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Article

Prototype Automatic Water Spray for Coal Dust Cleaning on Coal Conveyor

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A B S T R A C T

Coal dust generated during the transfer process via belt conveyors at PT Bukit Asam Tbk has significant negative impacts on the environment and the health of workers. The current manual method, involving direct water spraying, is ineffective in controlling airborne dust and increases safety risks due to water exposure and unstable working conditions. To overcome these challenges, this study developed a prototype of an Arduino-based automatic water spraying system as a safer and more efficient solution.The system employs a SHARP GP2Y1010AU0F dust sensor to monitor coal dust concentrations in real-time and an HC-SR04 ultrasonic sensor to regulate water spraying automatically, based on the detected levels. The prototype was tested under operational conditions and showed optimal performance, effectively reducing coal dust concentrations while improving health and safety standards in the workplace.This innovation offers a practical and sustainable approach to coal dust management, addressing the shortcomings of manual methods. By automating the process, it minimizes worker exposure to dust and eliminates hazards associated with direct water application. The system's efficient and safe operation highlights its potential for broader implementation in similar mining environments. This technology not only resolves critical issues in coal dust control but also introduces a forward-thinking solution that aligns with industry goals for improved occupational safety and environmental protection.

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I. INTRODUCTION

Mineral resources in Indonesia have quite a lot of potential and are almost spread throughout the archipelago [1]. PT Bukit Asam Tbk is known as an open-pit coal mining company that conducts continuous excavation starting with the removal of the overburden layer and continuing until the coal is found [2]. Coal is one of the natural energy sources needed in life and one of the energy sources in the world [3]. Coal is a sedimentary rock whose main material consists of carbon as a result of the formation of plant remains that have been subjected to heat and geological pressure for millions of years. Before it can be used, coal must go through the mining, processing, and transportation phases first in order to be converted into other energy [4]. PT Bukit Asam State-Owned Enterprise (BUMN) company that contributes to state revenue [5]. The company's operational activities cover various stages ranging from unloading, loading, to transporting At PT. Bukit Asam Tbk, coal mined from the West Banko Mining Front is transported using a Dump Truck to the Temporary Stockpile (Furthermore, the coal is put into the Dump Hopper and distributed using the Coal Handling Facility (CHF) to the Stockpile3. From Stockpile3, the coal is transported by conveyor and loaded into railway cars through. coal to the Train Loading Station (TLS) [6]. However, in the process of transporting coal to the TLS, there are a number of challenges, one of which is the problem of coal dust produced during the transfer of material from one conveyor to another. Coal dust that is released into the air not only has a negative impact on the environment, but can also pose serious risks to the health of workers. Various studies have indicated that long-term exposure to coal dust can cause serious respiratory diseases, Data from the WHO (World Health Organization) states that there are 1.1 million deaths due to occupational diseases worldwide, 5% of which is pneumoconiosis [7]. Exposure to this industrialization process can cause occupational diseases [8]. Pneumoconiosis is a chronic occupational disease caused by prolonged inhalation of dust marked by inflammation of the alveoli [8] and has the potential to increase the risk of Tuberculosis and Silicosis, is a chronic disease of the lungs caused by inhalation of silica dust due to prolonged exposure. Silicesis is a form of pneumoconiosis [9] .This disease generally occurs in miners. Currently, efforts to control coal dust in the CHF1 conveyor area of PT Bukit Asam are carried out through the use of manual waterspray operated by workers manually to wet the coal. However, this method is considered less effective and efficient, and poses a potential hazard to workers who must be near the conveyor area exposed to dust. Therefore, the development of a more efficient and safe dust control system is an urgent need [10].

The implementation of an automatic dust control system, such as High-Pressure Fog Spray Dust, can improve operational efficiency while reducing the risk of work accidents and environmental pollution. Therefore, by considering the existing problems and utilizing the results of previous studies, the development of an automatic water spray prototype for cleaning coal dust on the PT Bukit Asam conveyor is a relevant solution. The implementation of this technology is expected to improve the efficiency of water use, protect worker health, and reduce the risk of work accidents caused by exposure to coal dust [11].

II. METHODS

This research uses literature, observation, and consultation methods. Literature research is a search and literature research by reading various books, journals, and other literature publications related to research topics [12], Observation is a technique that is carried out for systematic observation and printing of symptoms that appear on the object of research, Through observation the researcher will be able to clearly see how the real condition of the research subject [13].

This prototype of the automatic water spray system was developed using Arduino Nano as the main control, Arduino Nano is a development of a microcontroller that has a small size that can be used for control [14].The SHARP dust sensor GP2Y1010AU0F used to detect dust concentration, GP2Y1010AU0F dust sensor uses infrared technology [15]. and the ultrasonic sensor HC-SR04 is

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used to monitor the water level in the tank. If the dust concentration is detected exceeding the specified limit, the system will automatically activate the water spray to reduce the dust.

Planning of Equipment of Hardware

Designing this tool involves several steps, namely creating a tool design, creating a circuit schematic, selecting components, and assembling components according to how the tool works. Then proceed with software design involving testing devices that have been previously assembled to enter program input and observe the results provided by the device.

Design of Electronic Devices and Software

When designing a device, a schematic diagram is very necessary to determine and detect errors in the wiring. Schematic diagrams can also represent an experimental device. Overall, the schematic diagram of the tool that has been designed can be seen in Figure 1 below.

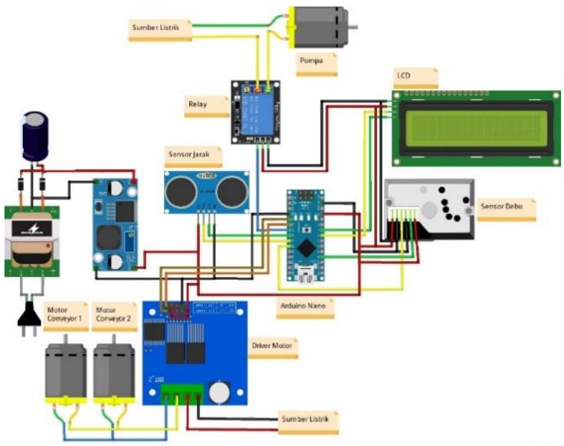

Figure 1. Circuit Schematic
Source: Personal Documentation

The way a tool works can be seen from a flowchart or process diagram of that tool from start to finish. To facilitate reading, what needs to be done is to create a Flowchart of the device that will be made.

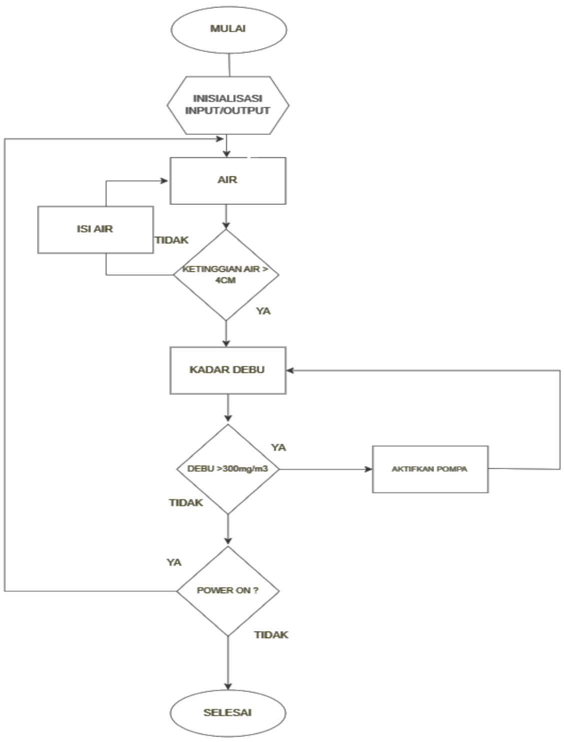

Figure 2. Flowchart
Source: Personal Documentation

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III. RESULT

Prototype testing showed satisfactory results. The power supply is measured at several points to ensure the system is functioning properly. The ultrasonic sensor works well to detect the water level in the main tank from a distance of 1 cm to 20 cm and provides information to the Arduino to activate the system. The dust sensor also works well in detecting dust particles of 300mg/m3, which then instructs the Arduino to activate the water spray pump.

The results of the voltage measurement show that all components are functioning according to the expected specifications. The voltage value obtained is still within the allowable limit, so that the system can be relied on in its operation.

Measurement Result

The measurement of the components was carried out five times to produce accurate results. Furthermore, it produces an average value with the formula below.

$$x = \frac{x_1+x_2+x_3+x_4+x_5}{n} = \frac{S_{xi}}{n} \quad \text{...(3.1)}$$

Where:

$\frac{S_{xi}}{n}$= Sum of all samples

X_1= Measurement

n = Number of Measurements

x = Average Price

The percentage of difference or error that occurs from the test or measurement results is known by using a formula. The formula for knowing the percentage of measurement error uses the following equation:

$$\%\, eror = \frac{Measurement - account}{Measurement}\, x\, 100 \quad \text{...(3.2)}$$

There is a high possibility of errors or differences in the results obtained. To reduce errors, refinement is needed to find out how big the error rate is.

Table 1. Voltage Measurement Results Using a Power Supply

No	Measurement Position	Measurement Points	Unit						Flat	Description
				1	2	3	4	5		
1	Power Supply	Input From PLN (TP1)	V_{ac}	223,0	223.1	223.0	223.1	223.0	223.0	*Input* Trafo
		Trafo (TP2)	V_{ac}	12.21	12.21	12.21	12.20	12.20	12.20	*Input* Dioda
		Dioda (TP3)	V_{dc}	15.09	15.09	15.10	15.10	15.10	15.09	*Input* *C*apacitor
		Capacitor (TP4)	V_{dc}	15.09	15.09	15.10	15.09	15.09	15.09	Input Step Down,
			$_{Idc}$mA	1.51	1.52	1.51	1.51	1.51	1.51	Arus
		LM2956 Step Down (TP5)	V_{dc}	5.11	5.11	5.11	5.12	5.12	5.11	*Input* Arduino,
2	Arduino Nano	TP6	V_{dc}	5.10	5.11	5.10	5.10	5.10	5.10	Relay input, dust sensor input, ultrasonic sensor
3	*Relay (1)*	TP7	V_{dc}	5.10	5.11	5.11	5.11	5.11	5.11	-

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	Relay (2)	TP8	V_{dc}	5.11	5.11	5.10	5.11	5.10	5.11	-
4	Mosfet L298N	TP9	V_{dc}	5.10	5.09	5.11	5.10	5.09	5.09	-
5	LCD 16X2	TP10	V_{dc}	5.06	5.03	4.98	5.01	5.02	5.02	-
6	Motor 1	TP11	V_{dc}	14.96	14.95	14.97	14.97	14.96	14.96	On
				0.1	0.1.	0.1	0.1	0.1	0.1	Inactive
			rpm	214.3	214.4	214.3	214.4	214.3	214.3	
	Motor 2	TP12	V_{dc}	14.95	14.96	14.97	14.96	14.94	14.95	On
				0.1	0.2	0.2	0.2	0.2	0.1	Inactive
			rpm	89.0	89.0	89.0	89.0	89.1	89.0	
7	Pompa 1	TP13	V_{dc}	11.10	11.15	11.10	11.10	11.11	11.11	On
				0.3	0.2	0.2	0.2	0.2	0.1	Inactive
	Pompa 2	TP 14	V_{dc}	11.10	11.10	11.15	11.10	11.11	11.12	On
				0.1	0.2	0.1	0.2	0.1	0.1	Inactive
8	*Ultrasonic Sensor Hc-Sr04*	TP15	V_{dc}	5.09	5.10	5.09	5.09	5.10	5.09	On
				0.2	0.2	0.3	0.3	0.2	0.2	Inactive
9	Sensor *SHARP GP2Y1010AU0F*	TP16	V_{dc}	5.11	5.10	5.11	5.11	5.10	5.11	On
				0.2	0.2	0.3	0.2	0.2	0.2	Inactive

The calculation of the transformer coil is calculated based on existing specifications using data that has been measured using equation 3.1, producing the following values:

$$a = \frac{N_1}{N_2} = \frac{V_1}{V_2} => \frac{N1}{N2} = \frac{220}{5} => \frac{44\,N1}{N2}$$

The output voltage of the transformer is based on the changes as shown in table 1, resulting in the following values:

$$a = \frac{V_{measurement}}{V_2}$$

$$V_2 = \frac{223{,}0}{\frac{44}{1}}$$

$$V_2 = 5{,}06\ v$$

Percentage Error on measurement

The results of the measurements carried out such as the data in table 1 will produce an average value at each measurement point. The average value serves to determine the percentage value of errors that occur when making measurements. To calculate the percentage of error, the following equation is used:

$$\%\ \text{Error} = |(\text{Datasheet} - \text{measurement})/\text{Datasheet}|\text{x}\ 100\% \quad ....(3.3)$$

$$\%\text{Error} = |(\text{Datasheet} - \text{measurement})/\text{Datasheet}|\text{x}\ 100\% \quad ....(3.4)$$

Using equation 3.3. and 3.4. The percentage error value for each component can be searched as follows:

% Error pada TP2:

$$\%\ \text{Error} = \left|\frac{\text{measurement} - \text{account}}{\text{measurement}}\right| \text{x}\ 100\%$$

$$\%\ \text{Error} = \left|\frac{12{,}20 - 5{,}06}{12{,}20}\right| \text{x}\ 100\%$$

$$\%\ \text{Error} = 0{,}58\%$$

By using the same formula as the calculation of the error counters for TP1, TP2, TP5 and TP6, the calculation of the error counters for each of the existing measurements points was carried out. Below is a table of the results of the calculation of the fault perserntase for each of the existing perngurkurran points.

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Table 2. Voltage Measurement Results Using a Power Supply

No	**Posisi Pengukuran**	**Letak Pengukuran**	***Data Sheet*/ Perhitungan (V)**	**Pengukuran (V)**	**Kesalahan (%)**	**Keterangan**
1	Power Supply	TP1	220	223,0	0,013	-
		TP2	5	12,20	0,590	-
		TP3	-	15,09	-	-
		TP4	-	15,09	-	
		TP5	-	5,11	-	-
2	Arduino Nano	TP6	5	5,10	0,02	-
3	Relay (1)	TP7	5-12	5,11	-	*In Range*
4	Relay (2)	TP8	5-12	5,11	-	*In Range*
5	Mosfet L298N	TP9	3,2-40	5,09	-	*In Range*
6	Input LCD	TP10	4,7-5,3	5,02	-	*In Range*
7	motor (1)	TP11	12-15	14,96	-	*In Range*
8	motor (2)	TP12	12-15	14,95	-	*In Range*
9	Pompa (1)	TP13	6-12	11,11	-	*In Range*
10	Pompa (2)	TP14	6-12	11,12	-	*In Range*
11	Input Sensor Ultrasonic HC-SR04	TP15	5	5,09	*1,76*	-
12	Input Sensor SHARP GP2Y1010A U0F	TP16	4,5-5,5	5,11	*In Range*	-

Equipment Work Test Results

This section usually discusses the results of the work test of the equipment to ensure that all tools are functioning properly and in accordance with the specifications that have been set.

Ultrasonic Sensor Testing HC-SR04

In this research Ultrasonic HC-SR04 has the function of measuring the volume of water in the tank.

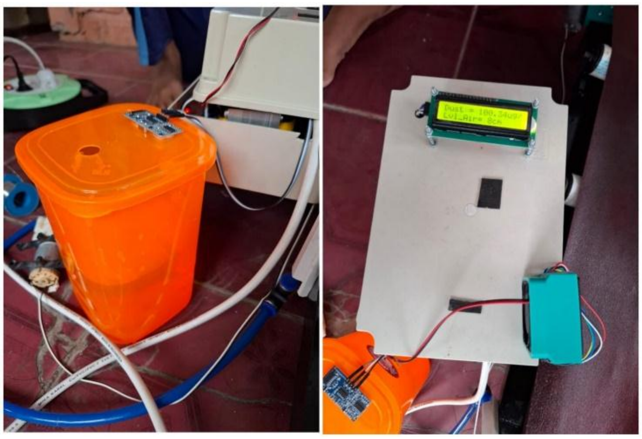

Figure 3. Ultrasonic Sensor

Table 3. Ultrasonic Ssensor Testing

No	Reading distance (cm)	Results
1	1-2	Pompa 2 On
2	2-4	Pompa 2 On

3	4-6	Pompa 2 On
4	6-8	Pompa 2 On
5	>8	Pompa 2 Off

The results of the Ultrasonic sensor test can be seen that the Ultrasonic sensor will detect the water level in the main tank from a distance of 1 cm to 20 cm. The pump will continue to run and fill water from the Reserve tank to the main tank when the water level is <8 cm and the pump will turn off when the water level is> 8 cm.

SHARP GP2Y1010AU0F Dust Sensor Testing

In the SHARP dust research, GP2Y1010AU0F is fursused as a detector of dust levels from the pouring of coal material on a conveyor and then activates the water pump.

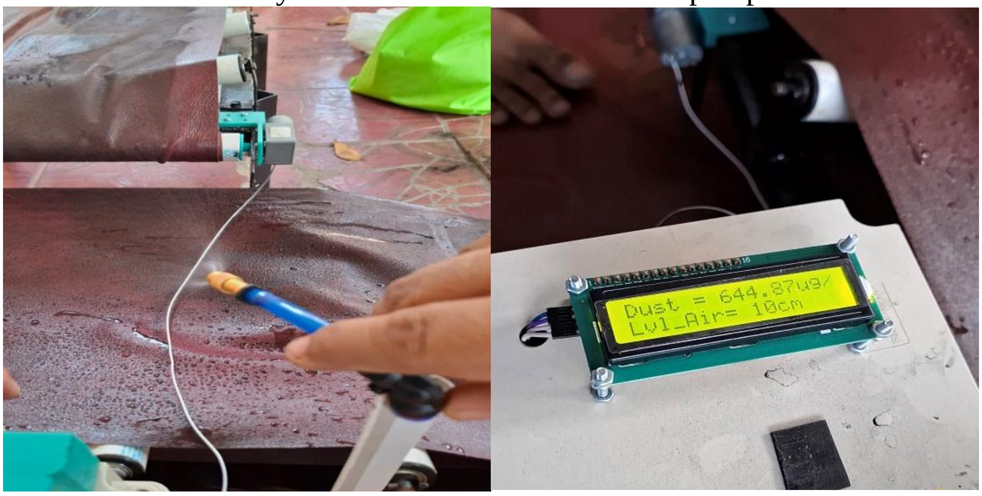

Figure 4. Testing SHARP GP2Y1010AU0F Dust Sensor

Table 4. Testing Dust Sensor

No	Minimum Particle detection value of milligrams (mg/m3	Results
1	100 - 150	Unreadable
2	150 - 200	Unreadable
3	200 - 250	Unreadable
4	250 - 300	Unreadable
5	300 >	Read

Based on the results of the test conducted on the SHARP GP2Y1010AU0F found that the sensor will give commands to the arduino nano to activate the pump if the reading value > 300 mg/m3 and vice versa if the reading value is less than 300 mg/m3 then the SHARP sensor GP2Y1010AU0F not give commands to the Arduino nano to activate the pump.

Motor Speed Testing

In the speed test, the motor functions to run the conveyor.

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Figure 5. Motor Rpm Testing

Figure 6. Motor Rpm Testing 2

Table 5. Motorcycle Testing

No	Coal load (kg)	Results (rpm)	
		Motor 1	Motor 2
1	0	215.4	85.1
2	0.1	210.2	82.0
3	0.2	205.1	79.0
4	0.3	200.0	76.1
5	0.4	195.0	73.3

From the results of this test, it can be seen that both Motor 1 and Motor 2 experienced a proportional decrease in RPM along with the increase in load. Motor 1 is able to maintain a higher rotational speed than Motor 2 at each load level.

Motor Speed Testing

In the speed test, the pump functions to suck water from the reserve tank to the main tank.

Figure 7. Pump Testing 2

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Table 6. Pump 2 Testing

No	Water Level (cm)	Volume (l)	Time (s)
1	1	0.1	6.24
2	2	0.2	12.49
3	4	0.4	24.94
4	6	0.6	37.49
5	8	0.8	49.98

From the results of pump 2 testing, it can be seen that the time required to fill water is inversely proportional to the volume. The smaller the desired water volume, the less time it takes to fill. This shows that the water filling rate is constant, so the filling time can be calculated proportionally to the desired water volume. Where the time required to reach a water height of 8 cm is 49.98 seconds. Analysis & Result Measurement.

The power supply which is the main source of voltage of this appliance is measured at the TP1 measurement point. Power supply measurements include transformers, diodes, and step downs. From the estimated results when the power supply is given a voltage of 220V, the normal estimated result is 223V with an error rate of 0.013%. Component controls and sensors such as the HC-SR04 ultrasonic sensor, SHARP GP2Y1010AU0F dust sensor, mosfet, relay, LCD, and motor are the next measurements on the Arduino NANO. The typical value obtained from the information estimation using the Arduino Nano power supply is 5.10 V. While the data sherert owned by the Arduino Nano is 5 V with an error rate of 0.02. The MOSFETs that drive the motor then have a rated average input voltage value of 5.09 V, which is still within the specified range of 3.2 to 40 V. By using a power supply, the measurement on the motor (1) that drives the conveyor (1) produces an average input voltage value of 14.96 V. This value is still within the specified limit of 12-15 V and can be used.

The equation applies to the reduction in motor (2) which has the ability to drive the conveyor (2) which gets a decent value and is still within the specified limit of 12-15 V, the normal information voltage value obtained is 14.95 V. from the test results also, it can be seen that both Motor (1) and Motor (2) experience a proportional decrease in RPM along with the addition of load. Motor (1) is able to maintain a higher rotation speed than Motor (2) at each load level, so that the coal material from the conveyor (1) will fall to the conveyor (2) at high speed as a result it is able to produce maximum dust from the impact of coal material to the conveyor (2) so that it is easy to clean. Pump (1) & pump (2) as a water suction and spraying tool where the voltage produced is good with an average voltage of both pumps being 11.11 V, with test results on pump (2) where it only takes 49.98 seconds to reach a water height of 8 cm. Then the decrease in the LCD as a display of the normal information voltage value obtained is 5.02 V. With a limit of 4.7-5.3 V, the value is quite good. Then at the decrease in the input voltage in the relay (1) the voltage value obtained when using four power supplies is 5.11 V, the value can be said to be good and can be used, this is because the difference in the value is still within the predetermined limit will be set at 5-12V. Then In the estimation of the Ultrasonic HC-SR04 sensor, the average information voltage value obtained when using a power supply is 5.09 which is a good value because the error rate is <2%, while for the Ultrasonic HC-SR04 sensor it will detect the water level in the main tank from a distance of 1 cm to 10 cm. The pump continues to run and fills water from the Reserve tank to the main tank when the water level is <8 cm and the pump will turn off when the water level is more than >8 cm.

In the estimation of the Ultrasonic HC-SR04 sensor, the average information voltage value obtained when using a power supply is 5.09 which is a good value because the error rate is <2%, while for the Ultrasonic HC-SR04 sensor it will detect the water level in the main tank from a distance of 1 cm to 10 cm. The pump continues to run and fills water from the Reserve tank to the main tank when the water level is <8 cm and the pump will turn off when the water level is more than >8 cm. The estimated input voltage of the SHARP GP2Y1010AU0F dust sensor on average when using the power supply is 5.11 V. The value obtained can be said to be good to use because

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the value is still within the limit that has not been fully determined, namely 4.5-5.5 V, while the recognized dust molecule identification value will activate the pump if the molecular recognition value is more than 300 mg/m3 or 0.3 grams of dust in every cubic meter of air. With this waterspray, it can certainly provide workers with the effectiveness of operating the waterspray which was previously done manually with a distance of > 100 meters from the office center, with this water spray can operate automatically without having to walk to the location where the waterspray is located. Then with this automatic waterspray as well, it can reduce the risk of worker accidents from the rotating conveyor, because the condition of the conveyor area full of dust can block the view, which is at risk that workers can fall into the conveyor area In addition, the health of workers is better maintained from exposure to coal dust because the dust is handled by this waterspray well. Finally, Waterspray can automatically control water usage, so it is more efficient in water use, which previously water spray continued to turn on if nothing turned off.

IV. CONCLUSION

Automatic Water Spray Prototype Tool for Coal Dust Cleaning on a Coal Conveyor that is pored with good dust and debris that has been sprayed, so that if applied, it can improve the operator's performance in turning on and off the waterspray, in addition to that it can reduce the risk of work accidents and keep workers in direct contact with dust exposure so as to maintain the health of workers properly.

Meanwhile, the sensors used function well as expected, such as the Ultrasonic HC-SR04 sensor which works when detecting a water level of <8 cm, then provides information that the water in the tank is low and will provide information to the Arduino to activate pump 2 to fill the tank with water, the SHARP GP2Y1010AU0F dust sensor also functions well for particle detection, where particles with a size of > 300 mg / m3 will be detected by the dust sensor to instruct the Arduino to activate the pump.

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