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DEVELOPMENT OF INTEGRATED GAS INSTRUMENTATION SYSTEM IN DIRECT REDUCTION PLANT

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Abstract

Direct reduction is the removal of oxygen from iron without melting process. In direct reduction process, the presence of mixture gas in accordance levels largely determines the performance of the iron produced. Therefore, it needs gas sensors system which has high accuracy and reliability in this process. Unfortunately, there are some things that cause decreasing in the accuracy and reliability of the gas sensor in this process. This paper aims to offer a system that can preserve the accuracy and reliability of the gas measurement system called as Integrated Gas Instrumentation System. The system tends to integrate gas sensor component using Specific Gravity (SG) with other components, such as water trap, filter regulator and monitor gas flow rate. The values of Specific Gravity Meter based on process that display in DCS system are compared with lab results for three type of experiments. Based on experiment results it can be said that the proposed system is able to improve the accuracy and reliability of direct reduction process.

Keywords: Direct Reduction Process, Specific Gravity (SG)

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1. Introduction

The conventional route for making iron consists of sintering or pelletization plants, coke ovens, blast furnaces, and basic oxygen furnaces. Such plants require high capital expenses and raw materials of stringent specifications. Coking coal is needed to make a coke strong enough to support the burden in the blast furnace. Integrated steel plants of less than one million tons annual capacity are generally not economically viable. The coke ovens and sintering plants in an integrated steel plant are polluting and expensive units [1].

Nowadays, there is a process for reducing the iron ore in solid form by reducing gases that is called as Direct Reduction. Direct-reduced iron (DRI), also called sponge iron, is produced by reducing gas produced form natural gas or coal. DRI derives its name from the chemical change that iron ore undergoes when it is heated in a furnace at high temperatures. The reducing gas is a mixture, the majority of which is hydrogen (H_2) and carbon monoxide (CO) which act as reducing agents [2-3].

In direct reduction process, the presence of mixture gas in accordance levels largely determines the performance of the iron produced. Therefore, it needs gas sensors system which has high accuracy and reliability in this process, i.e. Specific Gravity (SG). Accuracy and reliability of measurement system will guarantee quality of production result [4].

Unfortunately, there are some things that cause decreasing in the accuracy and reliability of the gas sensor in this process, namely: a mixture of dust, pressure level, gas flow rate, as well as the water content in the exhaust gases in the reactor process.

This paper aims to offer a system that can preserve the accuracy and reliability of the gas measurement system on direct reduction process called as Integrated Gas Instrumentation System. The system tends to integrate gas sensor component using Specific Gravity (SG) with other components, such as water trap, filter regulator and monitor gas flow rate.

2. Experimental and Procedures

2.1 Direct Reduction System

Direct reduction is the removal of oxygen from iron without melting process. Direct Reduced Iron (DRI), also called sponge iron, is a high quality iron product that is produced in pellet and lump forms and is generally used at an adjacent steelmaking facility. The iron oxide reduced at 800-1050 ^{o}C by interaction with reductants gas mixture (H_2 and CO) derived from natural gas or coal. A sponge iron is depicted in Fig. 1 [5].

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Fig 1. Sponge Iron

In general, the direct reduction process is divided into two sections, namely: reforming section and reduction section, as shown in Fig. 2 [5].

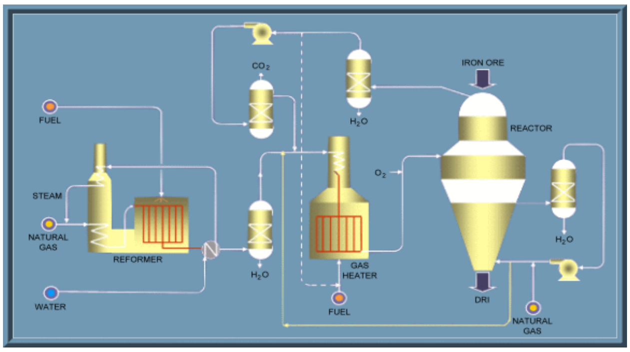

Fig 2. Diagram for Direct Reduction Process

In reforming section, natural gas (CH_4 and H_2O) is proceed by reformer process as reformed gas as H_2 and CO. These gases will be reused again with reduced gas that used in reduction process [5]. Chemical reaction occurs in this section is:

$$CH_4 + H_2O = CO + 3\,H_2 \tag{1}$$

There are two processes in the reduction section, namely the reduction circuit and cooling circuit. In reduction circuit, reformer gas mix with iron ore but in different direction in high temperature in reactor. Meanwhile, exhausted gas combine again with natural gas in order to make cooling circuit for reduced iron. Chemical reactions occur in this section are:

$$Fe_2O_3 + 3\,H_2 = 2\,Fe + 3\,H_2O \tag{2}$$
$$Fe_2O_3 + 3\,CO = 2\,Fe + 3\,CO_2 \tag{3}$$

H_2O will be trapped in next process. CO_2 will be absorbed and reuse again by mixing with reformed gas. Reduction section process is shown in Fig. 3.

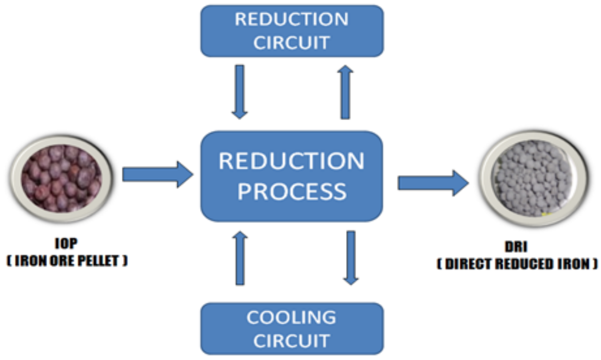

Fig 3. Reduction Section Process

2.2 *Existing System*

Krakatau Steel is one of the factories that produce sponge iron. The sponge iron is derived based on iron pellet imported from Brazil. The purification of iron pellet process becoming sponge performs direct reduction process. Overall, the direct reduction process control system using Distributed Control System (DCS) technology. All instruments are interconnected under a Process Control System (PCS). The system is able to display data collected and processed into graphical data. Graphical data are displayed on the screen in the screen using Human Machine Interface (HMI) [6]. An HMI of direct reduction process is shown in Fig. 4.

Direct Reduction is a process that involves many elements of gas, such as CH_4, CO_2, CO, N_2 and H_2, both prior to and after the process. Therefore, gas molecules instrument system becomes a critical point of the problems in this process. At present, the system uses the Gas Specific Gravity Meter NT 3098, as shown in the circle mark on the HMI in Fig. 4.

The SG NT 3098 specific gravity meter works by measuring the density of the gas under controlled conditions. The value of density obtained is directly related to the molecular weight of the gas, and thus to its specific gravity. A Gas Specific Gravity Meter NT 3098 is depicted in Fig. 5 [7].

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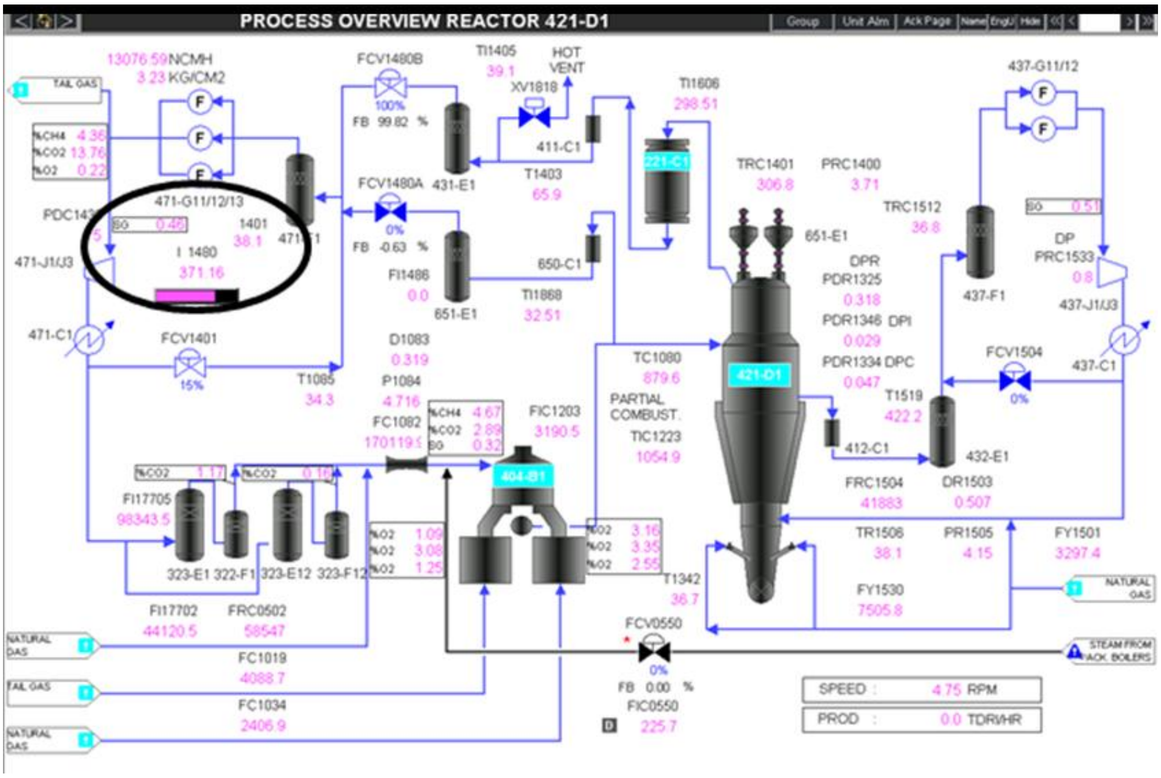

Fig 4. Overview of Direct Reduction Process in HMI

Fig 5. Gas Specific Gravity Meter NT 3098

Gas Specific Gravity Meter NT 3098 measuring system in Direct Reduction process is shown in Fig. 6. The reformed gas enters the instrument at the enclosure side and passes through a simple filter. The gas is then fed through input pipework so that it enters the gas Specific Gravity Meter. The gas Specific Gravity Meter consists of a thin metal cylinder which is activated so that it vibrates in a hoop mode at its natural frequency. The mass of gas which vibrates with the cylinder depends upon the gas density and the gas density for any particular frequency of vibration can be determined. The frequency is then converted by flowcom/converter to current so able to show in DCS/HMI display.

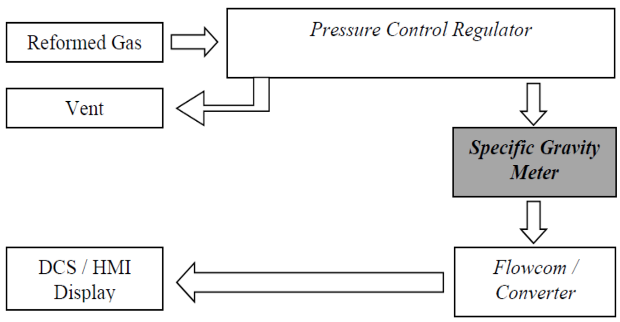

Fig 6. Existing of Gas Instrumentation System

2.3 *Modification Design*

As described before, there are some things that cause decreasing accuracy and reliability of the gas specific gravity meter in this process. The reduction process causes some residues, such as: fine sponges, cement dust and dust. In addition, the chemical reaction and changing of temperature also produces condensate water with a certain level. Both causes the gas flow rate in Specific Gravity Meter NT 3098

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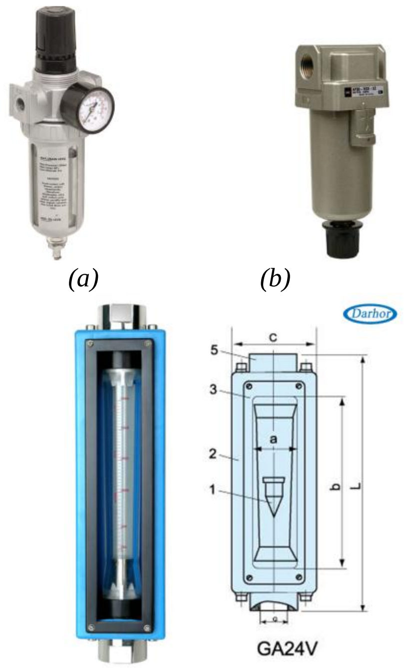
have some disturbances. Because of Specific Gravity Meter NT 3098 works by changing the frequency of the gas flow rate of into a current, then the things that interfere with the speed of flow rate will affect measurement accuracy. So, time to time, all of these things led Specific Gravity Meter NT 3098 becomes inaccurate readings.

Therefore, this research attempts to reduce the negative influence of these factors. An integrated gas instrumentation system has been designed. The system is consist of a Specific Gravity Meter NT 3098 and integrated with a water trap, a filter regulator and a flow meter monitor. A SMC water trap with 0.5”, a 0.3 µm filter regulator and flow rotatometer Darhor GA24V is depicted in Fig. 7, respectively.



(a) *(b)* *(c)*

Fig 7. Addition of Gas Instrumentation System: (a) SMC Water Trap, (b) Filter Regulator (c) Flow Rotatometer

A SMC water trap with 0.5” is a condensate tube that able to discard water in gas circumstances automatically. This discarding process occurs because of specific gravity different between water and gases. Consequently, gases entered to chamber purely. A filter regulator with 0.3 µm is used for filtering fine sponges, cement dust and other mixture dust. Finally, a flow rotatometer Darhor GA24V is performed here in order to monitor the flow rate in sensing element of Specific Gravity Meter. Therefore an operator is able to know when he should give maintenance process to the gas system.

Modification system block diagram with an integrated gas instrumentation system is shown in Fig. 8.

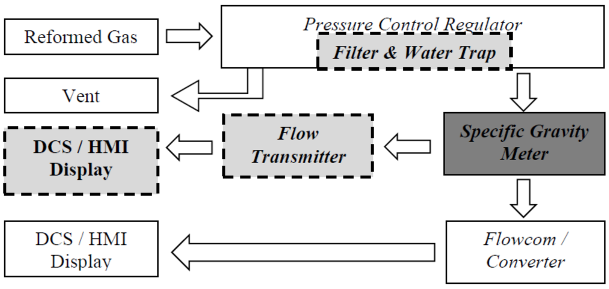
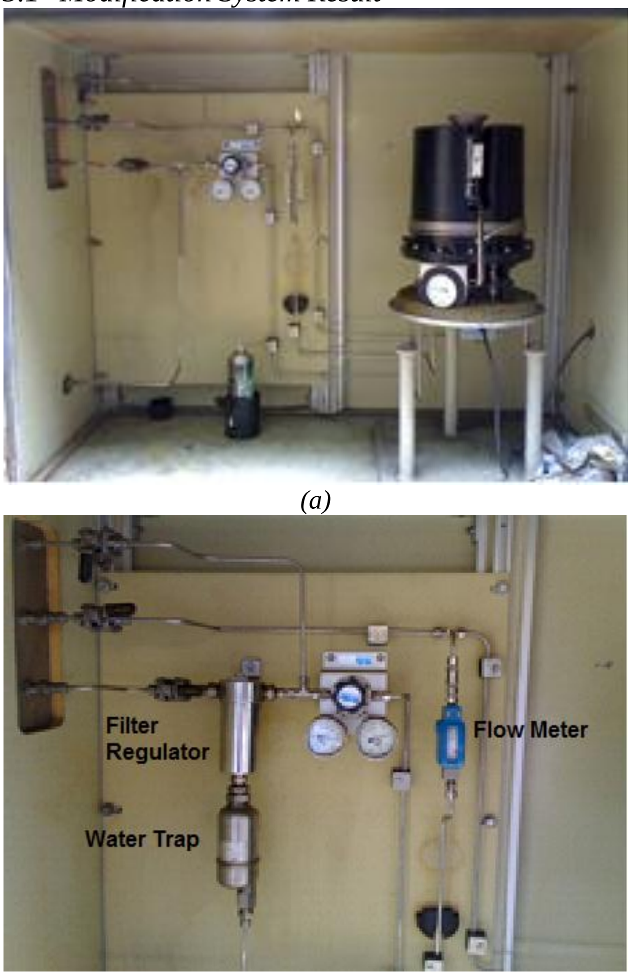


Fig 8. Modification of Gas Instrumentation System

3. Results and Discussion

3.1 Modification System Result



(a)

(b)

Fig 9. Comparison of Gas Measuring System: (a) Existing System and (b) Modified System

Based on modification design, a new gas measuring system is installed. A Specific Gravity

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Meter NT 3098 is installed and integrated with a SMC water trap with 0.5", a 0.3 µm filter regulator and flow rotatometer Darhor GA24V. Comparison of existing system and modified system of gas measuring system are shown in Fig. 9.

3.2 Result of First Experiment

First experiment use existing system in order to know the performance is. In these experiments, SG measuring was collected every five days. Then, the results of SG measuring that displayed in DCS and SG measuring based on Lab is comparing as shown in Table 1 and depicted in Fig. 10.

Table 1. SG Measuring in Existing System

Time	DCS	*Lab*	Deviation	Percentage
1	0.418	0.419	0.001	0.239
2	0.484	0,408	0.076	18.543
3	0.570	0.416	0.154	37.086
4	0.676	0.422	0.254	60.265
5	0.737	0.402	0.335	83.444
6	0.790	0.410	0.380	92.716

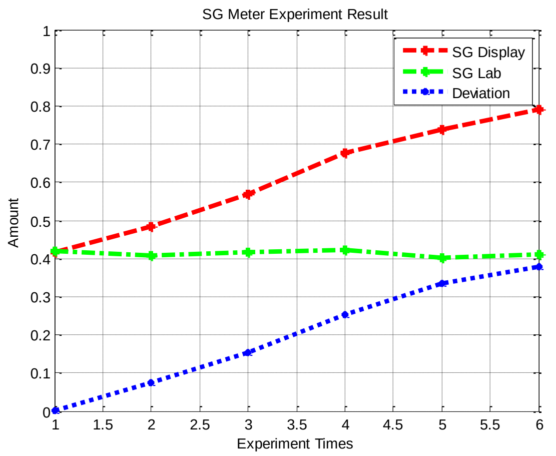

Fig 10. SG Measuring in Existing System

Based on the Table 1, it can be said that the existing system has some problems. After two or three measuring the deviation are highly increasing. The values of SG based on DCS have significantly different with value of SG based on lab. And, in sixth measuring the percentage of deviation become 92%. It means the performance of gas sensor become very low in the last measuring. It proves that there are problems with existing system.

3.3 Result of Second Experiment

In the second experiment, SG measuring system is augmented by water trap and filter regulator with 0.3 µm. As in the first experiment, the data was gathered every five days. Then, the results of SG measuring that displayed in DCS and SG measuring based on Lab is comparing as shown in Table 2 and illustrated in Fig. 11 as well.

Table 2. SG Measuring in Second Experiment

Time	DCS	*Lab*	Deviation	Percentage
1	0.416	0.415	0.001	0.241
2	0.457	0.418	0.039	9.302
3	0.479	0.420	0.059	13.952
4	0.510	0.414	0.096	23.254
5	0.524	0.425	0.099	23.254
6	0.609	0.416	0.193	46.508

Table 2 showed some improvement in value of SG based on DCS that compared to first experiment. Although there are still deviation between SG values based on DCS with value of SG based on lab, but this deviation is not as big as before. After sixth measuring the deviation is 0.193 but still with 46.5% percentage of deviation. This happens because the gas that comes into the sensing element of SG has been reduced from compensated water that had been trapped and the mixtures of dust that had been filtered before.

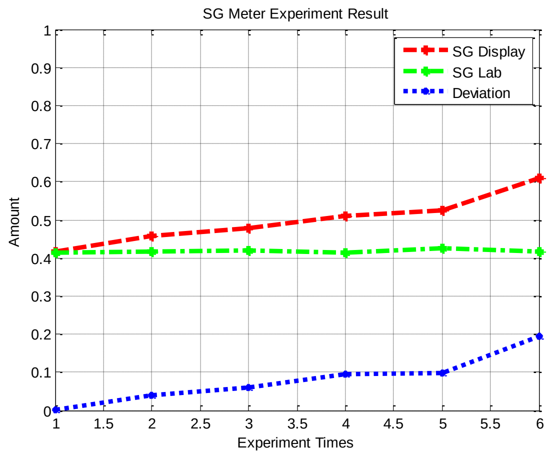

Fig 11. SG Measuring in Second Experiment

3.4 Result of Third Experiment

The integrated of SG measuring system that performed SG with water trap, filter regulator with 0.3 µm and flow rotatometer is performed in third experiment. The data was gathered every five days as before. The results of SG measuring that displayed in DCS and SG measuring based on Lab is comparing as listed in Table 3 and shown in Fig. 12 as well.

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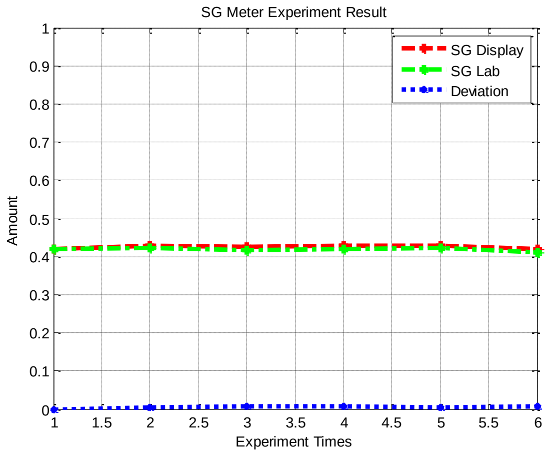

Fig 12. SG Measuring in Third Experiment

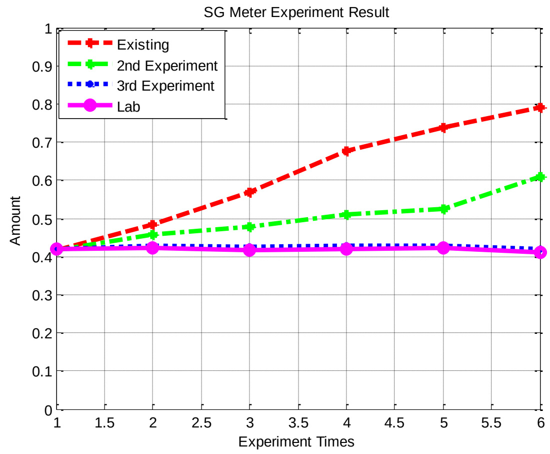

Fig 13. SG Measuring in All Experiments

Table 3 exposed some improvement in value of SG based on DCS that compared to first and second experiment. The SG values based on DCS almost same with value of SG based on lab. Even after sixth measuring the deviation is only 0.008 with 1.946% percentage of deviation. This happens because the gas that comes into the sensing element of SG has been reduced from compensated water that had been trapped, the mixtures of dust that had been filtered before and the flow rate of gases are controlled in corresponding value. So, the Specific Gravity Meter NT 3098 is able to work in better performance. Improvement of SG values form experiments in existing system up to third experiments compared with value from lab is shown in Fig. 13.

Table 3. SG Measuring in Third Experiment

Time	DCS	*Lab*	Deviation	Percentage
1	0.420	0.420	0.000	0.000
2	0.428	0.423	0.005	1.182
3	0.425	0.417	0.008	1.918
4	0.427	0.421	0.006	1.425
5	0.427	0.422	0.005	1.185
6	0.419	0.411	0.008	1.946

Statistical analysis of experiments results are performed in order to review performances of proposed system. Based on Fig. 14 it can be said there are declining of standard deviation from 0.108 in first experiment towards to 0.0027 in third experiment. Thus also happens in relative standard deviation from 0.613 to 0.424. In addition, increasing in the percentage of precision is increasing from 82.388 % to 99.215 % in the third experiment. This analysis proves that the proposed system can cause increasing of gas molecules performance measurement in the direct reduction process.

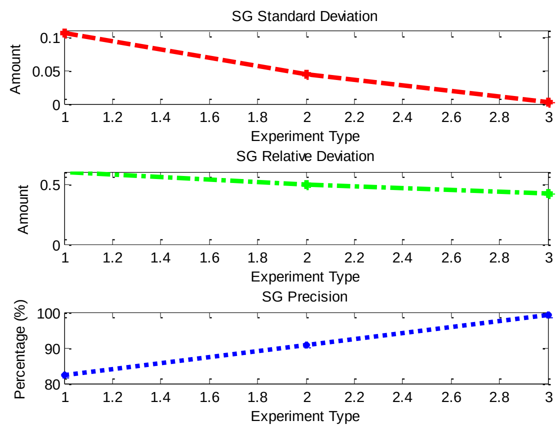

Fig 14. Statistical Review of SG Values

4. Conclusions

An integrated gas instrumentation system for improving performance of direct reduction process is designed. The system consists of a Specific Gravity Meter NT 3098 that augmented with a SMC water trap, filter regulator with 0.3 µm and flow rotatometer Darhor GA24V. Some experiments have been performed for review performances improvement. The values of Specific Gravity Meter

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based on process that display in DCS system are compared with lab results for three type of experiments. Based on experiment results it can be said that the proposed system is able to improve the accuracy and reliability of direct reduction process.

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