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Air Compressor Assembly, Installation and Evaluation on Agricultural Tractor

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Abstract: This study was carried out to develop an air compressor and container to be installed at the rear side of a tractor and operated from the power take-off shaft. Three iron frames and flexible hoses were used to link the air compressor and air container. The compressor was tested with three sizes of tires (254,406 and 965 mm) during three times per day (10.00 am, 12.00 and 3.00 pm). Tire air filling with the assembled compressor was compared with manual and electrical workshop compressing mechanisms. The results showed that the difference in average fuel consumption between tractor engine operated alone and the assembled compressor was only 117 ml/hr. There was no significant difference in fuel consumption when the compressor was operated at any time during the day. The time taken for air filling of the three sizes of tires (254, 406 and 965 mm) was 0.73, 2.0 and 5.3 hours for manual, 4.0, 4.01 and 4.1 hours for electrical workshop and 0.01, 0.05 and 0.12 hours for the assembled compressor, respectively. The difference in average total time taken for tire air filling between the three air compressing mechanisms was highly significant (P= 0.01). The average cost of tire repairing and air filling by the assembled compressor was 76% lower than the cost at the nearest electrical workshop.

Key words: Air compressor; assembly; instalation; tires; fuelconsumption

INTRODUCTION

Power source in agriculture is of great importance in determining the level of agricultural mechanization and production. In the farm there are three sources of power for carrying out operations, the human power (about 0.07 – 0.1 kW) for limited amount of work which seldom exceeds subsistence level farming, animal power which is mainly used for draft work or transport of goods and people and mechanical power (Grossley and Kilgour 1983). Mechanical power through tractors will continue to be an absolute necessity for agricultural production (Hunt 1983). The tractor engine is the prime mover for mobile or stationary farm machinery through direct coupling to the power take off shaft (PTO) or via belt pulley connection (Liljedahl *et al*. 1979). Transmitting of power from its source to the points of use is one of the important variables to the farm equipment designers. Krutz *et al*. (1984) stated that selection of proper power transmission systems on mobile agricultural machinery must take into account the customer requirements, cost constraints, field usage, operator safety and reliability.

The primary function of the transmission member is to affect the change in speed between the two shafts as well as in linking them. It is generally required that the transmission system should have adequate reliability, service life, simple construction and little resistance to motion. Moreover, it should produce little noise, offers substantial resistance to vibration and is easy to control. There are many power transmission systems used, but the most extensively used in agricultural machinery applications are V-belts (Kepner *et al*. 1982; Krutz *et al.* 1984). Shigley and Mitchell (1983) stated that the efficiency of V-belts ranges from 70% to 95 %. Gears and chains are also widely used for power transmission as linear or rotary motion (Hunt and Garver 1973; Spotts 1997; Crouse 1980). Other power transmission systems include bearings, shafts, and universal joints. Rotating shafts are of various lengths, diameters and types and they are subject to bending, tension, compression, or torsion loads, acting singly or in combination with one another (Shigley and Mitchell.1983; Hunt and Garver 1973).

During field operations, some parts of the machine may need repairing or maintenance. Some repairing maybe carried out in the field, and this will reduce time loss, but others may need to be taken for repairing in well-established workshops within the field or far away from the field. This means increase in unproductive time and extra costs in field operations. Repairing and refilling tires with air in tractors and other field machinery is a problem usually faced in the field and takes a lot of time to overcome, especially if the workshop is away from the field as in rural areas of developing countries.

The main objectives of the present research work were (i) to assemble and install an air compressor and an air container at the rear of agricultural tractor, (ii) to operate the compressor from the tractor power take off (PTO) shaft, and (iii) to test and evaluate the air compressor in the field for fuel consumption, time taken for air filling of tires and cost of repairing.

MATERIALS AND METHODS

The study was carried out in Darmally village, 325 km north of Khartoum town, Sudan. A Massey Ferguson tractor (FM 290) of maximum PTO power (74.8 hp) was used as a source of power. An air compressor engine operated at 2 hp was selected to generate suitable amount of air at reasonable pressure. The technical specifications of the compressor are given in Table 1. A cylindrical air container with suitable capacity that complies with the compressor was designed and assembled from strong local steel.

A frame of three parts (A, B and C), made of steel, was constructed for locating the compressor and air container. All technical designing criteria were considered when fixing the frame with fixing bolts. Frame A was designed for fixing the air container and the compressor to the tractor body. Assembly of frames B and C was used as adjustable base to make tension for the compressor belts (Fig.1). Other materials and tools used to carry out the installation were iron sheets, iron angles, iron flanges, fixing bolts, nuts, shims, flexible hoses and pressure gauges.

Table 1. Technical specifications of the compressor

Item	Description
Model No.	R-2y-0067
H.P.	2 hp
RPM	1000 rpm
Air filling	60 lb/m
Weight	5 kg
Length	60.96 cm
Diameter	19.1 cm
Full capacity	60 lb/m
Material (frame)	Steel
Steel thickness	0.64 cm

The compressor and air container were assembled and installed as follows: (i) the air compressor and the container were assembled (Brown 1997), (ii) the steel iron frame was fixed at the rear of the tractor for locating the compressor and air container, and (iii) transmission of power from tractor PTO shaft to compressor engine, through suitable pulleys and belts, was carried out (Dahab *et al*. 2007).

Some calculations were carried out for determination of the optimum speed (rpm) and required power from the tractor PTO shaft for operating the compressor. Tractor PTO shaft speed was approximately 500 rpm.

(a) **Power calculation:** The following formula of Shigley and Mitchell (1983) was used to calculate the power of the air compressor: Design power = Service factor (1.3) × Compressor transmitted power.(1)

$$\text{Design power} = 1.3 \times 2.0 = 2.6 \text{ hp}$$

(b) Pulley selection: The drive and driven pulleys were selected as follows (Krutz *et al*. 1984):

$$\frac{PDr}{PDn} = \frac{(rpm)n}{(rpm)r} \qquad \ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

where:

PDr = pitch diameter for the driver pulley (inch)

PDn = pitch diameter for the driven pulley (inch), proposed 5 inches (Fig. 2)

(rpm)r = driver pulley speed (rpm), 500 rpm available from the tractor PTO shaft

(rpm)n = driven pulley speed (rpm), which was used as compressor rpm (1000)

$$PDr = \frac{1000 \times 5}{500} = 10 \text{ inch (Fig 3)}$$

(c) V-belts selection: Determination of the required V-belts specifications was made in accordance with Shigley and Mitchell (1983):

(i) The centre distance between the drive and driven pulleys was 40 inches and this was found in line with the following equation:

$$C < 3\,(d + D) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where:

C = center distance

D = large pulley diameter

d = small pulley diameter

Therefore, from Table 2, a V- belt section A- was selected.

(ii) The pitch length of the belt was calculated as follows:

$$Lp = 2C + 1.57(D+d) + \frac{(D-d)}{4C} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

where:

Lp = pitch length of belt

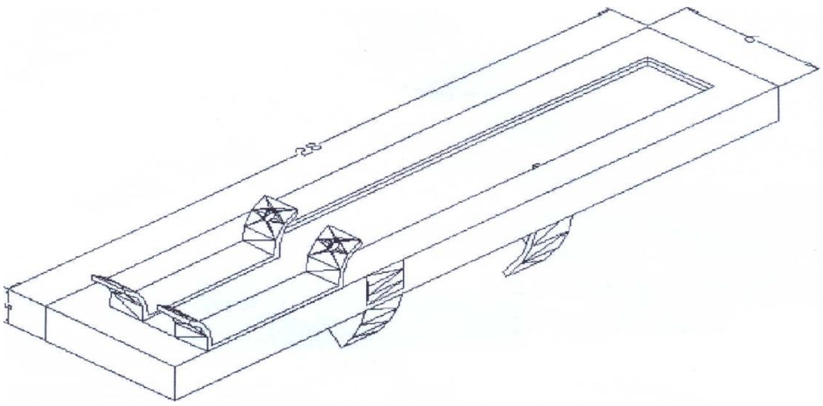
C = centre distance

D = pitch diameter large pulley

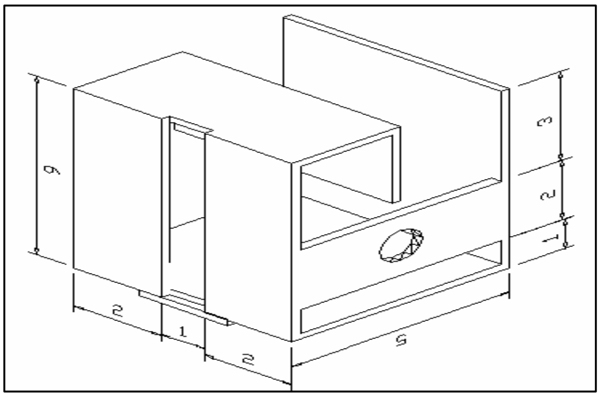
d = pitch diameter small pulley

Lp = (2 × 40) + (1.57 × 15) + (25/4×40) = <u>103.7063</u> inches

Frame A



Frame B



Frame C

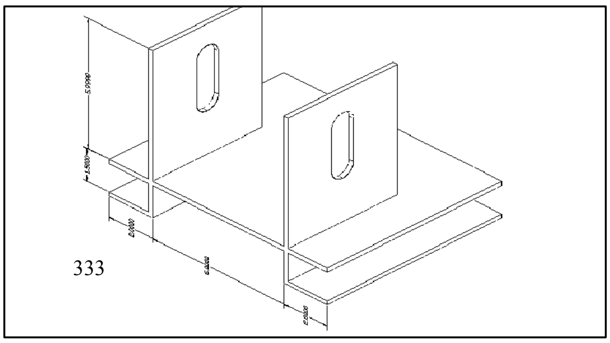


Fig. 1. Frames A, B and C for air compressor fixing

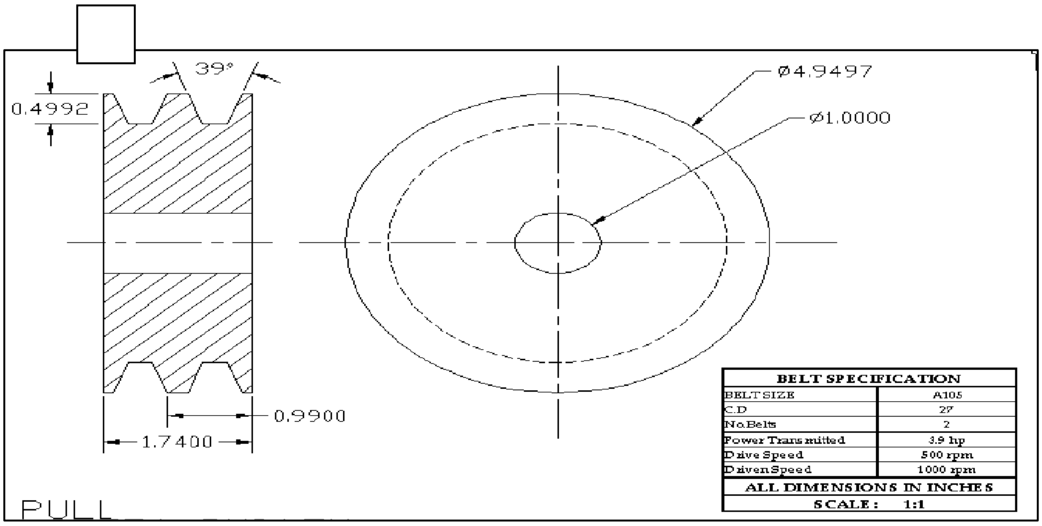


Fig.2. Compressor engine pulley driven

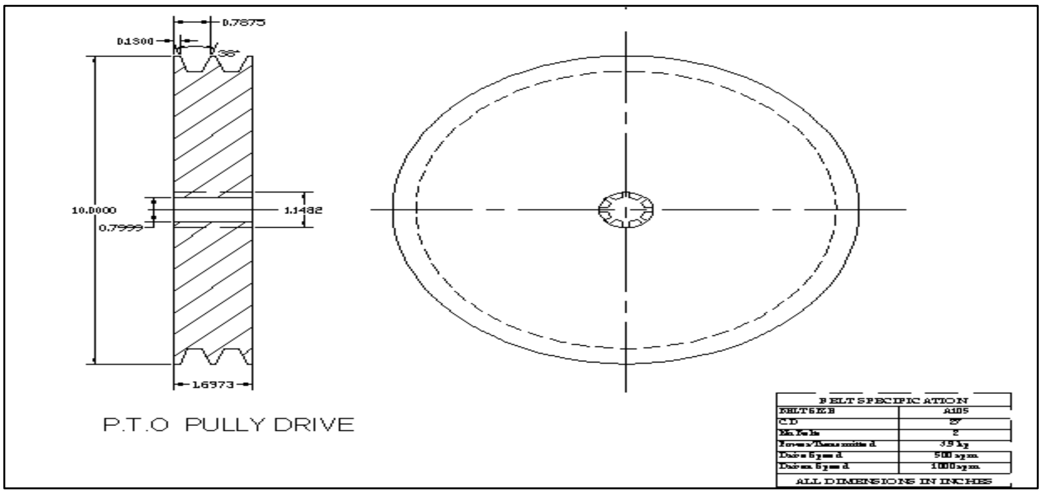


Fig. 3. Tractor P.T.O lley driver

(iii) The conversion quantities shown in Table 3 are used to calculate the inside circumference and to get the pitch length.

$$\text{Pitch length} = Lp - 1.3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

$$= 103.7063 - 1.3 = \underline{102.41} \text{ inches}$$

Table 2. Heavy - duty conversion V - belt section

Belt designation	Power range per belt hp.	Typical standard pulley sizes (inch)
series		
A	0.2 – 5.0	2.6 up by 0.2 increments
B	0.7 – 10.0	4.6 up by 0.2 increments
C	10.0 – 21.0	7.0 up by 0.5 increments

Table 3. Length conversion quantities for heavy-duty conventional series of belts

Belt designation	Size range (Inch)	Conversion quantity (ratio)
A	26-128	1.3
B	35-240	1.8
B	240 up	2.1
C	51-210	2.9
C	210up	3.8
D	120-210	3.3
D	210 up	4.1
E	180-240	4.5
E	240- up	5.5

Table 4. Standard length (Ls) and length-correction factors (K_2) for heavy-duty conventional V-belts

	K_2		
Ls	A	B	C
60	0.97	0.91	0.83
68	1.00	0.94	0.85
75	1.02	0.96	0.87
80	1.04	-	-
81	-	0.98	0.89
85	1.05	0.99	0.90
90	1.07	1.00	0.91
96	1.08		0.92
97	-	1.02	-
105	1.10	1.03	0.94
112	1.12	1.05	0.95
120	1.13	1.06	0.96
128	1.15	1.08	0.98

A, B and C = V-belt series

The nearest standard size of V-belt from Table 4 is A-105 V-belt.

(iv) The angle of contact of the small pulley (Øs) was as follows:

$$Øs = \pi - 2\mathrm{Sin}^{-1} \frac{(D - d)}{2C} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \ldots.(6)$$

$$Øs = \pi - 2\sin^{-1} \frac{(10 - 5)}{2 \times 40} = 173°$$

(v) The rated horsepower (Hr) was calculated as follows:

$$Hr = [(C_1 - \frac{C_2}{D} - C_3(rd)^2 - C_4 \log(rd)](rd) + C_2(1 - 1/ka) \quad ....(7)$$

where:

r = rpm of high-speed pulley, divided by 1000
Ka = speed ratio factor (Table 5)
d = pitch diameter of small pulley
C_1, C_2, C_3, C_4 = constants (Table 6)

$$= \{0.8542-(1.342/5)- 2.436(10)^{-4}\times 25 - 0.1703\times 0.7\}5 + 1.342(1-(1/1.1106)) = 1.43 \text{ hp}$$

$$Hr = 1.43 \text{ hp}$$

Table 5. Speed-ratio factors (Ka) for use in the power-rating equation

D/d range	Ka
1.00 to 1.01	1.0000
1.02 to 1.04	1.0112
1.05 to 1.07	1.0226
1.08 to 1.10	1.0344
1.11 to 1.14	1.0463
1.15 to 1.20	1.0586
1.21 to 1.27	1.0711
1.28 to 1.39	1.0840
1.40 to 1.64	1.0972
1.64-up	1.1106

D/d = Ratio of large pulley pitch diameter to small pulley pitch diameter

Table 6. Constants (C_1, C_2, C_3 and C_4) for rated power calculation

Belt section	C_1	C_2	C_3	C_4
A	0.854	1.34	$2.436(10)^{-4}$	0.170
B	1.506	3.520	$4.193(10)^{-4}$	0.293
C	2.786	9.788	$7.460(10)^{-4}$	0.521
D	5.922	34.72	$1.522(10)^{-4}$	1.064
E	8.642	66.32	$2.192(10)^{-4}$	1.532

(vi) The rated horsepower was corrected according to the contact angle by the following equation:

$$Hp = k_1 k_2 Hr \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

where:

Hr = corrected power rating

K_1 = correction factor of angle of contact (Fig 4)

K_2 = correction factor for length of belt (Table 4)

Hp = rated horse power.

$$Hp = 1.1 \times 0.97 \times 1.43 = 1.53 \text{ hp}$$

Since the assembled horsepower of the compressor is 2.6 hp and the calculated is 1.53 hp, the number of belts = 2.6/1.53 = 1.7 (≈ 2 belts). Therefore, two V-belts of A-105 are used between the drive and driven pulleys.

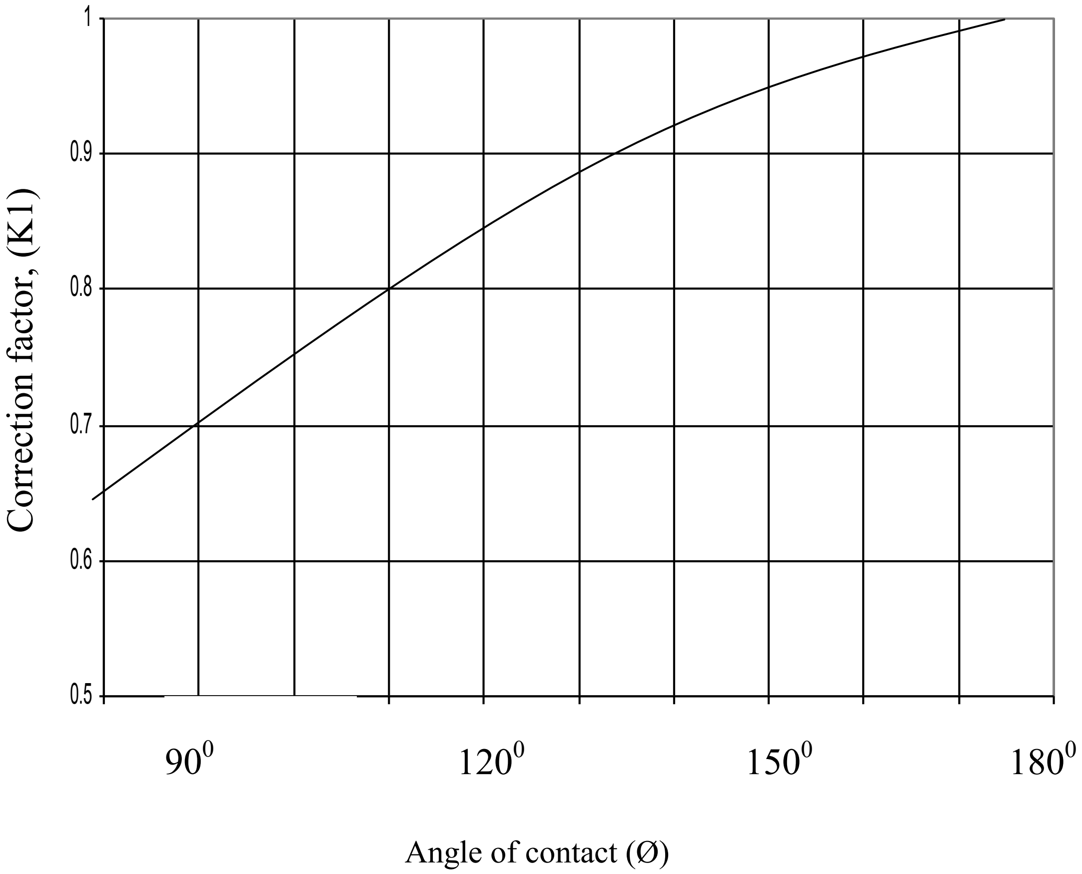


Fig. 4. Correction factor (K_1) for angle of contact Evaluation of an assembled compressor

Three tires of different sizes 254, 406 and 965 mm were used for compressor testing and were compared with manual and electrical air filling. Air compressor was evaluated and tested for fuel consumption, time taken for tires air filling and cost of repairing. The average fuel consumption was measured during three time periods a day, morning (10.00 am), mid-day (12.00) and afternoon (3.00 pm), for the tractor engine operated alone and with the assembled compressor.

RESULTS AND DISCUSSION

Compressor assembly

The compressor was assembled to generate air for filling of tires in the farm, to minimize waste of time, reduce cost of repairing and raise the rate of work for tractors and other field machineries. The materials were collected from the local market and assembled by local mechanics and labourers, therefore, it was not expensive. All components of the installed air compressor are shown in Plate 1.

Compressor evaluation

1-Fuel consumption: The results showed that the average fuel consumption for tractor engine operated with compressor at 10.00, 12.00 and 15.00 hr was 4360 ml/hr, while the tractor engine operated alone was 4243 ml/hr. Therefore, fuel consumption was increased by 3% due to operation of the compressor and this could be due to effect of load and temperature. No significant difference in fuel consumption was obtained when operating the air compressor with the tractor engine at any time period during the day.

2.Time required for tire air filling: The results revealed that for the 254 mm tire size, the total time taken for complete air filling was 0.01, 0.73 and 4.0 hours when using the assembled, manual and electrical air filling, respectively. For the tire sizes of 406 mm and 965 mm, the time taken was 2.01 and 5.3 hours for manual, 4.01 and 4.1 hours for electrical and 0.05 and 0.12 hours for the assembled and tractor operated compressors, respectively. As the tire size increased, the time required for filling was increased. The shortest time required for air filling (0.01hours) was recorded for the assembled compressor with a tire size of 254 mm, while the longest filling time was by the manual method for 965 mm tire size (5.3hours). The time taken for air filling of 254 mm tire was reduced more than 400 times when using the assembled compressor compared to the electrically driven workshop compressor. The filling time of tires in the workshop was longer than the assembled compressor, mainly because of the distance between the field and workshop (approximately 13 km). Therefore taking the tire for repairing in the workshop and coming back will take long time. The assembled compressor reduced the average total time of tire air filling by 98.5%. The difference between the two means, workshop and assembled compressors for tire filling time was highly significant (P = 0.01).

3. Cost: The cost of assembling and installing the compressor with its accessories was approximately 660 SDG (1$ = 2.2 SDG) (Table 7). The cost of renting a workshop without equipment for air filling and tire repairing may reach 200 – 250 SDG/ month. The running cost for tire air filling and repairing by the assembled compressor was 5.4 SDG, while using the workshop for tire air filling and repairing costed 22.5 SDG. Therefore, using the assembled compressor reduced the running cost of tire repairing and air filling by 4.2 times compared to the workshop.

In conclusion, the developed compressor is dynamic and available with the tractor at any time and place and, therefore, is very effective and useful in saving time, increasing the efficiency of machinery work and reducing the time and cost of production.

Plate 1. Parts of the designed air compressor installed on the rear of tractor

Table 7. Cost of air compressor and modified design parts

Item	Cost (SDG)
Compressor	250
Air container	200
Fasteners, shim, angles.. etc.	50
Workshop and labour	60
Pulleys corner	100
Total	660

1US$ = 2.2 SDG

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تجميع و تركيب و تقييم ضاغطة هواء على الجرار الزراعى

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موجز البحث: اجريت هذه الدراسة لتجميع ضاغطة وخزان هواء وتركيبهما فى مؤخرة الجرار وتشغيلهما من عمود الادارة الخلفى. استخدمت ثلاثة اطارات حديد و توصيلات مرنة لتثبيت وشبك الضاغطة و خزان الهواء. اختبرت الضاغطة بثلاثة احجام من اللساتك (254 ملم، 406 ملم ، 965 ملم) فى ثلاث فترات خلال اليوم (10 صباحا ، 12 منتصف النهار ، الثالثة ظهرا). قورن ملء اللستك بالهواء بالضاغطة المجمعة مع الملء بالضاغطة اليدوية والكهربائية فى الورشة. أوضحت النتائج ان الفرق فى متوسط استهلاك الوقود بين محرك الجرار بمفرده ومع لهواء 117 مللبتر/ساعة. لم يلاحظ اختلاف معنوى فى استهلاك الوقود عند تشغيل الضاغطة فى اى وقت خلال اليوم. الوقت المستهلك لملء احجام اللساتك الثلاثة (254 ، 406 ،965 ملم) كان 0.73 و 2.0 و 5.3 ساعة للضاغطة اليدوية ، 4.0 و4.01 و 4.1 ساعة للضاغطة الكهربائية ، 0.01 و 0.05 و 0.12 ساعة للضاغطة المجمعة. كان الإختلاف فى الوقت الكلى المستغل لملء الهواء بين الطرق الثلاث عالي المعنوية (مستوى 1%)، وكان متوسط التكلفة لإصلاح وملء اللستك بالهواء بالضاغطة المجمعة اقل بنحو 76% من التكلفة فى اقرب ورشة كهربائية.