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Digital losses calculation in pipes by Langelier saturation index

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Abstract

This research study is considered a takeover and the finish of the study of langelier saturation index.

Langelier saturation index considered the best take over to show up the effect of water on metal pipes either corrosive or scale forming which was invented in 1936 by Langelier W.F.

The research study discuss the method of langelier saturation index method and calculating the values of water components to get water effect water on metal piping system along with the experimental method by preparing water samples of two deferent types of metal pipelines which are Ductile iron and Carbon steel pipes for their expensive costs, high performance and commonness, the experimental method is to take 5 water samples classified as the LSI values analysis of alkalinity and calcium carbonate and then, the adjustment of pH, Total dissolved solids and temperature which are -0.2, -0.5, -1, -3, and -5 and each sample of Carbon and Ductile are submerged in a sample of water separately in a water basin (e.g sample 1 of ductile and sample 1 of carbon, submerged separately in water sample of LSI= -0.2).

And this period repeated every week after checking the weight loss of Ductile and Carbon samples and checking the water characteristics according to the LSI value along the experimental duration which are eight weeks

And then the accumulative weight loss for each five sample of Carbon steel and Ductile iron have found to show up the effect of LSI value against the two different samples of pipes in mg/l

From then from the calculation of the accumulative weight loss that based on LSI,l the rate of corrosion equation, pipeline age, periodic maintenance and time of replacement.

Keywords: BRACKISH WATER, PIPELINE CORROSION, DUCTILE IRON, CARBON STEEL, WATER COMPONENTS, LANGELIER SATIRATION INDEX

Introduction

Annually, the governments all over the world spend a huge budgets for projects of the infra-structure and water distribution systems in repairing or even replacements of the metal pipelines

Metal pipelines considered the best option for the water distribution and drain systems because of it's durability against the dynamic load, pressure and high temperature resistance but pipelines corruption always has it's serious consequences such as water leakage and therefore ground, buildings and infrastructure depression in the time between the water leakage and repairing or replacing procedure of the metal pipes

Metal pipeline characterized by strength, durability and high performance, but the corruption of metal pipelines has it's additional budgets due to corrosion which has a huge consequences in costs either pipelines cost, water leakage or even it's hazardous fundamental effects on building and roads (e.g. ground depressions) **(Wikipedia.com, in " ductile pipe iron" 5 june 2009)**

Knowing the efficiency of pipelines accurately against effects corrosive water components and calculating resistance and weight loss is the only solutions of monitoring the age of pipelines and the periodic maintenance dates, langelier W. F provided his saturation index that based on the values water components which are pH, total dissolved solids, calcium carbonate, alkalinity and temperature.

LSI=pH – pHs that gave indications of the essence of the water effect and it's tendency either corrosive effect **(-ve)** or even scale deposition effects **(+ve).**

Although in 1936 W.F. Langelier made his own theory as an indicator for the water components effect in which +ve or -ve effect against the metal pipelines, but it still gives indications only as for the corrosivity of water and has nothing with the pipelines age and the quantitive weigh losses.

Working on the method of LSI and converting the indications into accurate digital data and results in both of theoretical and practical is the main if the research study, that can be the only prevention from the countless damage that happening due to pipelines corrosion

By the theoretical methods of **LSI** equations which gives the indications of water components effects along with the experimental practice to get the weight loss & accumulative loss of pipelines samples, therefore the pipeline age, time of periodic maintenance and the critical case of replacement can be obtained in each of ductile iron and carbon steel pipelines, in addition to monitoring the deterioration percentage of pipelines between ductile iron and carbon steel and conclude the age.

Ductile cast iron pipes considered one of the most expansive pipes of the world infra-structure for it's performance and huge cross-sections and in the other hand side the carbon steel pipes are the most common pipes.

(National Standards Institute "NSI"/ American Water Association "AWWA" Standard, Jan 2018)

And according to the LSI equation, water sample prepared as for the values of water it's components based on the LSI and pH degrees

It derived an equation for the pH at which the saturation of water with the calcium carbonate pHs, and the result of langelier defined as the difference between pH and pHs values.

Although the information that obtained from the langelier saturation index is not quantitative, it still indispensable in estimating the requirement of water treatment for heat exchanges in industry process, boilers with pressure, network of cooling towers, and water treatment plant as well as a general indicator of water corrosively.

The LSI is expressed as the difference between the actual system of pH and the saturated pH

LSI = **pH** measured – **pHs** calculated

Where, pHs = (9.3+A+B) – (C+D)

$A = (\text{Log}_{10}\,[TDS] - 1) / 10.$

$B = -13.12 \times \text{Log}_{10}\,(C^{o} + 273) + 34.55.$ Which is (-13.12 & 34.55), are constant

$C = \text{Log}_{10}\,[Ca^{2+} \text{ as } CaCO_3] - 0.4.$

$D = \text{Log}_{10}\,[\text{alkalinity as } CaCO_3]$ **(Energy purse.com, Nov 2018)**

Where, the equation of LSI gives three indications according to the value depends on the outputs resulted from the equation.

LSI is negative, then water is under saturated with the calcium carbonate and considered corrosive in the distribution system

LSI is positive, then water is over saturated with calcium carbonate and has a tendency of scale deposition on the internal wall of pipelines

LSI is close to zero, then water is just saturated with calcium carbonate and neither be strongly corrosive nor scale formation effect on piping system

Materials and Methodology

main target of the study is the elicitation of the losses in pipelines depending on the effect of water components on pipeline samples which adjusted according to langelier saturation index.

LSI =pH - pHs (saturated) where

pHs = (9.3 + A+B) – (C+D)

A is representing of **TDS** value, **B** related to the value of **temperature, C** related the value of **calcium carbonate** and, **D** is the representing of saturated **Alkalinity** water value, the result either -ve or +ve has it's consequence in corrosion or even scale formation effect on the pipe samples.

The research study working on the -ve corrosive indications which results the weight loss values and monitoring the deterioration of pipe samples and extracting the annual digital weight loss of the internal wall of metal pipes and then, the pipe age and corrosion type and it's causative factor can be determined

This experimental procedure carried out along 8 weeks in order to show up a viral results about the different cases of **LSI** values that based on the equations of LSI, which achieves theory on a practical scale and it depends on the following material and tools for the procedure

Tools and Materials Used

1-pH meter, ATC –(fast read out), accuracy 0.01 degree

2-TDS & Temperature meter (fast readout), accuracy 0.01 degree

3-Sulphuric acid and Sodium hydroxide solutions solution -1 normal concentration

5-And, water samples with standard characteristics

6-Portable Gold Scale with accuracy of 0.01 mg/l.

7-Ductile iron & carbon steel samples with average weight of 187550 – 192000 for ductile and 203500 – 214570 for carbon and dimensions of 4.8cm ×3cm×1.5cm approximately

8-Two basins each one has five partitions

(Fig. 1-water basins)

The experiment procedure

According to the langelier equation, water has divided into five samples, each sample has a different prosperities, which adjusted according to the changing in pH, Alkalinity, TDS, calcium carbonates & temperature **LSI = pH - pHs equ.1**

Thus, pH is the measured pH of water sample & pHs as it follows

pHs = (9.3 +A+B) – (C+D), therefore, 9.3 is constant **equ.2**

Where, symbol A related to the amount of TDS, B for temperature, C for calcium carbonate, and D is for alkalinity of Caco3.In Order to realize the effect of water on the internal walls if pipelines it must b more than one sample of water, then the five water sample with a different pH and LSI are prepared as the following:

A standard water samples for the experiment have been analyzed at the "**Housing and building national research center – Egypt**" for the items of Calcium and Alkalinity and the result was 14 and 63 respectively, thus the amount of pH, TDS and temperature can be adjusted

Therefore, here is range of LSI from slightly corrosive (-0.2) to very serious corrosive (-5) in order to get a bigger chance and higher accuracy to assess the effect of the LSI equation, and then pH, TDS & temperature will be adjusted in order to serve the equation, water sample 5 is showed as it follows for an example.

- **pH_s = (9.3 + A + B) - (C + D)**, where:

A = (Log10[TDS] - 1)/10
= (Log10[100] - 1)/10
= 0.1

B = -13.12 x Log10 (C° + 273) + 34.55
= -13.12 x Log10 (10 C°+ 273) + 34.55
= 2.38 at 10°C where, (-13.12 & 34.55) are constant

Following **Arrhenius's law** which state that the reaction double speed for 10 C° increase in temperature.

(Luiz Otávio, 2006)

C = Log10[Ca^{2+} as $CaCO_3$] - 0.4
= Log10[14] - 0.4
= 0.7

D = Log10[alkalinity as $CaCO_3$] = 1.53
= Log10[63]
=1.79. By sub in **equation (1)**

pHs = (9.3 + 0.1 + 2.38) **-** (0.78 + 1.79)
=9.17 then;
LSI = pH – pHs where pH adjusted at 8.5
= 3.9 – 9.17
= –5 the value of sample #5 **(Paul Dillon, July 2000)**

LSI values are shown five samples from slightly to serious effect which are: [-0.2],[-0.5], [-1], [-3], & [-5]

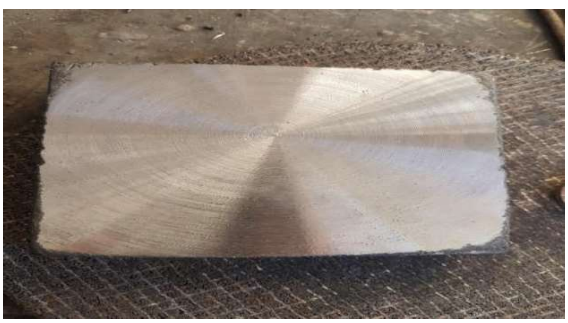
Samples	PH	Calcium	Alkalinity	TDS/mg	Temperature	LSI	PHs	Corrosion case
1	8.5	14	63	500	25	-0.2	8.7	Slightly
2	8.1	14	63	125	25	-0.5	8.6	Moderate
3	7.6	14	63	125	25	-1	8.6	Moderate
4	6.1	14	63	5000	25	-3	9.1	Serious
5	3.9	14	63	100	10	-5	8.9	Very serious

(Table 1 showing water components values)

The most common metal pipelines in the field of piping system industry is carbon steel tubes with it's three types and ductile cast iron pipes.

Two samples are taken as a sheet in the dimensions of length, width & thickness **10cm** × **10cm** × **2cm** from ductile cast pipe iron and the other from carbon steel tube.

Each one divided into 6 pieces converging parts (5 for the experimental usage & 1 as a model sample) with a dimensions of 4.7cm x 3cm x 1.5cm and then the pipe sample for both two types scaled accurately for it's weight.



(Fig 2 - pipeline sample before division)

(Fig 3 -pipeline samples after division)

Ductile cast iron	Weight	Carbon steel	Weight	LSI	pHs	pH
Sample 1	187550	Sample 1	203500	-0.2	8.7	8.5
Sample 2	187910	Sample 2	208780	-0.5	8.6	8.1
Sample 3	187730	Sample 3	208130	-1	8.6	7.6
Sample 4	187950	Sample 4	213910	-2	9.1	6.1
Sample 5	192000	Sample 5	214570	-3	8.9	3.9

(Table 2-showing the original weights of pipeline samples)

As It prepared there are two different samples of carbon steel and ductile cast iron which submerged in a same water sample basins separately

(e.g Carbon steel sample 1 and Ductile iron sample 1 submerged in water sample 1)

And then the monitoring of samples as it follows:

Water samples checked for the components adjustment every day as for prosperities and component values (e.g TDS, pH & temperature)

Metal samples scaled every week as for weight loss, weekly losses tabulated for each pipe sample, and water sample has it's label as for water component which are, pH, pHs and LSI, the duration of the experiments took 8 weeks in order to get 8 the read outs and calculating the accumulative weight losses of ductile iron and carbon steel samples and the equation curve the weight losses along the eight weeks

(Fig 4- pipelines sample after 3 days)

(Fig 5 pipeline samples after one week)

<u>Result and Discussion</u>

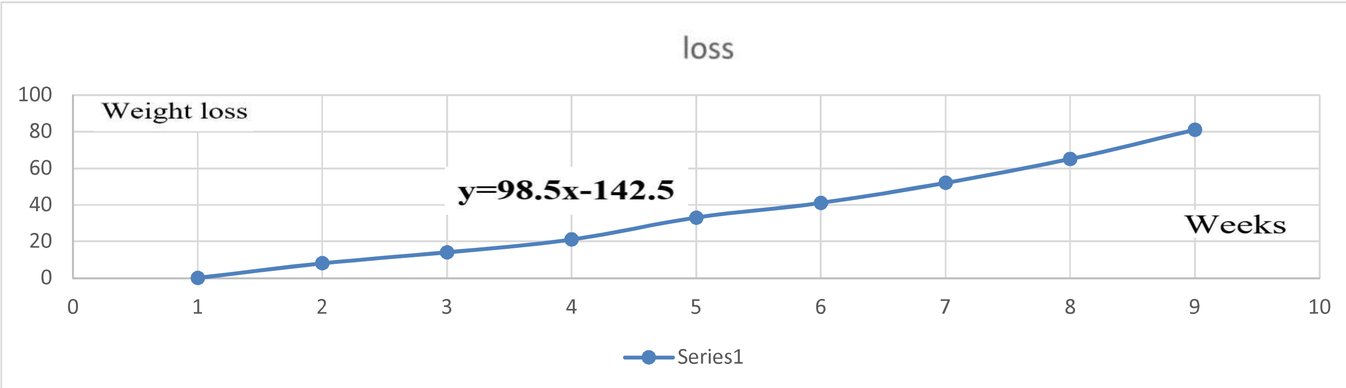
From scaling the weight losses of each sample of carbon steel and ductile iron there are ten tables, each table reported the weight losses and the accumulative losses of it's metal sample.

(LSI= -5), (pH=3.9), (TDS=100), &(temp.=10C°)

And, then there are two tables for sample 5 of metal pipes carbon steel, ductile iron and water component that has LSI -5n and it showing the following:

Weeks	Weight	Loss values(mg)	Accumulative loss(mg)
1	192000	0	0
2	191920	80	80
3	191860	60	140
4	191790	70	210
5	191670	120	330
6	191590	80	410
7	191480	110	520
8	191350	130	650
9	191190	160	810

(Table 3- sample 5/ Ductile for weight loss per week)



(Graph 1 Ductile s5/ accumulative loss Curve)

Pipelines rate of corrosion

According to the equation curve weight loss for ductile iron pipe Sample 5 at [LSI =-5]:

y=98.5x-142.5 the weight loss in weeks

To get the annual weight loss of pipes

y= 98.5 (4*12) – 142.5 ,4 Weeks*12 months =annually

= 4585.5 mg/ year

To get the loss in kg multiply the result by 1/(1000g*907.185kg), then:

= 4585.5/ (1000*907.185)

= 0.005046471 kg/ year (0.50% percentage loss)

Then, the annual weight loss per ton as it follows

Annual rate of corrosion:

= 0.005046471 Which is, **(ton=907.185 kg)**

= 4.57kg/ ton/ year

Assume, a ductile pipe with weight of **2.5** ton will be used for water that has **[LSI=-5]**

Then the weight loss in the pipe per year is:

= 4.57 × 2.5

= 11.425 kg/ton/year

Then, the weight loss of ductile pipe with the weight 2.5 ton in [LSI=- 5] is 11.425 kg/ ton/ year

Hence, the pipeline age as for ductile type with water that has [LSI=-5] is;

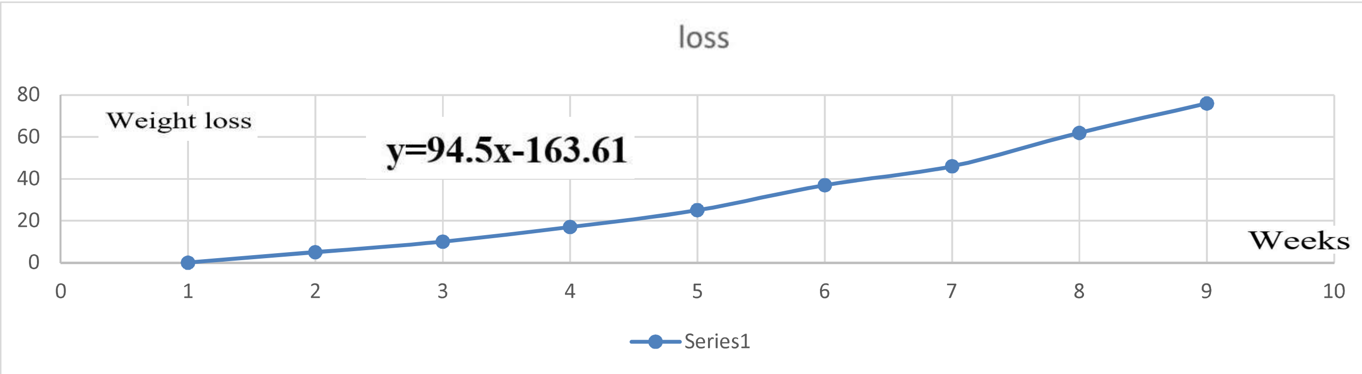
= 907.185 / 4.57

= 198.508 year approximately 198 years and 6 months

(LSI= -5), (pH=3.9), (TDS=100), &(temp.=10C°)

Weeks	Weight	Loss values(mg)	Accumulative loss(mg)
1	214570	0	0
2	214520	50	50
3	214470	50	100
4	214400	70	170
5	214320	80	250
6	214200	120	370
7	214110	90	460
8	213950	160	620
9	213810	140	760

(Table 4-sample 5/ carbon for losses per weeks)



(Graph 2-carbon s5/ accumulative loss Curve)

And similarly to the equation curve of weight loss for carbon steel pipe sample 5 at [LSI =-5]:
y=94.5x-163.61

To get the annual weight loss of pipes
y= 94.5 (4*12) – 163.6 ,4 weeks *12 months =annually
= 4372.4 mg/ year

To get the loss in kg multiply the result by 1/(1000g*907.185kg), then:

= **4372.4/ (1000*907.185)**
= **0. 0.0048197 kg/ year (0.48% percentage loss)**

Then, the annual weight loss per ton as it follows
Annual rate of corrosion:
=0. 0.0048197×907.185 And , (ton=907.185 kg)
=4.3 kg/ ton/ year

Then, the weight loss for the Carbon steel pipe with weight of **2.5** ton will be used for water that has **[LSI=-5]**
Then the weight loss in the pipe per year is:

= 4.3× 2.5
= 10.75 kg/ton/year
Then, the weight loss of carbon steel pipe with the weight 2.5 ton in [LSI=- 5] is 9.57 kg/ ton/ year
Hence, the pipeline age as for carbon type with water that has [LSI=-5] is;
= 907.185 / 4.3
= 210.97 year approximately 211 year for the LSI parameter

Then, according to the code the critical time for the periodic maintenance, repairing and replacement can be decided
And finally, the experiment along with the theoretical methods that based on langelier saturation index showed that ductile iron pipes is more effected than carbon steel pipes and deteriorated out relatively faster than carbon pipes by **6%** approximately at **(LSI =-5)**

Ductile pipe age –carbon pipe age

198.5 years – 211 years

= 12.5 years for the LSI parameter, then;

12.5 ÷ (average)/2

12.5 ÷ (198.5 -211)/2

12.5 ÷ 204.75 = 0.06 (6% as an age percentage)

Hence, ductile iron degrades faster than carbon steel by 6% due to the presence of carbon in ductile iron as a 3.2% from it's weight and that can make the resistance of pipe against water is lower, while the carbon percentage in carbon steel is maximum about 2.1% from it's weight which can solute in water forming carbonic acid due to the iron oxidation
It is also concluded that the metal pipelines deteriorates rapidly in low temperature than normal temperature

Consequently, LSI is one parameter of five parameters which are, velocity, dynamic load, gas pressure and soil acidity that should be well studied in term of the quantitive losses in order to figure out the pipeline ages, periodic maintenance, and time of replacement with avoiding water leakage that effect aggressively on building, ground infrastructures and to reduce wasting water

Recommendation

The indications of water components might shows the effect as an index, but working on finding out the quantitive weight loss of pipelines may make a revolution in the world of infrastructure.

working on the "rate of corrosion method" need some recommendations for the a professional domain of methodology framework to get the convertor application, which are:

1. The duration time of the experiments should be taken with a larger scope in order to get more quantitive weight losses for too much more accuracy, and multitude of pipelines sample is required in order to sort a more weight loss and getting a more and accurate loss readout for different types of metallic pipes , such as copper alloys, stainless steel or pipelines joints

2. The LSI for corrosive water values should be taken in a wider range (**e.g from -1 up to -8**) and With slight differences as much as possible such as, (**LSI = -1, -1.5, -2, -2.5 up to -10**) in order to figure out the variable effect of corrosive water on thee pipeline samples accurately
3. The other four parameters of pipeline deteriorations which are, water velocity, dynamic load, soil acidity & gas pressure should be well studied on a large scale, latest capabilities, detailed experiments and more accurate theories for the pipelines age convertor application

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