# The Effect of Pump House Layout and Compressor Tube Volume Variations on Efficiency of 2 Inch Hydraulic Ram Pump Performance

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Abstract: Water is an absolute necessity for the survival of life, because without water there will be no life in this world. The need for water is not a problem for areas that are close to water sources or are located under springs. In accordance with the laws of physics, water will naturally flow from a high place to a lower place, but in reality the land surface is not always flat, there are hilly and bumpy areas. If the area is higher than the water source, it will be difficult to get a sustainable water supply. One of the efforts to fulfill water needs in locations that are higher than the springs is by using a water pump. The types of pumps commonly used today are electric motor-powered water pumps or oil-fueled water pumps (diesel or gasoline). For urban areas, the need for fuel is not a problem. Meanwhile, in rural areas, fuel is very scarce and very expensive. The problem is the layout/position of the Input-Compressor-Waste (IKL) is still considered the same as the position of the Input-Waste-Compressor (ILK) and has no effect on the efficiency of the hydraulic ram pump performance. The purpose of this research is to design and make a hydraulic ram pump and to test those two positions (IKL and ILK) with variations in the volume of the compressor tube, so that it can be seen which position is the most ideal to produce the most optimal and efficient hydraulic ram pump performance. The methods used were a site survey, literary study, action method by designing a hydraulic ram pump installation and observing the effect of layout/position (IKL) and (ILK) with variations in the volume of compressor tube (6350 ml, 7230 ml and 8114 ml) and 3 variations of waste valve weight (130 grams, 190 grams and 357 grams) through the performance of the hydraulic ram pump. The result of this study indicated that the largest pumping discharge occurred in the compressor tube volume of 2800 ml and 5500 ml with a waste valve weight of 130 grams, 190 grams and 357 grams, which were 0.081 liters per second and 0.080 liters per second in the ILK hydraulic ram pump arrangement. The smallest average waste discharge occurred in the ILK hydraulic ram pump arrangement, which was 0.311 liters per second while in the IKL hydraulic ram pump arrangement it was 0.327 liters per second. The greatest efficiency according to D'Aubuisson and Rankine occurred in the compressor tube volume of 2800 ml, which increased from 120% and 75% in the IKL position to 127% and 81% in the ILK position.

## 1 INTRODUCTION

Water is an absolute necessity for survival because without water there will be no life in this world. Areas that are close to water sources or are located under springs, water needs are not a problem but areas that are located higher than water sources are difficult to get a continuous supply of water.

One of the efforts to fulfill water needs, especially in areas that are higher than the springs, is by using a water pump. The type of water pump that is commonly used today is a water pump powered by an electric motors or an engines water pump by using fuel which is difficult to obtain in rural areas. The solution is to use a hydraulic ram pump because the hydraulic pump works without the use of fuel or electricity.

The problem is that the placement of the pump house and compressor tube as well as the waste valve after the intake pipe, both with *Input-Compressor-Waste* (IKL) and *Input-Waste-Compressor* (ILK) arrangements are considered to have no effect on the performance of the hydraulic ram pump.

Various studies have been carried out as an effort to increase the efficiency of hydraulic ram pump performance, such as Muhamad Jafri, et al conducted a study entitled *Analisis Pompa Hidram*



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*2" dengan Sistim Kompresi Seri*, where the results showed that variations in air tube volume and pumping vertical lift height affect the efficiency of the hydraulic ram pump, the highest efficiency for series compression is 62.29%.

Eko Sulistiawan, et al, also conducted a study entitled *Pengaruh Volume Tabung Udara dan Beban Katub Limbah Terhadap Efisiensi Unjuk Kerja Pompa Hidram*. The results showed that the highest efficiency was 40.36% at valve load of 450 grams and volume of air tube 8100 ml, the lowest efficiency was 23.00% at valve load of 1220 grams and volume of air tube 5300 ml.

I Gede Bawa Susama and Rudy Susanto, conducted a research entitled *Peningkatan Kinerja Pompa Hidram (3 inch) Berdasarkan Posisi Tabung Kompresor dengan Saluran Keluar di bawah Tabung Kompresor*. The results showed that the largest output discharge occurred at a height of 4.1 m and increased from 0.112 liters per second in IKL arrangement to 0.121 liters per second or 121 ml per second in ILK arrangement. The maximum head occurred at a 4.1 meter plunge and increased from 12 meters in the IKL arrangement to 16 meters in the ILK arrangement. Meanwhile, the greatest efficiency occurred at a height of 3.1 meters and increased from 2.357% in the IKL arrangement to 2.618% in the ILK arrangement.

Research conducted by Toto Citramurti, et al., with the title *Pengaruh Beban Katub Buang di Bawah 450 gram Menggunakan Panjang Input 4 meter dan Ketinggian Output 10 meterTerhadap Kinerja Pompa Hydraulic ram* showed that the highest efficiency of the hydraulic ram pump according to D'Aubuisson is 31.48% with a waste valve weight of 50 grams and the length of the inlet pipe is 4 m.

Another research conducted previously by Rafael Mado, et al with the title *Design of a 1½" Hydraulic Ram Pump and Testing the Effect of Variation in The Launch Pipe Slope Angle Against the Performance* showed that the efficiency of the hydraulic ram pump decreases with the increasing of angle of inlet pipe, or the smaller the slope angle of the inlet pipe, the efficiency of the hydraulic ram pump increases. Based on previous research, this research determined the lowest slope angle of the inlet pipe, which is 5º so that the inlet pipe will be longer (17.24 m) with a height of 1.5 m of water fall.

Generally, research on hydraulic ram pump is carried out in a limited laboratory, so what differs from this research is the research is carried out directly at the water source, the delivery valve uses a unidirectional valve made of brass material 2 inches, the waste valve from a plastic pipe 2 inch and compares IKL with ILK on the performance of the hydraulic ram pump. Research conducted in the field aims to make it easier to implement.

The main issue raised in this research is the use of new and renewable energy in fullfil the needs of clean water for rural communities, especially those who have not been reached by electricity. The results of this study are expected to solve the problems mentioned above, so that the community can take advantage of the natural resources that are around them (river water), for the purposes of daily life such as drinking water, watering plants and feeding livestock. Thus the standard of living of the people will be better.

# 2 RESEARCH METHOD

## 2.1 Design of 2 Inch Hydraulic Ram Pump

The hydraulic ram pump is designed with an input diameter of 2" or 5.075 cm, an output diameter of 1.27 cm, a compressor tube volume (2800 ml, 5500 ml, and 8200 ml), IKL and ILK arrangement, inlet pipe tilt angle 50, water drop height 1, 5 m, lift height 5 m. The hydraulic ram pump is made using 2 inch iron pipe (T-shock), 2 inch double nipple, 2 inch elbow, ½ inch elbow, 4 inch iron pipe, 5 mm thick iron plate, 10 mm solid stainless, 40 mm ø steel axle, plastic pipe (ø 4 inch, 2 inch dan ½ inch), 50x50 iron elbow, 5 mm thick rubber, bolts and nuts. The results of the hydraulic ram pump design are as shown in Figures 1 and 2 below:

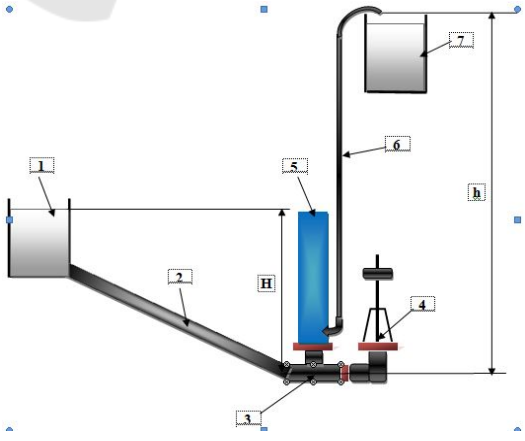



Figure 1: Hydraulic ram Pump Installation IKL Arrangement.

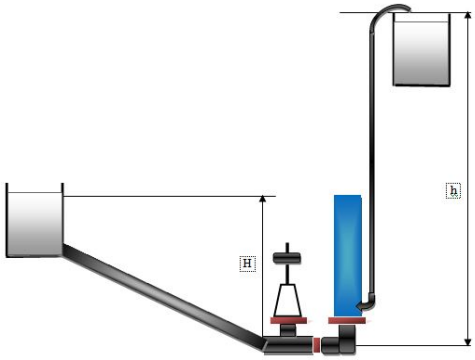
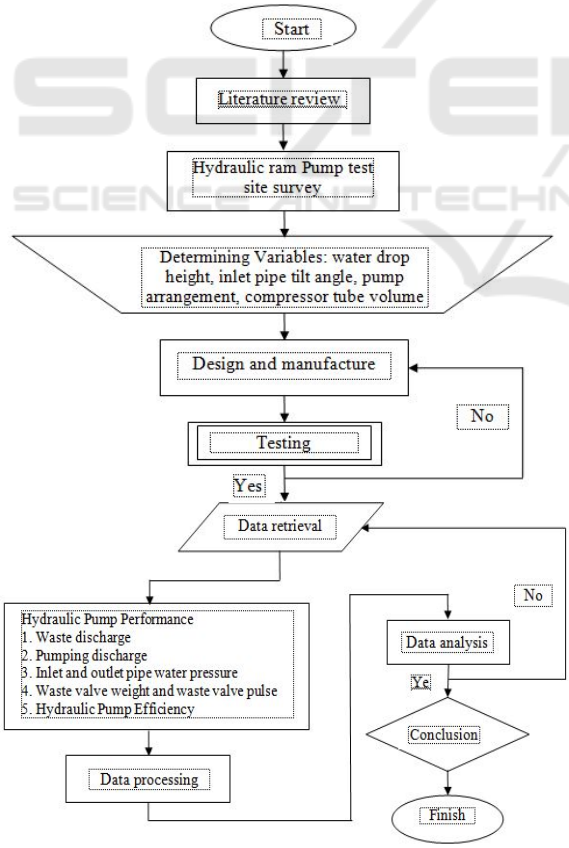



Figure 2: Hydraulic ram Pump Installation ILK Arrangement.

Captions:
1. Reservoir/water source 5. Compressor Tube
2. Inlet pipe 6. Delivery pipe
3. Pump housing 7. Reservoir tank
4. Waste valve H = Plunge height
h = Lifting height

## 2.2 Research Flowchart




## 2.3 Data Collection Method

The method used is an experimental method with 9 independent variables, namely: water fall height (H) 1.5 m, lift height (h) 5 m with a slope of 21.720 following the contour of the soil and the length of the exit pipe 13.60 m, the slope angle of the slide pipe ( 50) with a pipe length of 17.24 m, pump inlet water discharge (27-55 liters/minute), IKL position, ILK position, compressor tube volume (2800 ml, 5500 ml, 8200 ml). While the 7 dependent variables are: waste discharge (Q), inlet water pressure, outlet pressure, pumping discharge (q), waste valve weight, waste valve pulse and hydraulic ram pump efficiency (calculated using equation 1).

Testing and data collection were carried out directly at the location of the water source by conditioned the height of the waterfall (H) 1.5 m and measuring the water flow entering the pump with a result of 180 liters / minute, while the minimum water flow for the pump size 2 "is 27-55 liters / minute. The test will be carried out 9 times according to 3 variations in the volume of the compressor tube (2800 ml, 5500 ml, 8200 ml) and 3 variations in the weight of the waste valve (130 g, 190 g, 357 g) both at the IKL and ILK positions. The results were carefully recorded in the data table that has been prepared.

The hydraulic ram pump test scheme is as shown in Figure 3 below:

(a) IKL (b) ILK

Figure 3: Schematic of the hydraulic ram pump test installation.

In testing process, the researchers used several supporting equipments such as measuring cup, buckets, tapes, PVC glue, machete, shovel, roller

meter, pressure gauges, water fittings, nylon ropes, bamboo, pipe wrenches, stop watch. Data retrieval is done by reading the pressure on the pump inlet pipe, the pressure on the compressor tube and the outlet pipe, measuring the pulsation of the waste valve, measuring the waste discharge and pumping discharge.

## 2.4 Data Processing Method

The data that has been collected in tabular form is then made in graphical form to obtain the relationship between variations in the volume of the compressor tube, the weight of the waste valve and the pulse of the waste valve to the pumping discharge.

The efficiency of the hydraulic ram pump can be calculated in two ways:

According to D'Aubuisson (**Murni**, 2016)

$$\eta = \frac{q(H+h)}{(Q+q)} \quad (1)$$

According to Rankine :

$$\eta = \frac{q.h}{Q.H} \quad (2)$$

Whereas:

$\eta$ = hydraulic ram pump efficiency (%)
$q$ = result ($m^3$/det.)
$Q$ = waste ($m^3$/det.)
$h$ = head out (m)
$H$ = head in (m)

# 3 RESULTS AND DISCUSSION

The test result data can be seen in Tables 1 and 2 below:

Table 1: IKL Position.

| Comp. Tube Vol. (ml) | Waste discharge Q (lt/sec) | Pumping discharge q (lt/sec) | Pump Inlet Pressure (bar) | Comp. Tube Pressure (bar) | Press. out (bar) | Valve weight (gram) | Waste valve pulse ( x /menit) |
|---|---|---|---|---|---|---|---|
| 2800 | 1 0,263 | 0,081 | 0,4 | 0,4 | 0,4 | 130 | 51 |
| | 2 0,294 | 0,080 | 0,4 | 0,3 | 0,4 | 190 | 48 |
| | 3 0,400 | 0,055 | 0,4 | 0,4 | 0,4 | 357 | 35 |
| 5500 | 1 0,286 | 0,081 | 0,4 | 0,4 | 0,4 | 130 | 51 |
| | 2 0,313 | 0,078 | 0,4 | 0,4 | 0,4 | 190 | 47 |
| | 3 0,417 | 0,060 | 0,4 | 0,4 | 0,4 | 357 | 38 |
| 8200 | 1 0,286 | 0,065 | 0,4 | 0,3 | 0,3 | 130 | 52 |
| | 2 0,313 | 0,050 | 0,4 | 0,3 | 0,3 | 190 | 48 |
| | 3 0,370 | 0,030 | 0,4 | 0,3 | 0,3 | 357 | 35 |

Table 2: ILK Position.

| Comp. Tube Vol. (ml) | Waste discharge Q (lt/sec) | Pumping discharge q (lt/sec) | Pump Inlet Pressure (bar) | Comp. Tube Pressure (bar) | Press. out (bar) | Valve weight (gram) | Waste valve pulse ( x /menit) |
|---|---|---|---|---|---|---|---|
| 2800 | 1 0,263 | 0,081 | 0,4 | 0,4 | 0,4 | 130 | 52 |
| | 2 0,294 | 0,080 | 0,4 | 0,4 | 0,4 | 190 | 48 |
| | 3 0,357 | 0,062 | 0,4 | 0,4 | 0,4 | 357 | 37 |
| 5500 | 1 0,270 | 0,084 | 0,4 | 0,3 | 0,3 | 130 | 52 |
| | 2 0,313 | 0,078 | 0,4 | 0,3 | 0,3 | 190 | 48 |
| | 3 0,357 | 0,060 | 0,4 | 0,3 | 0,3 | 357 | 37 |
| 8200 | 1 0,280 | 0,078 | 0,4 | 0,4 | 0,4 | 130 | 52 |
| | 2 0,294 | 0,081 | 0,4 | 0,4 | 0,4 | 190 | 48 |
| | 3 0,370 | 0,062 | 0,4 | 0,4 | 0,4 | 357 | 37 |

The results of the hydraulic ram pump test on the layout of the pump house, IKL and ILK with 3 variations in the volume of the compressor tube and 3 variations in the weight of the waste valve, as shown in tables 1 and 2 above. The relationship between the volume of the compressor tube and the pumping discharge on the layout of the pump housing is presented in Figure 4. The position of the compressor tube which is placed after the input and the waste valve (ILK), gives a higher pumping discharge result compared to the position of the compressor tube which is placed between the input and the waste valve (IKL). The volume of the compressor tube also affects the pumping discharge. The larger the volume of the compressor tube the pumping discharge decreases, because the waste discharge is getting bigger. This is contrary to the results of research by Eko Sulistiawan, et al. [2] which showed that the larger the volume of the compressor tube, the higher the pumping discharge and the higher the efficiency.

Comparison of the pumping discharge value with the volume of the compressor tube on the layout of the pump house/compressor tube as shown in Figure 4.

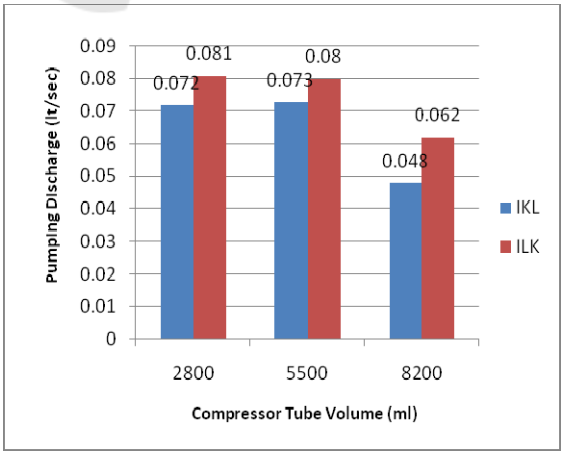



Figure 4: Comparison of the pumping discharge value with the volume of the compressor tube on the layout of the pump house/compressor tube.

The effect of compressor tube volume on the waste discharge and the location of the pump house/compressor tube is presented in Figure 5. The larger the volume of the compressor tube, the higher the waste discharge and the lower the pumping discharge. When viewed from the position of the compressor tube which is placed after the input and the waste valve (ILK), the result of the waste discharge is smaller than the position of the compressor tube which is placed between the input and the waste valve (IKL).

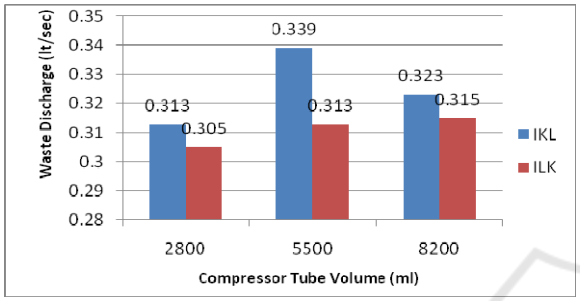



Figure 5: Comparison of the value of the waste discharge with the volume of the compressor tube on the layout of the pump house/compressor tube.

The value of waste valve weight on pumping discharge and waste discharge at the hydraulic ram pump with the IKL and ILK arrangement is shown in Figures 6 and 7. The position of the compressor tube which is placed after the input and the waste valve (ILK) shows the best pumping discharge results and produces less waste compared to the position of the compressor tube which is placed between the input and exhaust valves (IKL).

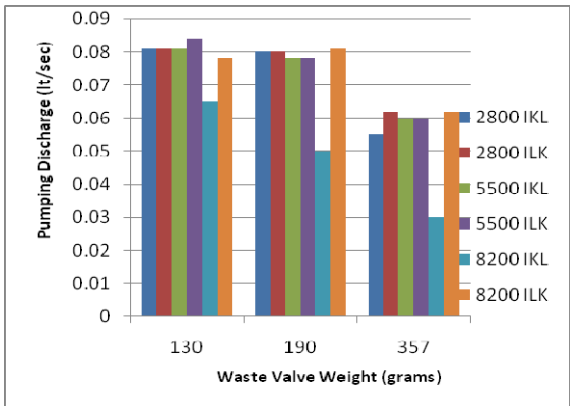



Figure 6: Comparison of the pumping discharge value with the weight of the waste valve on the layout of the pump house/compressor tube.

In general, the waste valve weight 130 grams (the smallest) produce most large pumping discharge (0.081 liters/sec). This is in line with the results of research by Toto Citramurti, et al., which showed that the weight of the 50 gram waste valve (the smallest) produced the largest pumping discharge and the highest efficiency, which was 31.48% (D'Aubuisson efficiency).

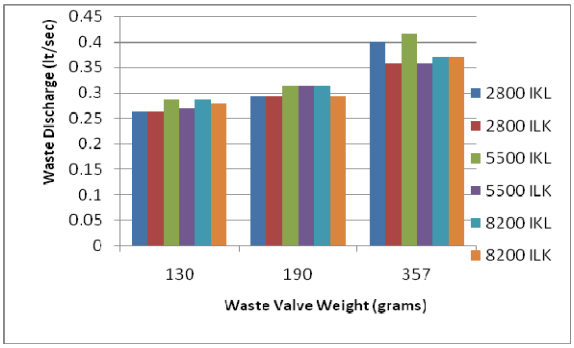



Figure 7: Comparison of the value of the waste discharge with the weight of the waste valve on the layout of the pump house/compressor tube.

The relationship of the waste valve pulse to the pumping discharge at the hydraulic ram pump with the composition of IKL and ILK is shown in Tables 1 and 2. The higher the number of pulses, the higher the pumping discharge.

The efficiency of the hydraulic ram pump as a comparison of the pumping discharge with the inlet and effluent discharge as well as the comparison of the volume of the compressor tube and the pumping discharge for both the IKL and ILK arrangements are presented in Figures 8 and 9.

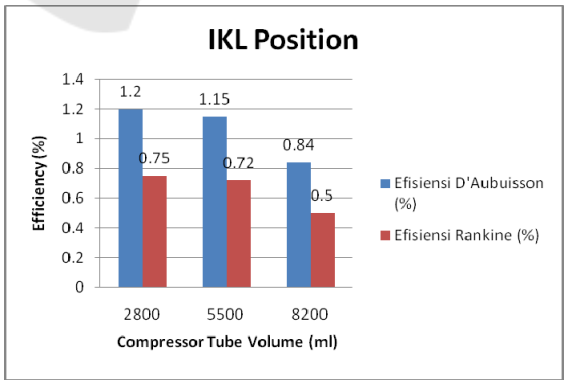



Figure 8: Graph of the relationship between the volume of the compressor tube on the efficiency of D'Aubuisson and Rankine at the IKL position

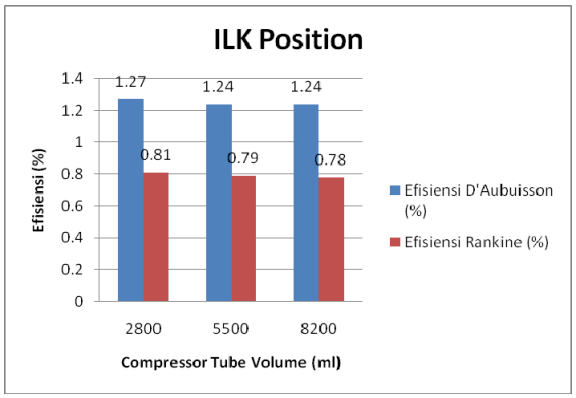



Figure 9: Graph of the relationship between the volume of the compressor tube on the efficiency of D'Aubuisson and Rankine at the ILK position.

In general, the highest efficiency values according to D'Aubuisson and Rankine were obtained in the composition of the ILK hydraulic ram pump and the three variations in the volume of the compressor tube (2800 ml, 5500 ml and 8200 ml), they were 127% and 81% at the compressor tube volume of 2800 ml, 124% and 79 % on the compressor tube volume of 5500 ml, 124% and 78% on the compressor tube volume of 8200 ml. The highest efficiency in the IKL hydraulic ram pump arrangement was only seen in the compressor tube volume of 2800 ml, they were 120% and 75%.

This is in line with the research results of I Gede Bawa Susana (2016), which showed that the highest efficiency was also obtained from the ILK hydraulic ram pump arrangement which increased from 2.357% in the (IKL) arrangement to 2.618% in the ILK arrangement.

The efficiency value obtained according to D'Aubuisson looks greater than 100%, both in the IKL and ILK hydraulic ram pump arrangements. This is due to the large amount of water entering the pump, which is 180 liters/minute (measurement results before testing). In addition, if the angle of inclination of the inlet pipe is smaller (50) and longer, the suction power and thrust and efficiency of the hydraulic ram pump will be higher. Research conducted by R. Sutanto (2019), also shows that the smaller the plunge angle used, the greater the output discharge produced; the greater the plunge angle, the smaller the suction and thrust of the hydraulic ram pump.

# 4 CONCLUSION

Based on the results of testing and data processing, it can be concluded as follows:

a. The largest pumping discharge occurred in the compressor tube volume of 2800 ml and 5500 ml with a waste valve weight of 130 grams and 190 grams, namely 0.081 liters per second and 0.080 liters per second in the ILK hydraulic ram pump arrangement.
b. The smallest average waste discharge occurs in the ILK hydraulic ram pump arrangement, which is 0.311 liters per second while in the IKL arrangement it is 0.327 liters per second.
c. The greatest efficiency according to D'Aubuisson and Rankine occurred in the compressor tube volume of 2800 ml. Which increased from 120% and 75% in the IKL position to 127% and 81% in the ILK position.

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