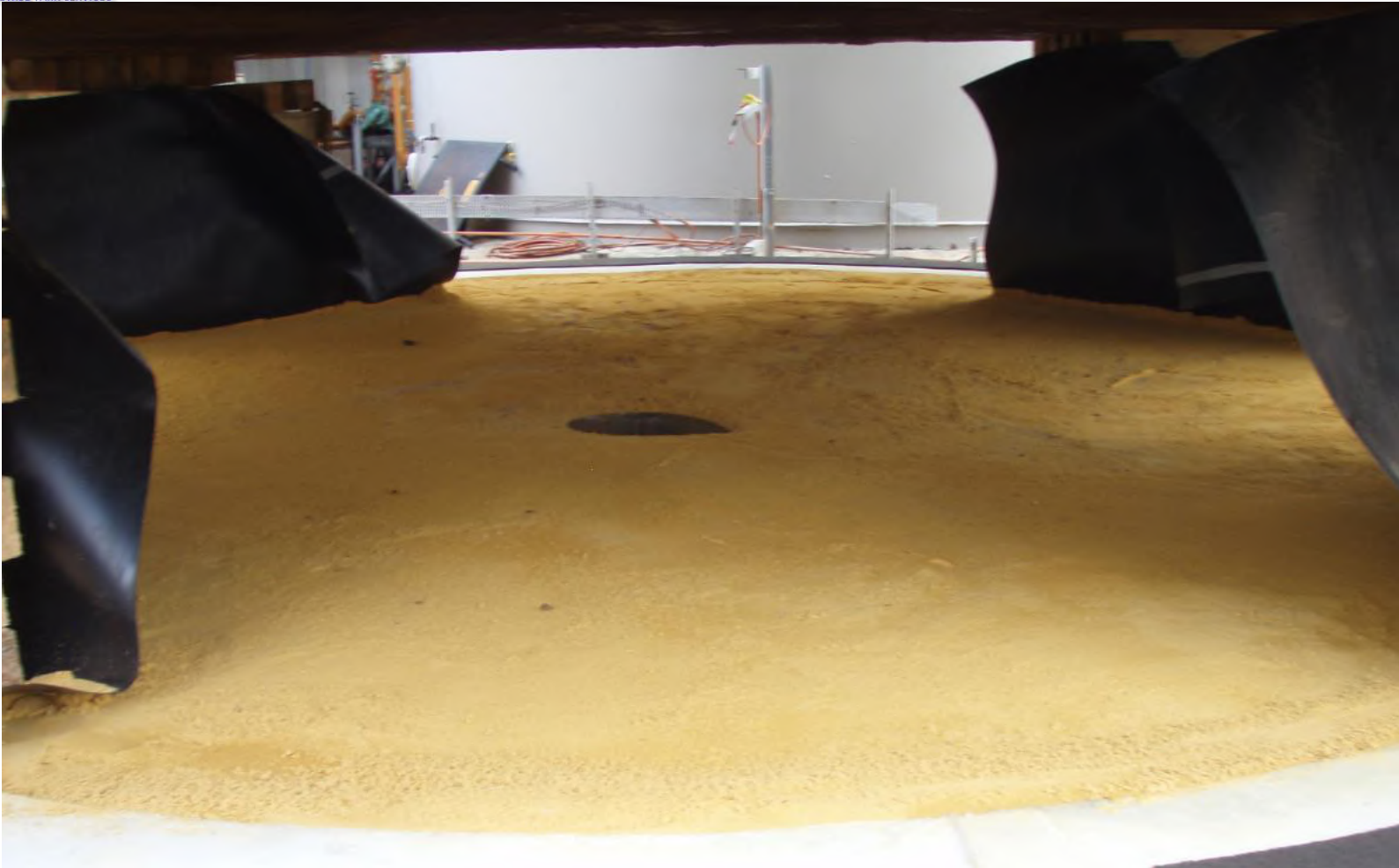




Upon attaining access height under the tank the lifting cribs are removed and the basecourse foundation cap is taken out. This particular tank dihedral of the floor was changed from Cone-Up to 1:120 Cone Down....hence further excavation was required. The concrete ring beam was not level which accounted for the tank differential settlement.



Formwork was laid out to pour the increase in height of the ringbeam and level the tank



After filling of the basecourse it was now time to place in the secondary containment. A drain pipe was incorporated in the basecourse to allow draining in the event of a release under the tank.









Geotextile and pea gravel is added to ensure free drainage in the secondary containment sump



Formwork is added to the sump to ensure the correct dihedral of the resulting fill of the basecourse. The basecourse is now ready for final fill and compaction. The new floor will also be laid on the basecourse







The new sump is added to the floor and welded into place





Lifting cribs are re-inserted around the tank and the tank is lowered

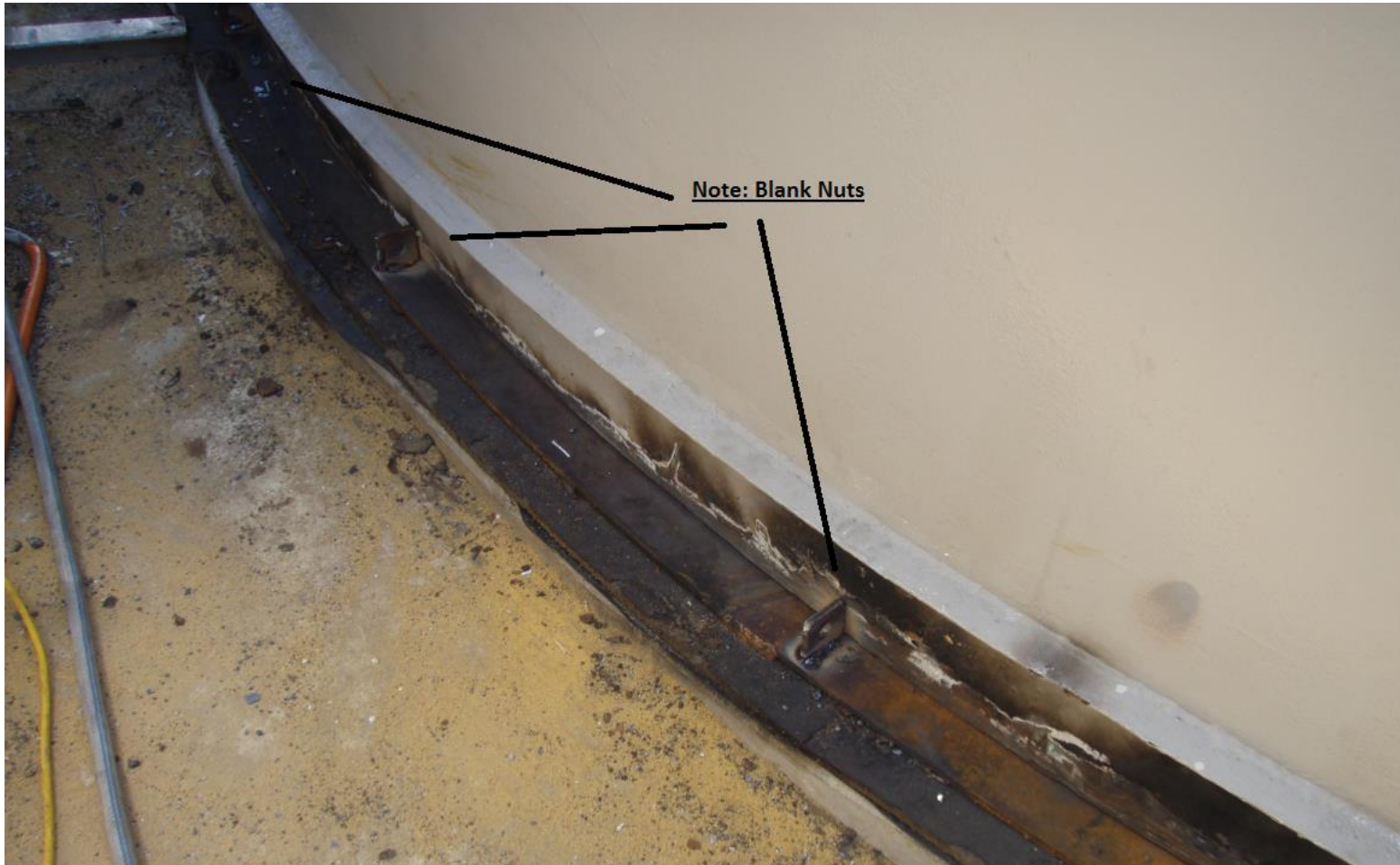




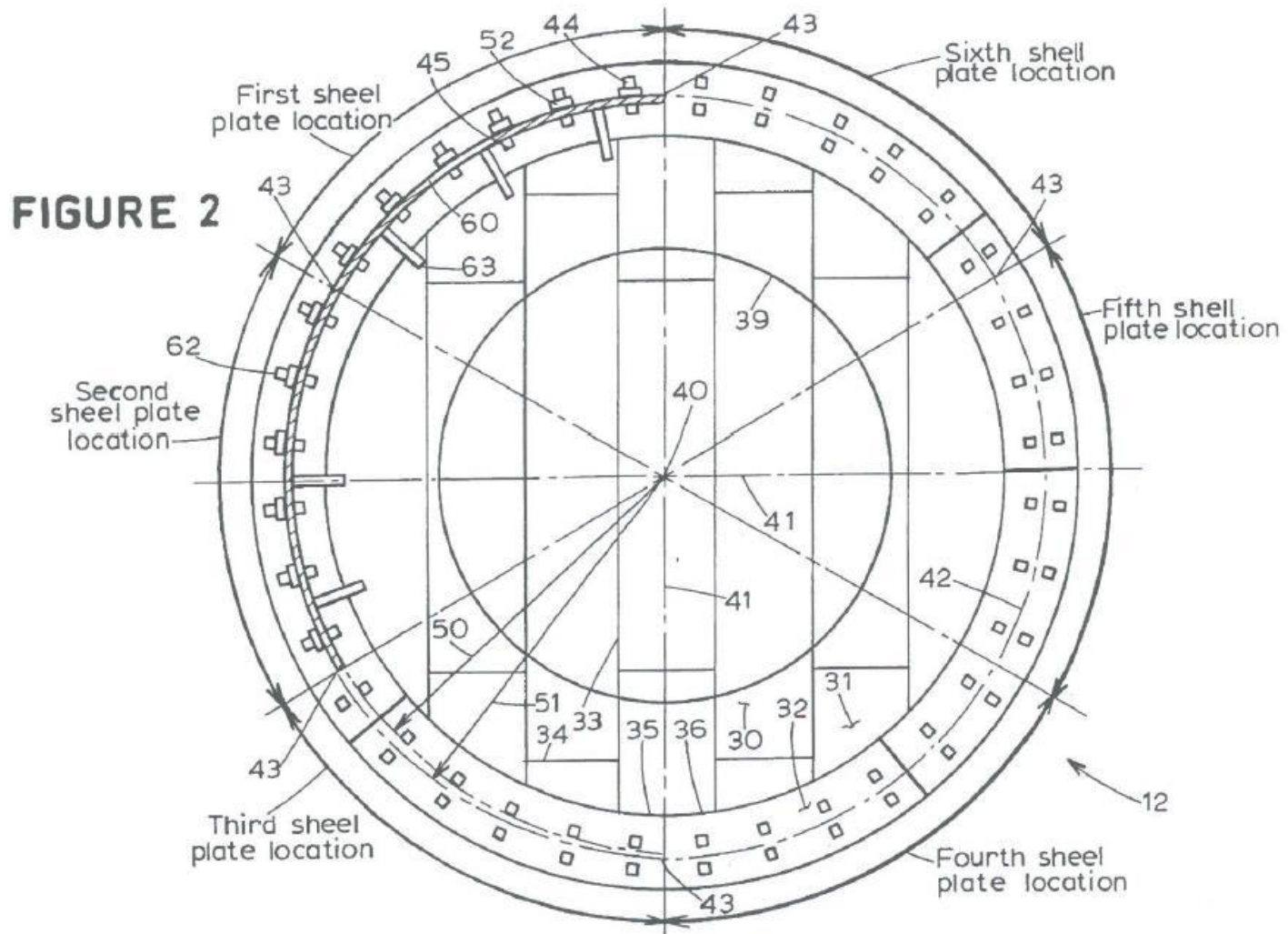
The tank remains at 6 inches above the new floor to allow the cutting out of the old floor

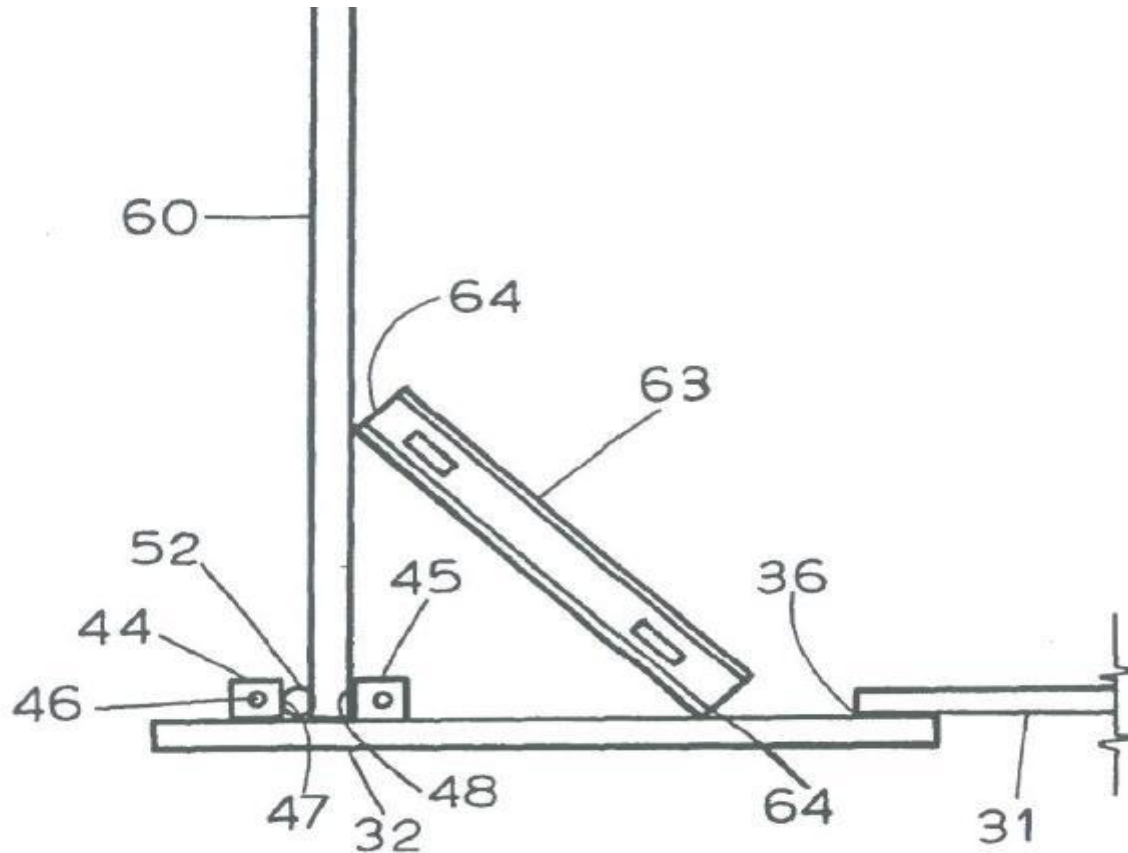


The old floor is cut out and pulled out from under the tank. Sidewalls are cut above the HAZ and the sketch plates released from the tank. The tank is the differentially lowered setting the sidewall onto blank nuts to ensure the roundness of the tank is maintained.









The setting of Blank Nuts (44 - 46) allow us to ensure that the tank wall is on the scribe line and can be adjusted by the insertion of the carrot pins (taper wedges - 52) ensuring the tank remains 'round'.

The tank can now be welded in the normal way and the floor welded internally.

The tank will then be boxed up and hydrostatically tested and certificated to API 653



WORLDWIDE TANK SERVICES
SPECIALIST INSPECTION LIFTING AND RELOCATION
OF BULK STORAGE TANKS
1, FORBES ROAD MANDURAH WESTERN AUSTRALIA
TEL. (61) 8 9535 8176 MOB 0439 913313

MAJOR BULK TANK INSPECTION CATEGORY 5 & 6 ABOVEGROUND TANK FINAL INSPECTION AND FIELD REPORT AFTER MAJOR REPAIR		
Tank No. ALMC T21		Unit/Location: North Fremantle Lube Plant
Facility/Business Unit: Australasian Lubrication Manufacturing Company Swan Street North Fremantle Western Australia		Original build standard and no API/BS/Other API 653 Plate attached to tank YES/ NO
Date(s) of Inspection: Final Inspection conducted on 13 th December 2012 after levelling of tank, new floor bottom plates and installation of secondary containment liner / leak detection.		Inspection Type: External / Internal Internal – External Inspection, NDT conducted on new floor welds, 100% Magnetic Particle Inspection of Annular Fillet Welds Internal/External and 100% Vacuum Box Testing of floor inter-plate welds
Bulk Tank Data Sheet attached YES/ NO See MDR File	Design Pressure Atmospheric	Product Stored: Base Oil
Overall Roof Condition from visual inspection : Good		NDT: See MDR File
Overall Shell Condition from visual inspection: Good		NDT: See MDR File
NDT inspection by: Are NDT Reports Attached: YES / NO See MDR File		(Company) Marine Inspection Services P/L
NDT test date: December 2012 – See MDR Report		Statutory Inspection to AS 1940 – API 653 4 th Edition Addendum 2
Comment on overall tank condition :		
Tank 21 is in good condition, compliant with AS 1940 and API 653 and considered fit for service. Tank 21 was refurbished after being identified with a lean exceeding the confines of Annex B of API 653. The refurbishment included the lifting of the tank off its base to 1.8M, recapping and levelling the concrete ring beam. Installation of a HDPE 1.5mm secondary containment Liner with leak detection piping, filling and compaction of basecourse foundation over liner, installation of a new floor bottom plate 8mm W.T – reversing the cone of the floor from the original cone up to a cone down 1:120 slope to a central sump with water drain piping. Extensive NDT was conducted on the repairs in keeping with the confines of both API 653 and API 650 including a full hydrostatic test of the tank as per the requirements of API 650 with a hold time exceeding 24hrs on 12th – 13th December 2012 – No leakage or settlement was observed. Are other tank repairs required? No Out-of-service maintenance required? No		

Tank Inspection Completed by an Approved Tank Inspector:

Name: Ivor P Wildin

Signed: _____

API 653 Reg. Inspector Name: Ivor P Wildin
API Registration Number Reg Inspector 1246
Inspection Closeout Date:



IVOR WILDIN
API 653 REG. INSPECTOR
NUMBER 1246

Tank rated at :- **FIT FOR SERVICE** / NOT FIT FOR SERVICE