Guidelines

Pressure Systems

The Integrity Management of Thermoplastic Storage Tanks

REFERENCE: IMG 02c
ISSUE: 01
DATE: 25/08/2016

DOCUMENT INFORMATION:	
REFERENCE:	IMG 02c
ISSUE:	01
DATE:	25/08/2016
PREPARED BY:	Pressure Equipment Technical Committee (TC 1)
APPROVED BY:	TC and TSC

DOCUMENT HISTORY RECORD:

ISSUE:	DATE:	CHANGE DETAIL:
01	25/08/2016	Initial Document

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1. Introduction

SAFed Guide IMG01 provides specific information on the regulations applicable to storage tanks containing hazardous substances. IMG02 gives an overview of the inspection of storage tanks. IMG02c contains specific guidance for thermoplastic tanks. GRP and metallic tanks are covered in separate guidance.

Thermoplastic storage tanks are used in chemical plants, factories and depots for the storage of substances. They form the primary barrier against loss of containment for the substances stored and therefore it is essential to maintain the tank's mechanical integrity.

This can be achieved through an appropriate management system for the operation and maintenance of tanks, in conjunction with a scheme of examination for the periodic examination and testing. An examination and testing regime will need to take into consideration the lifecycle, from original specification and design, through its operation to decommissioning.

This guidance is published in the UK and therefore refers to its regulatory framework. However, much of the description of good practice it contains may be relevant elsewhere.

Storage tanks may form a confined space and reference should be made to the Confined Spaces Regulations and SAFed guideline PSG 10.

2. Scope

This document provides guidance on managing the mechanical integrity of thermoplastic storage tanks through periodic examination and testing.

The maintenance or operation of the storage tanks necessary to ensure their continued safe operation is not covered in this document.

This document does not cover the inspection of pipework, or protective systems associated with storage tanks.

This document does not cover the inspection of the secondary containment (bund) which is addressed in IMG07 of this series.

The maintenance or operation of the storage tanks necessary to ensure their continued safe operation is not covered in this document.

If the tank contains or is likely to contain a relevant fluid it is a pressure system and is excluded from the scope of this document. It will need to be included within a written scheme of examination as required by the Pressure System Safety Regulations.

Types of Storage Tanks – Common Materials/Types

There are many different designs of thermoplastic storage tanks which are frequently flat bottomed although conical or inclined bases may be fitted within the shell. The tanks can be rectangular or cylindrical or unique in shape

They are manufactured from differing materials & in different ways. The most common materials being:

- High Density Polyethylene - HDPE
- Polypropylene - PP
- Polyvinyl chloride – PVC
- Polyvinylidene fluouride - PVDF

With regard to manufacture tanks can be blow or rotationally moulded, helix or spirally welded on a mandrel or manufactured/assembled on site.

They can also be manufactured as an assembly within a bund, as a standalone item or with an integral bund/leakage alarm system.

Each installation will require a specific inspection strategy based upon the design of the tank (shape, bunding arrangement etc.), material of construction, method of construction, nature of the content, operating conditions (including cycling), installation, design life, location, and the operating environment. These all require to be taken into account in identifying the relevant damage & failure mechanisms and inspection strategies that are appropriate for each storage tank. The scheme of examination will apply appropriate inspection techniques and will take account of the initial integrity assessment.

3. Initial Integrity Management of Thermoplastic Tanks

All thermoplastic tanks will require an assessment of initial integrity as described in section 4 of SAFed IMG02.

Where tank records are insufficient to establish its integrity the process flow chart indicated below will help to establish fitness for service.

The Competent Person may request additional information to enable him to determine whether any special requirements need to be included in the Scheme of Examination. Once the Scheme of Examination is completed a full examination of the storage tank in accordance with this document can be made. The inspection process should include reviewing any previous inspection records that are available.

To assist the Competent Person in preparing a suitable Scheme of Examination he will require the following information:

- Manufacturer and manufacturer's identification number.
- Date of fabrication.
- Design contents, specific gravity or pressure.
- Design temperature.
- Design specification.

- A drawing of the tank showing principal dimensions / thickness and materials.
- Design and construction standard / code, date of first use and safe allowable operating limits.
- The nature and maximum volume of fluid(s) contained, including any historical change of use, in addition to fluid(s) that may be used for other purposes such as cleaning.
- Details of any significant modifications or repairs that could affect fluid containment.
- Overview of operation (cycling / temperatures etc.) and maintenance performed

In addition the Competent Person may request a review of alarm/instrumentation testing.

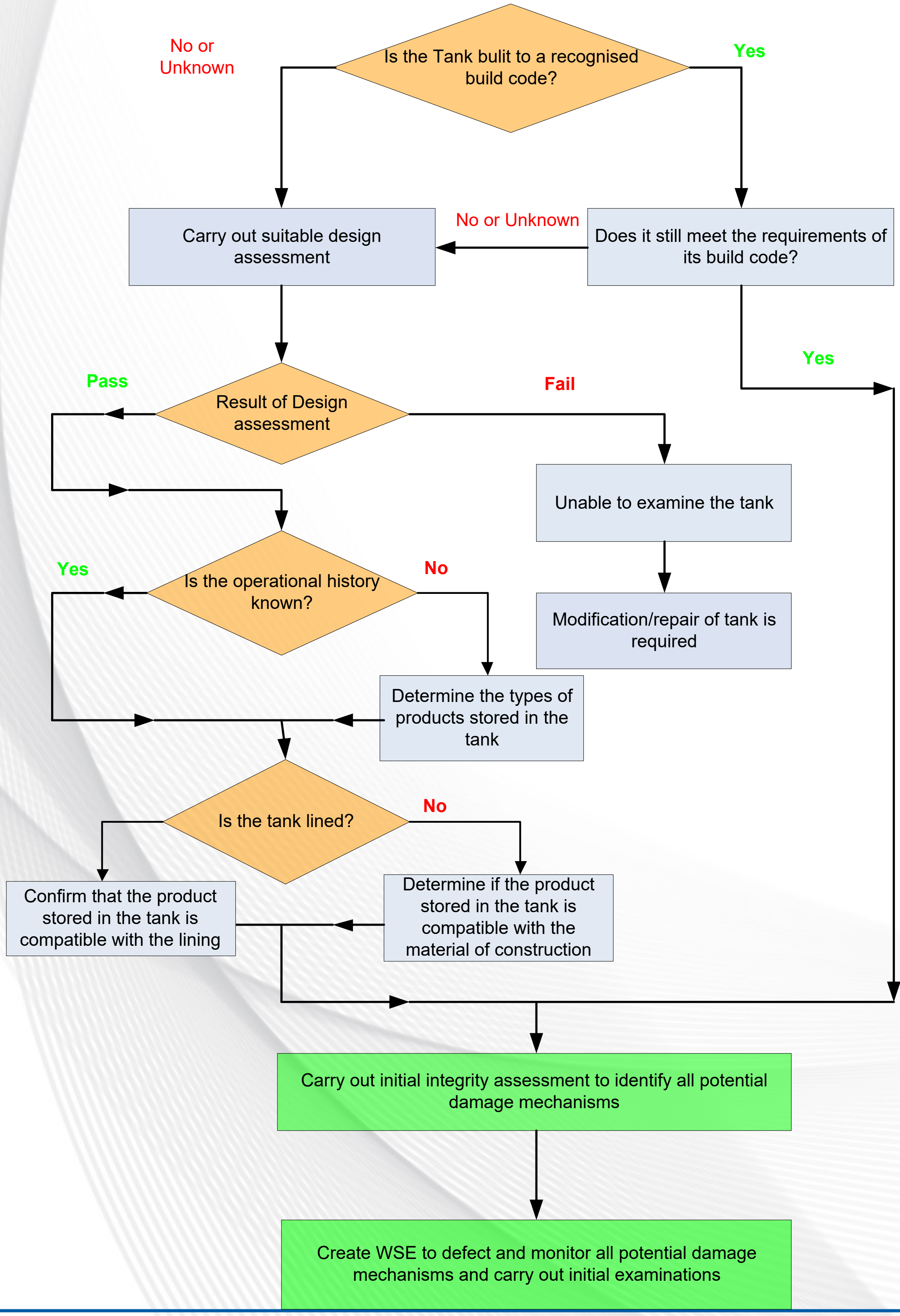
Where this information is not available further tests/assessment may be necessary. The process flow chart/decision tree indicated below will help to establish fitness for service.

In the event that fitness for purpose cannot be demonstrated a report might contain wording such as:

"*This report does not represent a condition assessment of the physical structure nor the integrity of the storage tank, its fittings nor any fitted Protective Devices in accordance with inspection procedures. No assessment of the bunding arrangement has been carried out.*

Other guidance is provided by such documents as SAFed – IMG01, DEFRA - Guidance note for the Control of Pollution (Oil Storage) (England) 2001 and HSE RR760 - Mechanical Integrity Management of Bulk Storage Tanks."

TANK CONSTRUCTION



4. Possible Damage Mechanisms

Below are some of the damage mechanisms which may be identified using certain techniques:

Damage mechanism	Location	Detection methodology	Comments
Manufacturing defects	External & internal	Visual	Excessive application of glue resulting in leakage & poor welding.
Fatigue	External & internal	Visual	As in steel fatigue is progressive structural damage that occurs when a material is subjected to cyclic loading – in the case of tanks filling & emptying. It is important to ensure that ladder and other attachments, piping connections, supports and agitator mountings are included in the inspection.
Creep Rupture -	External parts and attachments	Visual & measure ment	Thermoplastic tanks can be prone to creep at ambient temperatures.
Polymer or molecular degradation -	External	Visual	As a result of changes to the polymer bonds there is a change in the properties of the plastic i.e. tensile strength, colour, shape, etc.—of a polymer or polymer-based product under the influence environmental factors such as heat, light or chemicals such as acids, alkalis and some salts. These cracks propagate rapidly under harsh environmental conditions.
Environmental Stress Cracking ESC	External	Visual	ESC can lead to unexpected brittle failure of thermoplastic polymers. The exposure of polymers to certain chemicals may accelerate the craze cracking process and initiate crazing at lower levels of stress. The action of either a tensile stress or a corrosive liquid alone would not be enough to cause failure, but in ESC the initiation and growth of a crack is caused by the combined action of stress and a corrosive environment.
Thermally accelerated ageing	External	Visual	Elevated temperatures accelerate most of the age related failure mechanisms e.g. creep, fatigue & polymer degradation described above and shorten the working life of the plastic. The degradation is steady until the end of the induction period when it increases rapidly prior to failure.

Damage mechanism	Location	Detection methodology	Comments
Impact damage	External	Visual and holiday test. If tank is lined conductive - ity test	Examples include vehicular impact, scaffolding impact during erection and dismantling, access equipment, agitator paddles, etc.
Settlement of base or support structure	External	Visual	To avoid subsidence it is good practice for thermoplastic tanks to be installed on continuous, horizontal, flat, smooth surfaces e.g. a load bearing concrete plinth. This should be inspected prior to installation. Bitumen, sand etc must not be used between the tank & the flat surface as loss of the layer will result in uneven stresses possibly resulting in mechanical failure.
Localised overloading e.g. ladder supports, flat or sloping roofs & Holding down anchorages	External	Visual	Overload from personnel, tools and equipment or drainage restrictions from vegetation and other debris. Corrosion may occur below the base plate of the anchorage bolt. Corroded or over tightened, loose or missing bolts.
Earthing connections (where present)	External	Visual & resistance test	Visual examination for corrosion; if any doubt a resistance test, by suitably qualified personnel, should be called for.

Note: Appendix 1 contains photographs of typical defects

5. Scheme of examination for the periodic examination and testing

Section 6.2 of SAFed Guidance IMG01 sets out the general contents for a written scheme of examination. IMG02c sets out inspection methodologies which can be applied to thermoplastic storage tanks. Where these methodologies are applied depends on the specific type and mode of operation of each storage tank. It should be noted that there are many variations in design so each case is individual

Although bunding will not form part of the tank examination itself, it is good practice to consider the adequacy of the bunding arrangements at the initial examination. This may be carried out by:

- Visual examination of the bund arrangement to ensure adequacy of capacity, current condition, general integrity and suitability.
- If the bund is manufactured from masonry or concrete the structure should be built to suitable standards such as CIRIA guidelines (Oil Storage). All penetrations e.g. fill or drain lines, must be fully sealed to prevent leakage. The bund must be impervious to leakage & a membrane may be fitted to ensure this.
- It is recognized good practice for the bunding to be constructed to ensure that “jetting” beyond the bund in the event of puncture is avoided. Examples of control mechanisms;
    - Keeping the container as low as possible
    - Increasing the height of the bund wall
    - Leaving sufficient space between the tank & bund walls
    - Not sitting one tank above another
    - Providing screening

6. Flat bottomed tanks

Tanks built after 2000 are generally built to BS EN 12573 or similar specification. e.g. BS EN 13575, BS EN 12573.

In addition to the general requirements the following types of inspection may be included in the scheme of examination.

- Thickness survey of shell
- Dye penetrant checks of base weld if applicable – also ultrasonic checks
- Circumferential tank measurements to check for creep
- High voltage spark testing of welded joints acoustic emission
- Thermography
- Barcol hardness tests

Foundation

Visually assess foundation flatness and bottom elevation to look for signs of excessive tank settlement & check all anchor points including any fitted earthing connections etc.

Check for broken or cracked concrete, particularly around any annular ring. Examine for any cavities under the foundation and evidence of moisture ingress or growth of vegetation.

Check that run off rainwater from the tank shell flows away from the tank base.

7. Underground Tanks

Storage tanks may be sited underground or be mounded. Such tanks must be designed to take the soil loading & may be externally & internally ribbed for additional strength

Due to the nature of such tanks they obviously form a challenging environment to determine mechanical integrity. The inspection regime for these types of tanks may take the form of the following inspections;

- Internal visual inspection
- Dimensional survey
- For mounded tanks these should be de-mounded at determined intervals to check the external condition.
- Underground tanks are normally anchored down to prevent movement & may float if the water table rises and the contents are either of a lower specific gravity than water or the tanks is near empty. The integrity of anchors should be considered. If a mounded or buried tank settles after installation, this can have serious repercussions for the fixed pipework.

Where excavation of the tank is necessary care should be taken to avoid damage to the tank.

Rectangular underground tanks

8. Remote Visual Inspection (RVI) & Non Invasive Inspection (NII)

Many of the sections above discuss the need for a full internal examination, however developing technologies may allow for remote examination reducing the risks associated with gaining entry into a tank to carry out a full internal examination. For example new camera technologies may be able to provide sufficient visual proximity to provide an equivalent examination without the need for man access. This Remote Visual Inspection is carried out from the outside of the tank with only the camera entering the tank through a suitable nozzle. There are many benefits of these techniques.

Advantages

- Potential reduction in the costs associated with preparing a tank for man entry.
- Reduced exposure of personnel to confined spaces.
- Can be used where man access is not possible.
- Can be used where access has not been provided in the original design of the equipment.

- Can be used for pre entry screening, i.e. in order to determine the condition of the tank prior to a planned shutdown.
- Potential reduction in shut-down / start-up issues.
- Higher plant availability.
- Can provide video/still photographs as a permanent record of the examination.
- Some Non-Invasive Inspection techniques can be carried out whilst the tank is in service.

Disadvantages

- Requires good access for the camera equipment.
- Equipment is expensive and rarely intrinsically safe.
- Requires special operator training.
- Examination takes longer
- Tank will require cleaning, in some cases higher cleanliness than for tank entry. (Man entry)
- Defect interpretation and sizing can be more challenging.
- May still require man entry to confirm defect type and size.

When considering RVI it is vital that all potential degradation mechanisms are correctly identified in order to apply suitable Non-Invasive Inspection techniques. Any RVI/NII techniques applied would need to be evaluated on a case by case basis as to the capabilities and limitations in detecting the anticipated degradation / defects which would normally have been detected by a full internal examination. For any RVI/NII technique the probability of defect detection should be considered. The RVI/NII techniques must be justifiable in terms of the techniques used and the periodicity of examination.

Where these techniques are to be used as part of an examination procedure under a Scheme of Examination then their use should be defined within the Scheme of Examination. The inclusion of the techniques within a Scheme of Examination should be considered as part of a formal technical review of the Scheme. The technical review of a Scheme of Examination should lead to an examination regime at least as effective as the previous scheme. Failure to carry out effective examinations may lead to an increased risk of degradation leading to an incident. Non-Invasive Inspection should not be seen as an option in lieu of any procedural requirements of existing Written Schemes.

It may be appropriate to use Non-Invasive Inspection techniques in order to extend the periodicity between full internal (person entry) examinations but should not be considered a replacement for a full internal examination. If, for example, it was found through evaluation that Remote Visual Inspection could detect all predicted degradation mechanisms for a vessel then the period between full internal examinations could justifiably be increased with the Remote Visual Inspection examinations falling between full internal examinations. Recommended Practice DNV RP G103, Non-Intrusive Inspection, provides structured guidance as to when RVI/NII may be appropriate in support for deferment of internal visual examination.

Where any RVI/NII regime is in place the opportunity for a full internal examination should be taken whenever the tank is opened. Opportunistic examinations such as this allow for the identification of any unexpected degradation and help in the justification that the selected Non-Invasive Inspection techniques remain suitable for the examination of the tank.

9. Summary

This document highlights the main types of storage tanks that are used in industry, and provides guidance on the type of inspection regime that may be called up within a Scheme of Examination to ensure their continuing integrity during operation.

These are general guidelines and each individual storage tank is different and as such will need an individual assessment to confirm its history, operating conditions, future loading etc to determine an inspection strategy that is suitable fits the risks encountered.

10. References

SAFed IMG01 – The Mechanical Integrity of Plant Containing Hazardous Substances

SAFed IMG02 – The Integrity Management of Storage Tanks

SAFed IMG02d – The Integrity Management of Protective Devices

SAFed IMG07 – The Integrity Management of Bund Walls Associated with Storage Tanks

HSE PM86 – Thermoplastic tank integrity management

HSL/2006/21 – Specification and Inspection of Thermoplastic Storage Tanks

CBA / SAFed – Non-metallic Storage Tanks manufactured prior to 2007 – Guidance for Operators

BS EN 13575:2004 Thermoplastic tanks made from blow or rotationally moulded polyethylene. Tanks for the above ground storage of chemicals. Requirements and test methods.

BS EN 12573-1:2000 Welded static non-pressurised thermoplastic tanks. Part 1 General principles.

BS EN 12573-2:2000 Welded static non-pressurised thermoplastic tanks. Part 2 Calculation of vertical cylindrical tanks.

BS EN 12573-3: 2000 Welded static non-pressurised thermoplastic tanks. Part 3 Design and calculation for single skin rectangular tanks.

BS EN 12573-4:2000 Welded static non-pressurised thermoplastic tanks. Part 4 Design and calculation of flanged joints.

BS EN 1778:2000 Characteristic values for welded thermoplastics constructions.

Determination of allowable stresses and moduli for design of thermoplastics equipment.

BS EN 13341:2005 Thermoplastics static tanks for above ground storage of domestic heating oils, kerosene and diesel fuels. Blow moulded polyethylene, rotationally moulded polyethylene and polyamide 6 by anionic polymerisation tanks. Requirements and test methods.

DNV RP G103, Non-Intrusive Inspection.

11. Useful References:

RR760 Mechanical Integrity of Bulk Storage Tanks.

Environment Agency Web Site:

https://www.gov.uk/government/organisations/environment-agency

Appendix 1 – Examples of defects found in GRP tanks

Picture 1- UV degradation – note the change of colour

Picture 2 - Localised overloading on support crack

Picture 3 - Environmental Stress Cracking (ESC) horizontal cracks with through wall cracking

Picture 4 - Discolouration due to polymer or molecular degradation

Picture 5 - Degradation due to UV – note the multiple fine cracks

Picture 6 - Environmental Stress Cracking (ESC)

Picture 7 - Fatigue crack induced by manufacturing defect, which has propagated

Picture 8 - Vegetation growth at foundation and detached pipework