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(RESEARCH ARTICLE)

A study of the corrosion rate in oil and gas pipelines by weight loss

Hanan Ahmed Alnakra [1, *] and Ayman Ahmed Ali ALnakra [2]

[1] *Department of Chemistry, Benghazi University, Alkufra, Libya.*
[2] *Internal corrosion engineers, The bright star, Ajdabiya, Libya.*

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Abstract

Corrosion phenomena means to the deterioration of metallic materials due to chemical and electrochemical reactions, because these materials are always trying to reach a state of lower energy potential, . the sole resource in most of the . In this study, The main objectives of this research are to further broaden the mechanistic understanding of. The traditional weight difference method was used to calculate corrosion rates Metal used .The sample metal used was a bar-shaped low-alloy steel labeled B It is used in the oil fields in the form of conveyor pipes inside refineries. And it was analyzed Chemically and using a spectrophotometer This study presents an overview of the corrosion threat to gas and liquid pipelines by Weight loss method .The results of the study found that there was a loss in weight for the samples used during a period that ranged between(92 days , 145 days and 198 days), and this loss ranged during the overall samples from(0.8847-0.001) grams. The amount of weight loss indicates the rate of corrosion of the pipes and the presence of corrosion. Corrosion rates ranged(8.4143-0.004) MPY.

Keywords: Corrosion; Pipes spectrophotometer; Weight loss method

1 Introduction

Corrosion is the main problem affecting the pipeline system in the United States. Briefly, corrosion refers to the destructive reaction of a metal with its environment. It takes place in the presence of a supportive medium, which is referred to as an electrolyte. Corrosion leads to problems such as leakages that lead to disasters such as fires and explosions. Therefore, it affects the safety concerns and standards held in oil and gas pipelines. There are different ways of preventing or controlling corrosion that mostly focus on the prevention of contact between the pipes and the medium or environment that leads to corrosion. Oil and gas pipes are made of low-carbon steel, which makes them susceptible to corrosion[1].

In different countries, different sources of energy such as fuels, natural gas, fossils and oils are used Oil and gas are the dominant sources of energy for production and supporting life in the United States and the world over .Corrosion has been identified as the main challenge affecting the safety concerns of the pipeline technology in the United States [2].

The fatal consequences of corrosion reinforces the need to engage in constant monitoring, which aims at identifying the presence and extent of corrosion. This paper focuses on the specifics of corrosion in oil and gas pipelines, which will include a discussion of the reasons for corrosion, disadvantages and the methods of inspecting corrosion. The discussion will seek the views of different sources and individuals regarding different aspects of corrosion in oil and gas pipelines under analysis. Iron corrosion is one of the most complicated and costly problems facing utilities. A large number of parameters affect pipe corrosion, including quality and composition, flow conditions, biological activity, and corrosion inhibitors. The surfaces of materials such as metals and alloys corrode when they are exposed to moist environments. Many substances contribute to corrosion, such as O_2, H_2O, CO_2, SO_2, H_2S, Cl^-, NO_3^-, OH^-, H^+, electrical current, marine life,

* Corresponding author: Hanan Ahmed Alnakra

and even dirt and bacteria. The annual worldwide costs incurred due to metallic corrosion are estimated to be in the range of $700–1000 billion. The average cost of losses incurred annually by corrosion of materials in the UK is £10 billion (3.5 % of the gross domestic product (GDP)), in Germany it is 22.5 billion Euro (3 % of the GDP), and in the US the value is up to $300 billion (4.2 % of the GDP). Moreover, corrosion can lead to additional indirect costs, a waste of natural resources, and safety concerns, and its remediation adds to global concerns over sustainability. In addition, experts believe that 25–30 % of money lost could be prevented with proper corrosion protection [3].

Many methods are used to control the corrosion of metals and alloys, Corrosion monitoring is carried out continuously to obtain realtime information. Nondestructive testing and corrosion monitoring are including different techniques, sensors instruments, data analysis, and use of standards such as corrosion inhibitors [4], surface modification [5], anodic/cathodic protection [6], coatings [7], and plating [8]. The effectiveness of these methods is dependent on factors such as the type of metal, environment, and type of corrosion agent. Although the use of an organic coating is a cost-effective way to prevent corrosion, after curing, defects and holes exist in the resin matrix (epoxy, polyurethane, etc.) [9], and corrodents can easily pass through the coating via these defects and holes to reach the surface of the metal. Some fillers (TiO_2 [10,11], SiO_2 [11,12], Fe_2O_3 [12,13], ZnO [14,15], Al_2O_3 [16], $CaCO_3$ [17], graphene [18,19], cement, bentonite, talc [20] etc.) Nondestructive testing and corrosion monitoring are important measures in detection prediction and prevention of corrosion in natural gas systems .We should distinguish between corrosion monitoring inspection, and survey. Inspection and survey operations are used to make the resin matrix more compact to extend the lifetime of the coating. When the coating is damaged, corrosion rapidly occurs. The combination of active and passive forms of protection has proved to be an efficient method to improve the effectiveness of coatings [21]. Generally, inhibitors are mixed with liquid during application, and in the coating, corrosion inhibitors are used to form a thin layer of active protection against corrosion; however, the direct addition of a corrosion inhibitor may destroy the integrity of the coating and it cannot sustain inhibitor release. Therefore, mesoporous materials with adsorption or ion exchange properties have been proposed as supports for corrosion inhibitors, materials such as mesoporous SiO_2 [22], metal–organic frameworks (MOFs) [23], covalent organic frameworks (COFs) [24], and layered double hydroxides (LDHs) [25]. However, materials such as MOFs and COFs are very expensive, which can prohibit their use in industry.

In the corrosion studies an attempt to provide the industry with an updated understanding of factors that influence iron pipe corros .The term “corrosion” (in a system) is defined as the electrochemical deterioration of a metal . Corrosion occurs when an electric current flows from one part of the metal (anode) through the (electrolyte) to another part of the metal (cathode). Corrosion takes place at the anode only. The cathode is the driving force ofthe corrosion action, as shown in the equation;

$$\text{Metal} \rightarrow \text{Metal ions} + \text{electrons} \quad ...(1)$$

This process degrades the metal, reduces its strength, thickness, and in some extreme cases, creates pits and then holes in the material. At some point in the corrosion process , the metal can no longer do its job as a system component. Corrosion, in general, and pitting corrosion, in particular, must be guarded against in order to ensure the long term integrity of the cooling system.[26] In the corrosion of iron the reaction may proceed

by a single step oxidation Fe into ferric ion :

$$Fe \rightarrow Fe^{+3} + 3e^- \quad ...(2)$$

In practice, a two-step process occurs in which iron is first oxidized to ferrous ion depending on the anode potential,

$$Fe \rightarrow Fe^{+2} + 2e^- \quad ...(3)$$

And then is oxidized into ferric ion

$$Fe^{2+} \rightarrow Fe^{+3} + e^- \quad ...(4)$$

The reactions above take place at the anode and must be balanced by other reduction processes that occur at the cathode. For example:

$$O_2\ (gas) + 4H^- + 4e^- \rightarrow 2H_2O \quad ...(5)$$

$$O_2\ (gas) + H_2O + 4e^- \rightarrow 4OH^- \quad ...(6)$$

The formation of OH- at the cathode causes the pH here to be higher than in the bulk solution. Eventually, ion migration of OH^- occurs, towards the anode, which promotes the formation of ferric hydroxide

$$Fe^{+3} + 3OH^- \rightarrow Fe(OH)_3 \ldots(7)$$

$Fe(OH)_3$ appears in the form of reddish brown colloid. This ferric hydroxide may react further in the presence of ferrous ions to produce Fe_3O

2 Material and methods

2.1 Practical part

In the current research, after analyzing the metal used chemically and using the (St-) device, type (37) metal was used .As shown in Table (1), and from, (Spectrometer OE) (Thermo ARL Waveform Spectrometer (3460 It is a low-carbon steel according to the American standard (Standard). During this analysis, the steel classification Metal used The sample metal used was a bar-shaped low-alloy steel labeled B It is used in the oil fields in the form of conveyor pipes inside refineries. And it was analyzed Chemically and using a spectrophotometer

Table 1 Chemical composition of the sample used

Chemical Composition	Analytical wt %
Fe	98.89
C	0.16
Si	0.07
S	0.02
P	0.01
Mn	0.71
Ni	0.001
Cr	0.04

The samples were prepared by measuring a piece of metal exposed to corrosion500 (mm * 500 mm) from one of the tanks. Samples were prepared by taking a piece of metal exposed to corrosion and measuring it(8mm).

3 Results and discussion

The results obtained were shown in Table (2) the rate of corrosion or the role of in corrosion is that all chemical reactions inside the pipes of are affected, stimulated, and their speed increases with a rise in which leads to an increase in the speed of corrosion of pipes from results paper on the specifics of corrosion in oil and gas pipelines results of the study found that there was a loss in weight for the samples used during a period , which will include a discussion of the reasons for corrosion, disadvantages and the methods of inspecting corrosion.

3.1 Weight loss method

This method is sometimes called the gravimetric method and is widely used to measure corrosion rates .General, erosion and other types of corrosion, which help in understanding the effect of these types of corrosion This method included preparing models in the form of regular cubes, as was mentioned in the topic of preparation. The samples were then weighed using a sensitive scale, and their original weight was calculated, as was the case. Calculate the surface area exposed to the corrosive medium, and the models were immersed in the corrosive medium after completion .The immersion period specified for the corrosion process took the samples out of the solution (the corrosive medium) and cleaned them of any products created the corrosion and solution were then washed with distilled water, dried, and then the samples were weighed once Again, the amount of difference in weight was found as follows :Change in weight = original weight - resulting weight

There are many ways to reduce weight in a speed or corrosion rate test, and the easiest method is summarized in: Cleaning the slice of the material (model) on which the test is to be performed, then weighing it before exposing it to the distinct medium and weighing it afterward. The difference in weight in excess of the amount of corroded material across the surface area of the sample The specified time range From this data, the corrosion rate can be determined from the following: [27-28]

$$R(MPY) =(WL)22.273 ⁄ D×A×T$$

R(MPY) :Corrosion rate in millimeters per year
WL: weight loss in grams, D: Density (gm per cubic centimeter)
T.: Time (day) A: Area (square millimeters)

Table 2 The Results the Corrosion Rate MPY of the samples

	Exposure Days	Initial Weight/G	Retrieved Weight/G	Weight Loss/G	Coupon Factor	MPY
S1	92	9.7025	9.3563	0.3462	0.875	3.2927
S2	92	9.829	9.2923	0.5367	0.875	5.1045
S3	92	9.8857	9.1627	0.723	0.875	6.8764
S4	92	9.7619	8.8771	0.8847	0.875	8.4143
S5	92	9.8 513	9.1231	0.7301	0.875	6.9439
S6	92	9.6501	9.3472	0.3029	0.875	2.8808
S7	145	9.9192	9.9098	0.0094	0.875	0.057
S8	145	9.8982	9.8938	0.0044	0.875	0.027
S9	145	9.7613	9.4853	0.276	0.875	1.67
S10	145	9.762	9.6139	0.1481	0.875	0.89
S11	198	9.6975	9.1601	0.5374	0.875	2.37
S12	198	9.7252	9.2310	0.4942	0.875	2.18
S13	198	9.8876	9.8333	0.001	0.875	0.004
S14	198	9.8343	9.5777	0.1147	0.875	0.51

3.2 Corrosion Rates (ia)

The corrosion rate is defined as the quantity of corrosion that occurred at the surface area over a given length of time. This rate can be obtained by measuring the before and after weight of metals exposed to a corrosive environment. The general method of corrosion rate is the result of applying driving force (L) and anodic resistance (R). The driving force is the difference between Corrosion Potential ($Ecorr$) and Equilibrium Potential (Eeq). Also, the driving force can be referred to as the forces pushing anodic reaction of corrosion equation and so, it is contrasted with the anodic resistance (R). Hence, formulation of corrosion rate is the ratio of L and R, which is ia = L /R formally. [21] Corrosion rate also can be obtained by electrochemical methods. To be able to employ the electrochemical methods, Faraday's law can be used to turn electrochemical into gravimetric parameter

$$I.t/F = \Delta W \; Wm/\mathrm{z}$$

3.3 Uniform Corrosion

Uniform corrosion is also known as general corrosion. This corrosion is the consistent loss of metal over an entire surface. Although it is shown like the most dangerous corrosion type by its appearance, it's quite easy to predict before it happens. Therefore, this corrosion is possibly the most well-known of all corrosion types by engineers. To get more comprehensive, engineers of NACE (National Association of Corrosion Engineers) have created a unit to be able to measure the corrosion rate (1 mil =0.001 in). Table 2 shows how the various rates of corrosion can be classified to correspond to the acceptable usage of materials.

Table 3 Classification of Corrosion Rate by its performance. [29]

Category	Corrosion Rate	Performance
I	< 0.15 mm/year (0.005 ipy or 5.9 mil)	good corrosion resistance to the extent that they are suitable for critical parts (e.g., valve seats, pumps shafts, and impellors)
II	0.15-1.5 mm/year (0.005-0.05 ipy or 5.9-59 mil)	satisfactory performance, if a higher rate of corrosion can be tolerated (e.g., tanks, piping, valve bodies, and bolt heads).
III	> 1.5 mm/year (> 0.05 ipy or > 59 mil)	usually not satisfactory

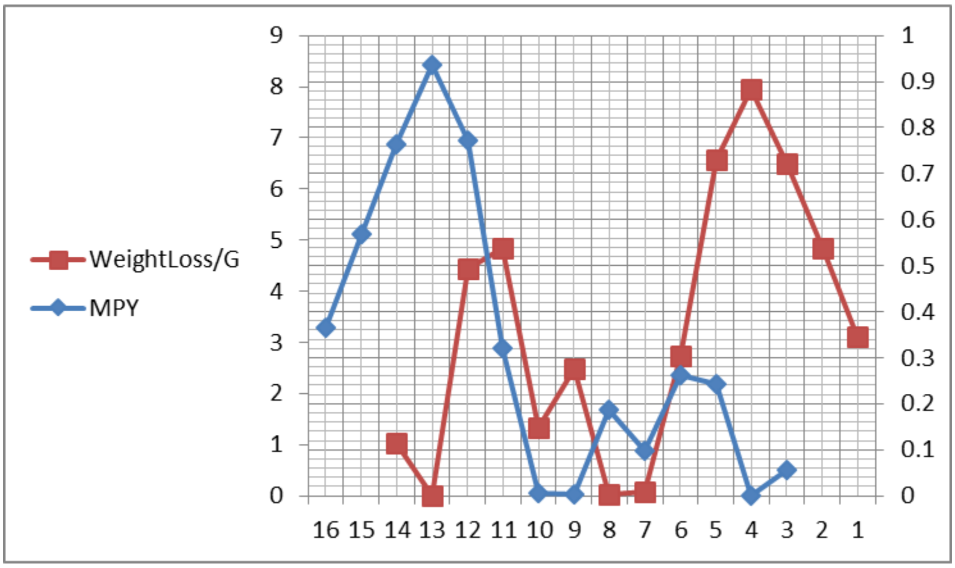

Figure 1 The relationship between the corrosion rate with Weight loss

In Figure 1, we see the results of the corrosion rate with weight loss. The results showed that losing weight in a solution indicates an increase in corrosion rates inside the pipes because the increase in the acidity of the medium due to some compounds inside the oil pipes, such as sulfide acid, carbonates, and the mixture of oil components, affects the piece of iron that is exposed to corrosion.

3.4 Time effect

The corrosion rate increasing with increasing time at constant concentration according to the result of corrosion rate.

The corrosion rate as shown in Fig2

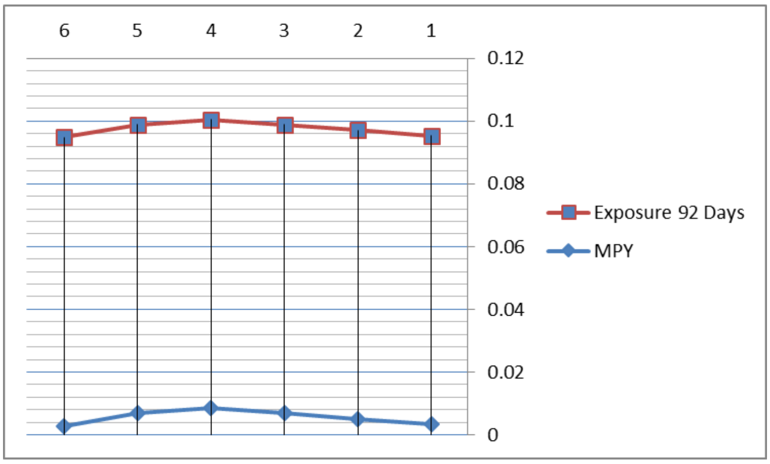

Figure 2 Effect of Time (92 Days). on Corrosion Rate at Different sample

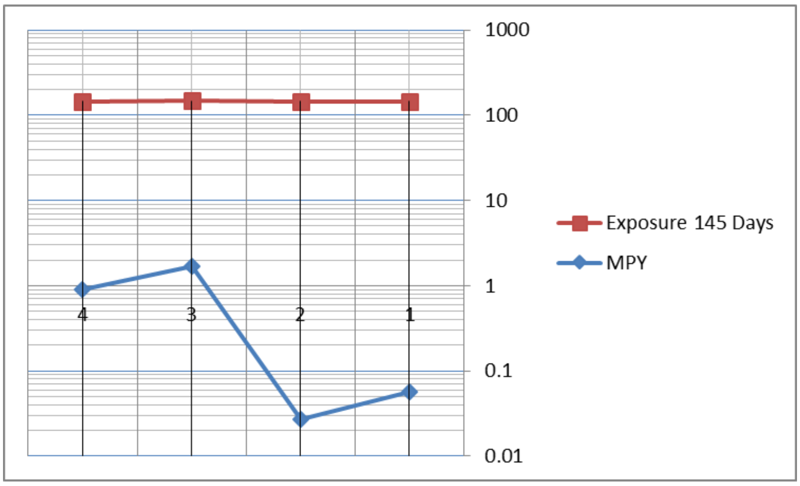

Figure 3 Effect of Time (145 Days). on Corrosion Rate at Different sample

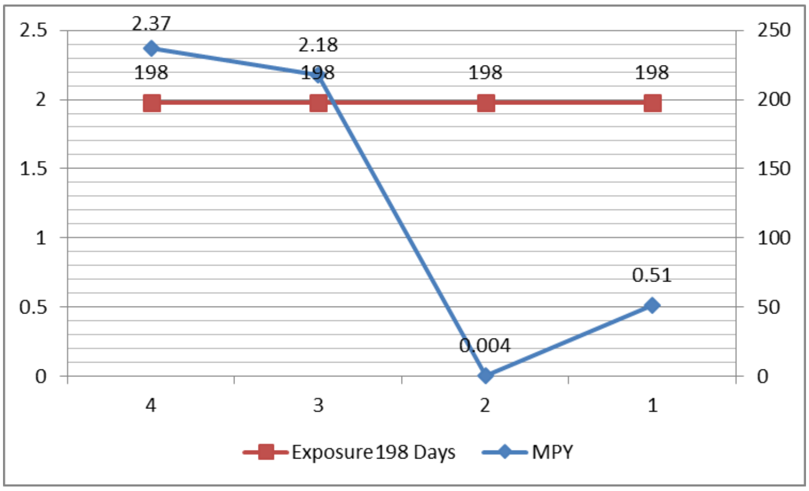

Figure 4 Effect of Time (198 Days). on Corrosion Rate at Different sample

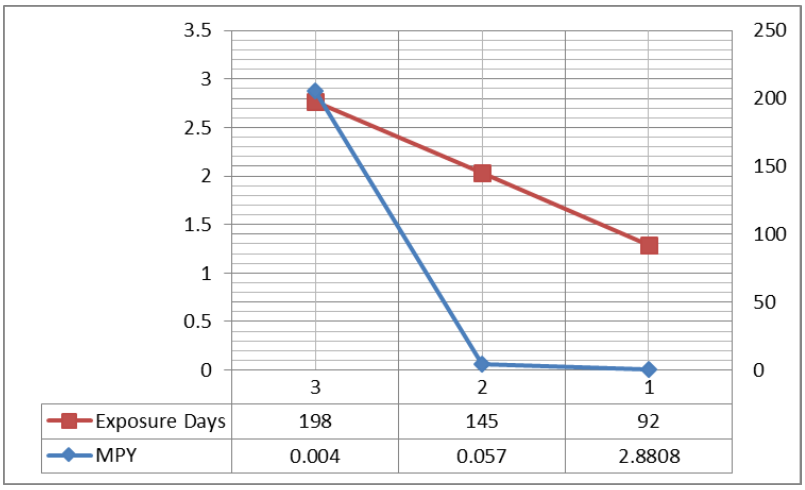

Figure 5 Effect of Time (,92,145,198 Days). on Corrosion Rate

The figure 5. shows the effect of time on corrosion rates (92, 145, 198 days). Depending on the length of time the medium was exposed to the same conditions causing corrosion, corrosion rates were found to range(0.004-2.8808)mpy.

3.5 Temperature effect

The corrosion rate increased at temp. (25,50 and 70) °C for 92, 145 and 198 days because temp. increasing caused low passivity of corrosion inhibitors at 100 °C, the temp. effect will be less on the corrosion rate at 3 and 5 days because of the passivation film that will reduce heat transfer on the metal surface

The corrosion rate will be very high if the ferrous ion is oxidized to ferric oxide very rapidly. If the rate of oxidation of Fe2+ to Fe3+ is very high so that Fe(OH)3 is formed on the surface and becomes protective, the rate of corrosion decreases. The attack by oxygen afterward appears in the form of pitting. The pits of varying dimensions accompanied by oxide deposits can be observed. When both CO2 and O2 are dissolved in the condensate the rate of reaction between carbonic acid and iron is increased. At higher flow rates, the attack by oxygen is increased. As stated earlier, the rate of corrosion of iron is increased in the presence of both carbon dioxide and oxygen.

3.6 Factors affecting the rate of corrosion

In view of the importance of steel as a material of construction its corrosion will be used to illustrate the factors affecting the rate of corrosion. 1. Effect of temperature ¬ In the pH range 4-10 where O2 reduction is the cathodic reaction of the corrosion cell, the rate of corrosion increases with increasing solution temperature up to 80 °C and then the rate of corrosion decreases with further increase in temperature. ¬ The decrease in the rate of corrosion beyond 80 °C is attributed to the decrease in O2 solubility in water. ¬ In acid medium where the cathodic reaction of the corrosion cell is H2 evolution, the rate of corrosion increases with increasing temperature according to Arrhenius equation: r = rate of corrosion; A = constant; E = activation energy; R = gas constant; T = temperature

$$\text{Rate of corrosion } r = A\, e^{-E/RT}$$

4 Conclusion

Corrosion is an emerging issue that requires urgent attention through the development of new designs and mechanisms of prevention and control. The effects of corrosion have proven to be a threat to the sustainability and efficiency of pipelines in the distribution of oil and gas from the production centers to the users. Oil and gas are important sources of energy in the United States and the world, which justifies the need to invest in effective strategies and methods of distribution. This paper focuses on the specifics of corrosion in oil and gas pipelines, which will include a discussion of the reasons for corrosion, disadvantages and the methods of inspecting corrosion. The results of the study found that there was a loss in weight for the samples used during a period that ranged between(92 days , 145 days and 198 days), and this loss ranged during the overall samples from(0.001-0.8847) grams. The amount of weight loss indicates corrosion in oil and gas pipelines. The lack of effective means of distributing oil and gas would not only challenge engagement in productive activities but also threaten survival due to the increased likelihood of accidents. Corrosion leads to mechanical reduction of the strength of oil and gas pipes, which leads to leakages and other problems. Leakages are dangerous because they expose populations to the risk of explosions and fires, as well as damaging the surrounding environment. In addition, the prevalence of accidents that relate to corrosion in oil and gas pipes decreases public confidence in the system because it challenges the hyped safety aspects of the pipelines. Various protective mechanisms put in place to control corrosion in oil and gas pipelines focus on the properties of low-carbon steel, which is the main material used in the manufacture and construction of pipes. As has been discussed in the paper, there is need to invest in the mechanisms of detecting and inspecting corrosion in the pipes because it is the foundation of prevention and control. Technology has provided limitless possibilities for the achievement of the same, but there is need to invest more in determining the best approaches of detecting, preventing and controlling corrosion, which will improve the associated outcomes.

Nondestructive testing and corrosion monitoring are important measures in detection, prediction and prevention of corrosion in natural gas systems. We should distinguish between corrosion monitoring inspection, and survey. Inspection and survey operations

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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