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Investigating elements of storage tank with Internal Floating Roof and essential parameters for design

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Abstract*—In this paper, with investigating a sample storage tank with vertical fixed roof, quantities of losses are mentioned. Due to large amount of loss in storage tank with fixed roof, storage tank with internal floating roof (IFR) for storage of aromatic products are suggested. In this study, elements of IFR are introduced. The next, essential parameters for IFR design are investigated. Finally, it can be said that, storage tanks with internal floating roof are better than storage tank with fixed roof for storage aromatic products because quantity of losses are low and the Volatile organic compounds (VOCs) into the atmosphere prevent.
***Keywords*—Internal floating roof, losses, elements of structure, design, Volatile organic compounds**

I. INTRODUCTION

Double roof storage tanks have gained wide acceptance by the petroleum and chemical industry for storage of aromatic products (even crude oil) and other hydrocarbons in atmospheric above ground storage tanks the roof consists of a internal floating roof and on top of it there is a fixed roof to minimize the evaporative lost from storage tanks. The hydrocarbons usually have high vapor pressure, where, decreasing surface contact with air can decrease evaporative lost from these types of tanks.

The internal floating roofs, however may experience structural problems in large diameter tanks e.g. roof buckling and finking failure? There are two types of evaporative loss in the internal floating roofs: Standing loss and working loss. The main reason for the standing loss in the storage tanks is losing vapor during the using of a tank due to differences between temperature and pressure which is called breathing loss. Working loss usually occurs during loading and unloading of the storage tanks [1].

The evaporative loss amounts have been reported recently on case study storage tank which are shown in table 1 and 2.

TABLE1: PROPERTIES OF A STORAGE TANK

Type of storage tank	Vertical fixed roof
capacity (gal in year)	20000
Diameter (ft)	44
Height (ft)	15
color	white
Number of filling in year	30
Average temperature in year (F)	71
Maximum temperature in year	79
Minimum temperature in year	57
Atmospheric pressure (psi)	14.7

TABLE2: LOOSES IN STORAGE TANK WITH VERTICAL FIXED ROOF

Emission Report for : Annual			
Type: Vertical Fixed Roof Tank			
Unit: lbs			
Product	Working Loss	Standing Loss	Total
Gasoline	1497646	129836	1627482

As it can be seen, the total amount of evaporative loss from a fixed roof tank is 1627482 lb. Where, the total amount of evaporative loss from a double roof storage tank with an internal floating roof is 6843 lb [2], which is mainly from holes and seals around the internal floating roof. It is clear that using double roof storage tanks may cause decrease by almost 99 percentage compared to a single roof tank.

In 1980 Epsetin and Buzek have done several researches on the design of pontoons for floating roofs. [Design of pontoons …, Floating roof analysis …, structure and displacement]. In these series of publications, the authors have shown that typical floating roof pontoons are subjected to substantiate axial stresses considering the geometry of the cross section. The interactive approach they used enables the designer to understand the forces and the consequence of design changes. In the works, the overall stability of the pontoons was discussed and simplified equation for the critical radial loads was presented.

In this work we will introduce all the mandatory parts to be used in an internal floating roof for a sample gasoline storage tank. In the next section, design criteria's will be introduced and finally we will report some preliminary design results.

II. INTERNAL FLOATING ROOF PARTS T

Pontoon type IFR consists of closed cap tube to float on top of aromatic products. Main beams, which make stable structure for holding covering sheets.

A. Main Beams

Beams are the main parts of the structure of IFR where, by connecting cross beams and structural pontoons a stable structure can be achieved.

B. Cross Beams

The cross beams are installed perpendicular to the main beams to allow joining of the sections of surface sheeting. The cross beams resemble the main beam expect that they are slightly lower in profile than the main beams when installed. Cross beams are to be installed upon completion of main beam alignment.

C. Pontoons

There are two types of pontoons: structural and nonstructural. The structural pontoons have plates or channels with gussets weld onto the end caps. These structural pontoons are the main support system of the IFR. The structural pontoons come in various lengths. The special structural pontoons attach to the perimeter. The second type of pontoon is called an auxiliary (nonstructural) pontoon and offers no contribution to the structural support of the IFR. They are provided only for buoyancy and are normally concentrated at the perimeter area. They have only flat caps welded onto the ends [3].

The main beams are installed on top of and perpendicular to the structural pontoons and provide a grid work for the surface sheeting to be laid upon and fastened to and help to stiffen the perimeter ring. All main beams are cut to the proper length at our factory. No field cutting is required. The auxiliary pontoons should be left outside of the tank until they are ready to be installed. The special pontoon and special beam identifying numbers should be marked on the tank shell. These identifying numbers can normally be found on the perimeter sections at the angels and channels that are bolted onto the perimeter to accept special beams and special pontoons.

These identifying numbers are also shown on the general arrangement drawing. The channels are used for attaching the pontoons to the perimeter and the angles are used for attaching the beams to the perimeter. When bringing the pontoons into the tank, they should immediately be placed at their respective locations. The standard structural pontoons should be placed on the tank bottom in their respective approximate locations between the special structural.

Assemble each row of structural pontoons following the pattern shown on the general arrangement drawing on the tank bottom. Assemble each row of pontoons by attaching an interior leg sleeve to the special pontoon and the first standard structural pontoon with four stainless steel bolts and aluminium nuts. The top of the leg sleeve has a hole drilled through the tube. The nuts should be on the side opposite of the leg sleeve. Do not tighten the nuts at this time. Be sure that the test plugs and tube seams are oriented so that they will be pointing upward when the pontoons are standing. It is standard practice to locate the leg sleeves on the outside of the pontoon rows. Complete assembly of the first row by attaching the remaining standard structural pontoons to the previously assembled pontoons. On large tanks, it may be desirable to assemble no more than five or six pontoons in any given row to minimize handing difficulties when raising the pontoons [4].

D. Seal

There are several different seal arrangements available for internal floating roofs. Each seal has its own specific areas of service. Seal materials have to be reviewed and are subjected to change depending on the product stored. The most common seal arrangements are Single wiper seal, Double wiper seal, Mechanical shoe seal and Foam Bag seal. As a case study we have choose foam Bag seal for our sample design.

Description of the Primary Resilient Foam Bag Seal

The resilient foam bag seal consists of an envelope (bag), which is filled (packed) with "log" shaped sections of foam material. The envelope (bag) is sometimes referred to as the scuff band. It is a circular 'rubber tube', similar to a bicycle inner tube and fits in the annular space of the external floating roof storage tanks, located between the floating roof and the tank shell. This envelope (bag) is made from a reinforced rubber material, while the foam logs sections are made from expanded resilient foam material. The foam "logs" are normally manufactured to a hexagonal or trapezoid cross-section. The width of these foam logs is usually 2 to 4-inches wider than the annular rim gap between the floating roof and the shell. These foam sections, also known as "logs", are supplied in 10 to 12-feet lengths. One edge of the envelope (bag) is fastened to the floating roof's rim angle, then the foam logs are placed inside it the envelope cavity, after which both edges of the envelopes are drawn together and fastened to the floating roof rim angle, using bolting and clamping hardware. The resilience of the foam logs material are suppose to provide the necessary radial pressure required for the seal envelope surface to maintain full contact against the tank's shell wall, therefore sealing any egress (way out) for the stored product vapours from escaping from the tank interior.

Definition of Liquid or Vapour Mounted Seal

If the bottom of the primary foam bag seal contacts the liquid, it is defined as a liquid-mounted seal. If the seal is mounted up higher where it cannot contact the liquid surface, it is known as a vapour-mounted seal.

Fragility of the Primary Envelope Fabric

The Primary Envelope Fabric is manufactured from a coated reinforced elastomeric material. This fabric is relatively thin and very delicate when compared to its equivalent in the mechanical scissor shoe seal, which is the stainless steel shoe plate. The primary seal envelope fabric's surface can easily tear or puncture by abrading against the inner shell welded imperfections, shell surface roughness, or shell defects. Wear of Envelope Fabric against Tank Shell the abrasive effect of the tank's shell inner surface on the envelope fabric's outer layers is very apparent. The floating roof continuously moves up and down causing the primary foam bag seal that is attached to the roof's rim, to rub against the inner surface of the storage tank's shell. The relative rough surfaces of the tank's shell inner wall will effectively within a certain time, wear away the seal's envelope outer layers. This is a continuous process. Due to the summer's high ambient heat, the tank's steel shell becomes hot, heating up the surface of the seal envelope making it even softer and weaker, accelerating the abrasion process. The average age of the envelope fabric is 5 to 7 years depending on the amount of "travel" the seal has done. After that, is usually has to be replaced due to the envelope cracking and the stored product have passed through these cracks and contaminated the foam logs [4].

Deterioration of Envelope Fabric from the effect of stored product

If the primary foam log seal is liquid-mounted, the bottom portion of the primary seal is solidly immersed into the stored product. The immersed outer surface of the primary foam bag seal will start slowly to disintegrate due to the chemical reaction between the stored product and the primary seal envelope material. The foam log material acting as a sponge will immediately absorbs the stored product. Within a very short period, all the foam logs will be contaminated with the stored product. The foam material then starts to rapidly decompose. This leads to the disintegration of the inner seal material (the foam logs), which consequently causes the primary seal to lose its form and resilience, hence, the primary foam bag seal ceases to function as an effective seal.

If the primary seal is vapor mounted, the lower section of the seal's outer fabric (envelope) will be heavily exposed to the stored product vapors. These vapors will also wear away the outer surface of the seal envelope. In many instances, the envelope fabric will start to tear and break up, allowing the stored product vapors to enter and contaminate the foam logs. As the tank is filled and emptied, the floating roof is raised and lowered, at the same time the outer side of the foam bag will be moving against the wetted surface of the shell. The outside surface of the primary foam bag seal will be also coated with the stored product and at the same time exposed to the abrasive effect of the tank's shell wall, which are the main factors in the wear of the foam bag seal envelope material.

Since the polyether foam log material has very poor resistance to aromatics it will deteriorate rapidly. The foam logs will become heavy with the product causing the seal to sag, resulting in the widening of the gap between the seal's outer surface and the shell, exposing the stored product to the atmosphere. This gap exposing the surface of the stored product to the atmosphere, becoming the major source of evaporation losses of the stored product. In contrary, the movement of the Primary Shoe Seal Plates against the Storage Tank's inner surface has no effect on the wear of these plates. These plates are made from Stainless Steel, which is highly resistant to abrasion in addition to its very smooth surface allowing it to "glide" over the shell surface with minimum resistance.

The Weakness of the Foam Log Construction

The design of this type of Primary Seal is based on the resilience of the open cell urethane polyether foam "logs". The foam logs' basic function is at all the times to maintain the primary seal's initial profile shape, filling the annular gap between the shell and the floating roof. The foam materials (foam logs) are made from expanded open cell urethane polyether foam. This material is supposed to have enough internal suppleness and resilience to quickly recover a deformation and return to its original form. However, the primary foam bag seal is continuously subjected to considerable compression forces. As the tank's floating roof moves up and down during the filling or emptying of the tank, the seal is exposed to the horizontal radial forces especially when the roof is navigating through "tight" annular gap area. Due to these forces and within a short period, the foam logs will gradually start to deform and continue to deform to the minimum annular gap that it is exposed. Soon, the primary seal will take a permanent "set" to this width having lost its resilience and ability to expand back and close the initial gap it was designed. Gaps will appear between the seal and the tank's shell wall; the stored product surface will become visible and start to evaporate its stored product.

Incompatibility to many Stored Products

The primary seal's envelope is either directly exposed to the stored product with a portion of it immersed into the liquid or its lower section is engulfed in a vapor rich atmosphere of the stored product. Therefore, it is essential that the envelope fabric must be compatible to the chemical effects of the stored product. For example, Saudi Aramco Technical Support Services in Dhahran had conducted in February 1996 an intensive study and laboratory testing on the impact of elevated temperatures on elastomers exposed to MTBE or Gasoline blended with MTBE.

The test temperature was 47 degrees centigrade, in comparison to tests carried out by most seal vendors at 27 degrees centigrade. The Saudi Aramco's test program established the definite deterioration of the conventional electrometric fabrics used as seal components on Saudi Aramco storage tanks in higher ambient temperatures, when exposed to MTBE concentrations in MTBE gasoline blends. The study also advocated the utilization of the mechanical primary shoe seal as a durable seal with PTFE fabric material having greatly reduced vapour permeation. Crude oil is known to have disastrous effects on various foam bag seal envelope material.

Contamination of the Primary Foam Seal Material

In many instances, the envelope fabric starts to tear and break up, allowing the stored product to enter and contaminate the foam logs. These contaminated foam logs and seal fabric will be considered hazardous waste and will require special disposal procedures. The tank will have to be taken out of service for the primary seal to be replaced. On the other hand, the Primary Shoe Seal mechanical components are manufactured from Stainless Steel components that are not affected by the force loading that the Primary Foam Bag Seal is exposed.

Source of clogging up downstream equipment

When Primary Foam Bag Seals starts to deteriorate, parts of the envelope fabric and foam log material breaks off from the primary foam bag seal and sinks to the tank bottom. This material is then pumped out of the tank through the discharge line. This debris has known to clog up strainers, block valves and cause significant shutdown of pumps, measurement instrumentation, and other equipment. The mechanical shoe seals components do not deteriorate.

Short Operational Life

Foam Bag Seals on an external floating roof tank has a typical life of five (5) to seven (7) years compared to at least 20 to 30 years for mechanical shoe seals.

Maintenance and Repair Limitations

The foam bag seal can only be efficiently maintained repaired or replaced with the tank out of service. This incurs significant costs, including desludging, cleaning and degassing the tank. This does not include the inconvenience of having the tank out of service. For the external floating roofs, the mechanical shoe seal is bolted to the rim angle; therefore, all components are easily accessible for maintenance, repair and even replacement with the tank remaining in service.

Sealing Efficiency

Both seals have been exposed to numerous testing facilities including the API 19.2. The Mechanical shoe seal has excellent sealing factors and provides excellent sealing characteristics. It seals at all rim gap variations it is designed for providing a tight seal against the tank shell wall, protecting the stored product from ingress of rain water. The primary foam bag seal due to its construction will wrinkle during its assembly providing numerous gaps against between the foam bag seal edge and the tank's shell surface, allowing rainwater to enter the tank and contaminate the stored product.

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Potential Fire Hazard

A large number of oil companies have now refrained from using the "Foam Bag" Primary Seal, since it is considered a fire hazard, being very difficult to extinguish, if a contaminated primary foam bag seal is ignited by lighting or other sources of ignition. The Shoe Seal has available Fire Retardant Primary Fabric tested in accordance to DIN 21118.

Effect of Ultraviolet (UV)

The Mechanical shoe seal and its primary seal fabric are not affected by the ultraviolet. Most of Primary Foam Bag Fabrics are affected by the ultraviolet that causes the envelope fabric deterioration. In Table 3 primary scissor shoe seal with Primary foam bag seal compare [4].

TABLE3

COMPARISION BETWEEN PRIMARY SEALS
PRIMARY SCISSOR SHOE SEAL and PRIMARY FOAM BAG SEALS

ITEM	PRIMARY SCISSOR SHOE SEAL	PRIMARY FOAM BAG SEAL
OPERATIONAL LIFE	20 – 30 YEARS	5 – 7 YEARS
INSTALLATION WITH TANK IN OUT OF SERVICE	INSTALLATION WITH TANK IN OR OUT OF SERVICE - EASY INSTALLATION	INSTALLATION WITH TANK ONLY OUT OF SERVICE – INSTALLATION CAN BE DIFFICULT
MAINTAINENCE	MAINTENANCE WITH TANK IN OR OUT OF SERVICE	MAINTENANCE ONLY OUT OF SERVICE
RESISTANCE TO WEAR	EXCELLENT – LONG LIFE STAINLESS STEELCOMPONENTS	VERY POOR – SHORT LIFE - FOAM BAG ENVELOPE ABRADES RAPIDLY
STRUCTURAL STRENGTH	RETAINS INITIAL FORM	DEFORMS WITH TIME
COMPATABILITY TO VARIOUS STORED PRODUCTS	COMPATIBLE TO ALL PRODUCTS	INCOMPATIBLE TO MANY PRODUCTS
FIRE HAZARD	FABRIC FIRE RETARDENT	CONSIDERED WORLDWIDE AS A FIRE HAZARD
EFFECT ON OTHER EQUIPMENT	NONE	CAN CLOG UP DOWNSTREAM EQUIPMENT
SEALING EFFICIENCY	EXCELLENT – ZERO GAP	POOR - AFTER CERTAIN TIME WILL BECOME OUT OF COMPLIANCE WITH MAJOR GAPPING ALLOWING PRODUCT TO BE CONTAMINATED BY RAIN WATER
ULTRAVIOLET EFFECT	NONE	DETERIORATES THE ENVELOPE FABRIC

E. Column wells

The column well is sealed by a column seal plate that is tethered to the column well. The column seal plate diaphragm can be custom fabricated to fit the column.

F. legs

As landing support, for internal floating roof, this part needs to have enough bending capability to support IFR weight.

In this section all the structural parts of an IFR have been introduced. In the next section we will talk about structural and buoyancy design of the roof.

III.ESSENTIAL PARAMETERS IN INTERNAL FLOATING ROOFS DESIGN

Many parameters are important in the design of the internal floating roofs. One of these parameters is the structural design of the IFR. In storage tank, storage wall deformation should be limit because of an excessive deformation of the storage tank can cause floating roof malfunction. Based on the M.N. Hamdem research results, the effect of the liquid height on the allowable edge settlement, deflection shape and associated moment distribution becomes more significant only when the tank foundation is relatively soft or is highly rigid and a oderately rigid foundation is the best practical choice for reducing the possibility of bulge formation and yielding due to excessive deflection at points along the beam span. [5]. The internal floating roof should be designed under the applied loads in API code. After that deformations should be controlled. Storage tanks with floating roofs have suffered severe damages during past earthquakes. Based on the R. Shabani and F.G. Golzar research, to evaluate the seismic response of the cylindrical liquid storage tanks with floating roofs Hamilton's variational principle is used. This study investigates the seismic response of the tanks accounting for nonlinearity due to large deflection of the deck plate. The ground motions include the long-period far-field record of Tokachi-oki, the near-source record of Kobe and far-field record of El Centro. It is found that accounting for large deflections in some cases could slightly magnify the roof deflection. However, usually the suppressing effect of the large deflection is more pronounced. Moreover, the frequency range in which large deflections have a suppressing effect is where ground motions are rich in the frequency content. These results are applicable for all of the ground motions considered in the analysis [6].

Storage tanks are important facilities for the major hazard installations to store large quantity of crude oil. There is several fire types can occur with large diameter open top floating roof storage tanks. Boilover is considered one of the most dangerous fires in large-scale oil tank. The world has witnessed many incidents due to boilover in floating roof storage tank [7].

Volatile organic compounds (VOCs) emitted from petrochemical plants and storage facilities play a key role in forming ground-level ozone, which causes breathing problems for humans and damages plants. External floating-roof oil storage tanks are a major source of VOC emissions. Wind passing over the fittings that penetrate the tank roof cause product to evaporate from the surface of the tank [8]. Internal floating roofs and seals should be designed to minimize evaporation and emissions resulting from evaporation.

IV. CONCLUSIONS

In storage tanks, internal floating roof are effective in reducing the amount of evaporation.

The members of IFR should be designed against a variety of forces. Also the deformation of internal floating roof should be controlled which IFR integration is sufficient.

Storage tanks with floating roofs have suffered severe damages during past earthquakes and the frequency range in which large deflections have a suppressing effect is where ground motions are rich in the frequency content.

To prevent the Volatile organic compounds (VOCs) into the atmosphere, internal floating roofs and seals should be designed to minimize evaporation and emissions resulting from evaporation.

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REFERENCES

[1] S American petroleum institute, Evaporation loss from fixed – Roof tanks, Bulletin 2518, Washington, D.C. June 1962.

[2] A. Rahbaran Dadbakhsh and H. Isayi, " Comparison and validation of evaporation from reservoirs of oil products using formulas and software", Oil, Gas and Environmental conference, Shiraz, 2008.

[3] Welded steel tanks for oil storage, API standard 650, Appendix H, 2013.

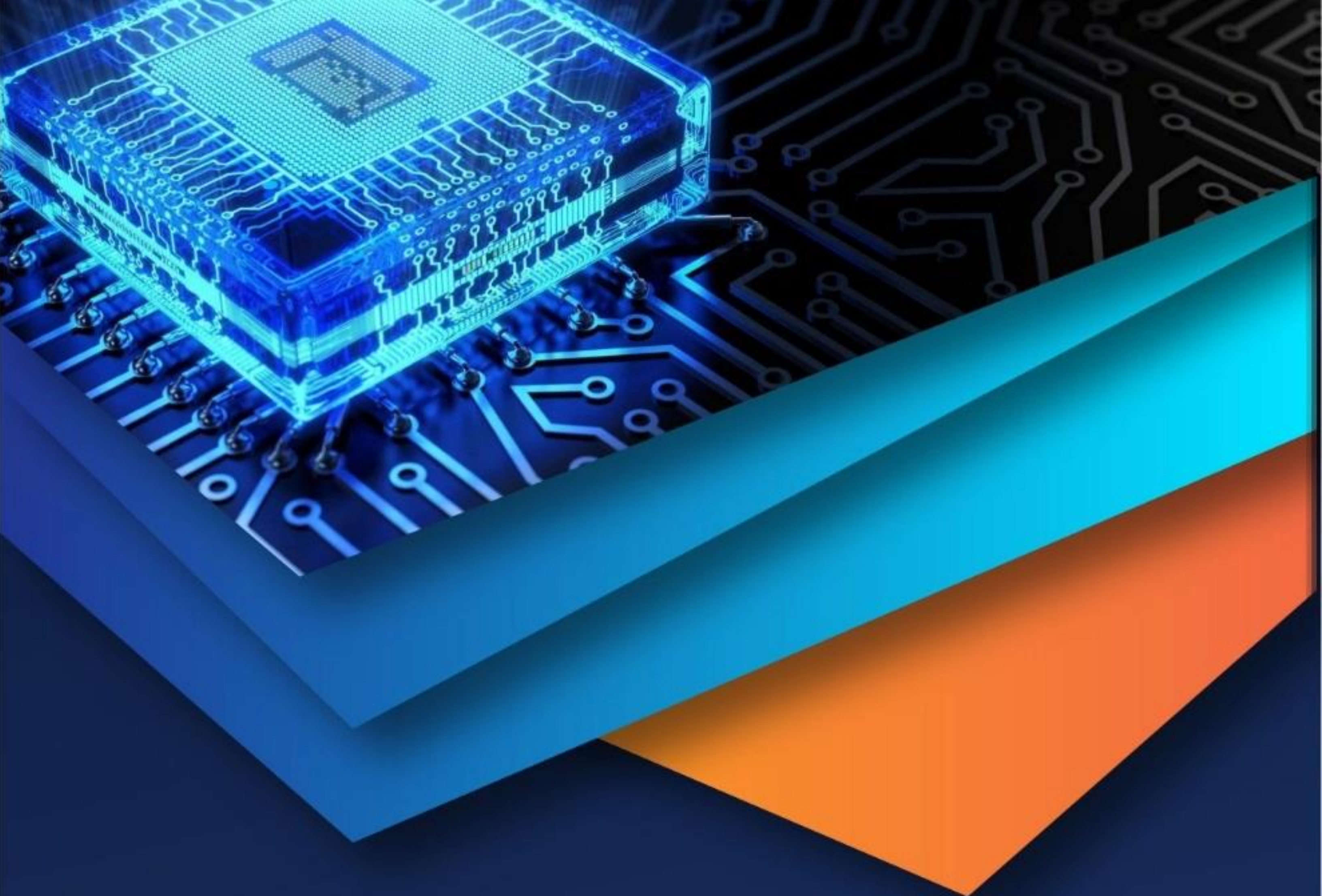
[4] INSTALLATION MANUAL FOR CTS B.V. STANDARD ALUMINIUM PONTOON TYPE INTERNAL FLOATING ROOF Manual, 2013.

[5] M.N. Hamdan, Osama Abuzeid, Ahmed Al-Salaymeh," Assessment of an edge type settlement of above ground liquid storage tanks using a simple beam model", Applied Mathematical Modeling 31, Pages 2461–2474, 2007.

[6] R. Shabani, , F.G. Golzar, ", Large deflection analysis of floating roofs subjected to earthquake ground motions", Nonlinear Analysis: Real World Applications,Volume 13, Issue 5, Pages 2034–2048, October 2012.

[7] Ibrahim M. Shaluf, , Salim A. Abdullah," Floating roof storage tank boilover", Journal of Loss Prevention in the Process Industries, Volume 24, Issue 1, Pages 1–7, January 2011.

[8] Humphrey Pasleya, Colin Clark, "Computational fluid dynamics study of flow around floating-roof oil storage tanks", Journal of Wind Engineering and Industrial Aerodynamics, Volume 86, Issue 1, Pages 37–54, May 2000.



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