DESIGN AND FABRICATION OF KNAPSACK SPRAYER

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JANUARY, 2001

DEDICATION

This project is dedicated to God Almighty and to my beloved sister Mrs Mary Mokwunye.

ACKNOWLEDGEMENT

I am grateful to God for his mercy towards my life throughout the period of my studies. My gratitude to Dr M. G Yisa, the head of Department of Agricultural Engineering, Federal University of Technology, Minna.

My thanks goes to Mr and Mrs Victor Mokwunye, (whom have been my parent and guardian) for their moral and financial support. I also express my thanks to the following people; all the staff in the Department of Agricultural Engineering, Federal University of Technology, Minna, Mr James Musa, Mr Joy Simeon, Mr Akin Oni, Bro Gbenga Awotunde, whose advice, encouragement and contribution led to the success of this project.

NOTATIONS

1. σ_r ------------------------------------- radial stress [N/m^3]

2. σ_t ------------------------------------- tangential stress[N/m^3]

3. σ_z ------------------------------------- axial stress[N/m^3]

4. σ_y. ------------------------------------- yield stress [N/m^3]

5. M.A ------------------------------------- mechanical advantage.

6. f ------------------------------------- friction factor

7. h_f ------------------------------------- head loss

8. ρ ------------------------------------- density of water (fluid) [kg/m^3]

9. k ------------------------------------- loss due to conveyance coefficient.

10. t_c ------------------------------------- thickness of cylinder (mm)

11. v_t ------------------------------------- volume of tank (m^3)

12. r_1, r_2 ------------------------------------- radius of the cylinder (m)

13. t_t ------------------------------------- tank thickness (mm)

CHAPTER ONE

1.0 INTRODUCTION

Once a seed has been sown and it germinates, there is no guarantee that it will become a mature plant, fruit, be harvested and the crop stored. There is danger that the plant may be lost at several stages in its growth as a result of damage by weed, disease, and insect .e. t. c. Of all these dangers, the menace of weed is most predominant, such that weed competition in the initial stage of crop growth can be so severe that plants remain stunted and final yield are a mere fraction of the true potential. Fortunately, many of these dangers are mow identifiable and control measures now made available, such that weed free condition are now possible with the application of these control measures.

Control techniques (measures): - Unwanted plant (weed) can be eliminated by

- Cultural method (techniques) which involves burning, hand weeding, tillage e. t. c.
- Biological technique :- It involves suppression of weed by the action of one or more organisms
- Chemical control: - It is the application of chemical in liquid form. When the chemical is to be applied in a liquid form, water is commonly used as the carrier and such a machine is called a sprayer.

A manually operated sprayer, which can be mounted on the back of and operator for spraying, is known as **knapsack sprayer**.

Knapsack sprayer can be used to apply pre- and post emergency herbicide.

CHAPTER TWO

2.0 LITERATURE REVIEW

The search for a free weed condition has led to more and more research in the area of spraying equipment. Such quest favours the technological advancement in the building of an improved, efficient and durable spraying machine.

The knowledge that different crops will require different application rates, dosage differences at certain periods of their growth has led to the building of different spraying machines.

Babatunde (1986) constructed hand carried, **battery operated spinning- disc sprayer**. This lightweight sprayer has a plastic spray head with small DC motor, which drives a rotating disc, a liquid reservoir, a handle and a power supply unit. The main use of this sprayer has been on tropical crops e.g. cotton and only a small area could be sprayed per day. This is caused by decreased in battery voltage as power is been used which in turn affect the uniformity of droplet distribution.

In 1987 the International Institute for Tropical Agriculture (I I T A), Ibadan carried out a research towards building a conventional sprayer and was able to come out with a sprayer called **Dribble Bar**. This type of sprayer has been explored to reduce herbicide drift. Liquid was fed at low pressure or by gravity through small holes and uniformity of spray could not be achieved. This led to a low patronage by farmers of this type of sprayer.

Allman and Company Limited (1975) built **compression sprayer**, in which a small tank usually made of plastic and 0.5-3 litres capacity is pressurised by a plunger-type pump to a pressure of up to 5 bars. It uses a cone nozzle, the pattern of which can sometimes be adjusted. At a recommended height of 1m above the ground, it sprays an area of $1.20m^2$ on the ground per discharge.

Tractor-powered sprayers: - The majority of sprayers in use in large farms are mounted on the tractor three- point linkage (cooper-pegler l.t.d. 1977) but this imposes a limit on the tank capacity. The pump is usually mounted on the power take-off of the tractor and connected to the spraying unit by suction and delivery hoses. These sprayers range from 200-1000 litre in tank capacity and 6-18m in boom width.

Variation in spray deposit is liable to increase with wide booms, due to greater movement of the end of the boom relative to the ground unless the land is very even. The efficiency of spray was noticed to be very high since large area of land was sprayed at a constant pressure and nozzle of the same size with a fixed height above the ground.

Aircraft sprays: - there are certain statutory requirements laid down for aerial spraying from civil Aviation Authority (CAA) Florida 1983.

Aircraft application of herbicides may be done with helicopter or with fixed-wing aeroplanes. In aircraft sprays, spraying is done very rapidly and large area is always covered. Ground condition and terrain do not affect aircraft spray, though drift hazard is common. The risk of crop injury to the multiple- cropping small holding s that do the landscape in the vicinity of corporate farms should be carefully considered before air craft spraying in a given farm is undertaken.

Small power sprayers: - there are many uses for small power sprayers, which are available in many farms. They are used in home gardens, in parks, on small farms and in experimental work.

A special type of small power sprayer is the **logarithmic dosage sprayer** used in experiments. The idea of a logarithmic delivery of a spray solution was introduced by Pfeiffer et al in 1955. This was a sprayer large enough to handle an 8-ft boom, and it was mounted on a land rover for field experimentation. A number of these were manufactured by Fisons pest control limited of Felixstowe, Suffolk, England.

Soon after the initial appearance of the logarithmic sprayer a number of smaller models were constructed, varying from wheel-mounted rings for field plot work to track-mounted models for use in small field and green house experimentation.

The logarithmic dosage sprayer has distinct advantage in field testing of herbicides. It delivers the chemical at a logarithmically decreasing rate that is if one start with a one-percent solution, after a certain number of feet the concentration will be ½ percent. After the same number of feet, ¼ percent, and so on until a dilution is reached that is no longer useful. The advantage of this sprayer is that on single specie one can readily ascertain the minimum lethal dose of a chemical, the maximum tolerated dose, and the maximum dose that produces no symptoms.

The design and construction of a knapsack sprayer is aimed at building a sprayer with external pumping unit which could generate high enough pressure to maintain constant evenly spray of the herbicide.

It became necessary to fabricate this machine because the pumping unit of manually operated knapsack sprayers are all built inside (internally) the tank and maintenance and repair of this machine becomes a problem.

Since this machine is to be carried on the back, light materials were used in its construction to eliminate weight problem experienced in most of the previous existing sprayer in use there by reducing fatigue.

uniformity of application, rate of application, and spray drift as influenced by droplet size are all largely determine by nozzle design and conditions of their operation. The nozzle converts the spray liquid into spray droplets. Nozzle construction plus the pressure of operation determines the size and uniformity in size of droplets of a given solution.

Filters or strainers: - filters or trainers are built and placed on the intake in the spray tank. Its function is to prevent foreign matter such as twigs, insects, leaves e.t.c., from getting into the spray tank and block the nozzle. This is important especially if the water contains trash or dirt.

Hoses: - the hose is used to provide a connection for the passage of spray solution from the tank to the spray lance and to the nozzle.

Tank: - the tank carries and stores the chemical, and is usually made of non-corrosive material.

The pump unit: - the pumping unit is where the necessary pressure is generated for forcing herbicide out of the sprayer. This consists of the cylinder, valves and piston.

The following were considered in the design of the pumping unit.

1. The material needed to construct the pumping chamber must be strong enough to withstand the high pressure that will be generated.
2. The larger the diameter of the cylinder the shorter the stroke. The longer the stroke length the smaller the cylinder bore.

First valve: - the first valve is a component that controls the entry of water to the cylinder. It is a one way valve. It opens and closes as the piston moves to the bottom dead centre (B.D.C) and top dead centre (T.D.C) respectively.

Second valve (discharge): - this is the valve that allows water into the hoses. It is required that it closes very quickly so as to reduce slippage. Slippage arises partly because the valve takes time to close and also because of back leakage of water past the piston.

Seals: - the seals perform their function as rings in an engine cylinder. The seal around the piston fills perfectly the gap between the piston and the cylinder bore preventing water from falling out.

3.1 Design Calculation

3.1.1 Design of pressure cylinder

For constructional convenience, a choice of 2mm thickness of mild steel was made for the cylinder material. Therefore, to determine the maximum radial, tangential and axial stresses in the cylinder, we use the following

$$\sigma_{r\,max} = \frac{r_1^2 p}{r_2^2 - r_1^2} - \frac{r_1^2 r_2^2 p}{r_2^2 - r_1^2} * \frac{1}{r^2} \quad \text{- - - -} (1.0)$$

$$\sigma_{t\,max} = \frac{r_1^2 p}{r_2^2 - r_1^2} + \frac{r_1^2 r_2^2 p}{r_2^2 - r_1^2} * \frac{1}{r^2} \quad \text{- - - -} (1.1)$$

$$\sigma_{z\,max} = 1/\pi \frac{F}{r_2^2 - r_1^2} \quad \text{- - - - - - -} (1.2)$$

Where r_1 = radius of cylinder

r_2 = radius of cylinder plus thickness

P = assumed pressure acting in the cylinder

Note that in thick wall cylinders, maximum radial and tangential stresses are obtained when $r = r_1$

Diameter of cylinder = 70mm (by choice)

$$r_1 = \frac{d}{2} = \frac{70}{2} = 35mm$$

r_2 = 35 + 2mm + thickness = 37 mm

r_1 = 0.035, r_2 = 0.037, P = $7 * 10^{-5}$ N/M^2 (assumed pressure)

F = P * A = $7 * 10^{-5} * (0.07)^2/4 * \pi$ = 2694.3 N

Note σr = radial stress

σ_z = axial stress

σ_t = tangential stress

$\sigma_{r\,max} = [(0.035^2 * 7 * 10^5)/0.037^2 - 0.035^2] - [(0.0352 * 0.0372 * 7 * 10^5/0.037^2 - 0.035^2) * 1/0.035^2]$

$\sigma_{t\,max} = [0.033^2 * 7 * 10^5 / 0.037^2 - 0.035^2] + [0.035^2 * 0.037^2 \times 7 \times 10^5 / 0.037^2 - 0.035^2 * 1/0.035^2$

$\sigma_z = 2694.3\ N/ \pi(0.037^2 - 0.035^2)$

$\sigma_{r\,max} = 4.85 * 10^7$

$\sigma_{t\,max} = 5.3 * 10^7$

$\sigma z_{max} = 5.96 * 10^5$

Failure test based on Von – Mises theory

Let $\sigma_{t\,max} = \sigma_1$

$\sigma_{r\,max} = \sigma_3$

$\sigma_{Z\,max} = \sigma_2$

by von mises theory, failure will occur when

$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 2\,(\sigma_y)^2$ — — — — (1.3)

σ_y = yield strength of steel = 280Mpa (Mark's standard Hand book 1987)

$(\sigma_1 - \sigma_2)^2 = 2.74 * 10^{13}$

$(\sigma_2 - \sigma_3)^2 = 2.29 * 10^{13}$

$(\sigma_3 - \sigma_1)^2 = 2.025 * 10^{13}$

Sum = $5.05 * 10^{13}$ N/M^3

$2\,(\sigma_y)^2 = 2\,(280 * 10^6) = 1.568 * 10^{17}$ N/M^2

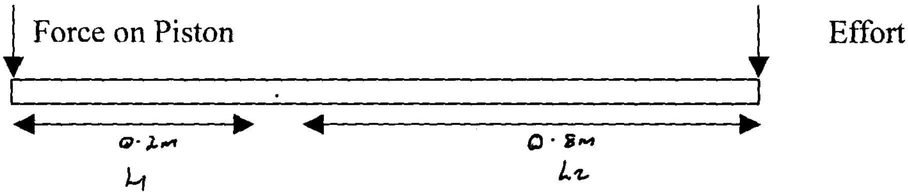
Therefore

$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 < 2\,(\sigma_y)^2$

M.A. = O.8/0.2 = 4

NOTE: When M.A is greater than one, less effort will be applied in pumping.

From ergonomics point of view (M C Cormic 1984) a person should not lift a load of more than 23kg equivalent to 230N load and the average effort is assumed to be 180 N equivalent to 18 Kg



Moment = Clockwise moment = Anticlockwise moment

Effort x 0.8 = 494. 8 x 0.2

$$\text{Effort} = \frac{494.8 \times 0.2}{0.8} = 123.\ 7002\text{N}$$

3.1.3 Determination of height attained by liquid at operating pressure in the pressure chamber of the cylinder

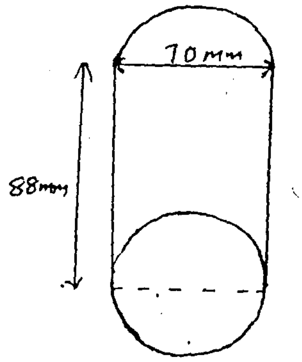


Fig: 2 Pressure Cylinde:

Volume (v) = area * height

$V_1 = A * L$ - - - - (1.5)

From Boyle's law

P_1 atm, $V_1 = P_2 V_2$ - - - - (1.6)

V_1 = initial volume of liquid in cylinder

V_2 = final volume of liquid in the cylinder

P_1 = atm pressure

P_2 = assumed pressure

$$V_1 = A * L = \Pi (0.035)^2 / 4 * 0.088 = 8.47 * 10^{-5} m^3$$

L = length of cylinder

A = area of cylinder

$P_1 V_1 = P_2 V_2$

$V_2 = P_1 V_1 / P_2$

Note $P_2 = 7 * 10^5$ N/m ^{2} (assumed)

$V_2 = (1 * 10^5 * 8.47 * 10^{-5}) / 7 * 10^5 = 1.21 * 10^{-5}$ m ^{3}

Therefore liquid height attained

$V_2 = A L$

Where L = length

A = area

V_2 = volume

$L = V_2 / A$

$= (1.21 * 10^{-5} * 4) / \Pi (0.035)^2 = 1.26 * 10^{-2}$ m

$L = 1.26 * 10^{-2}$ m liquid height attained

3.1.4 Determination of velocity in hose

Hose diameter is 12mm (standard specification)

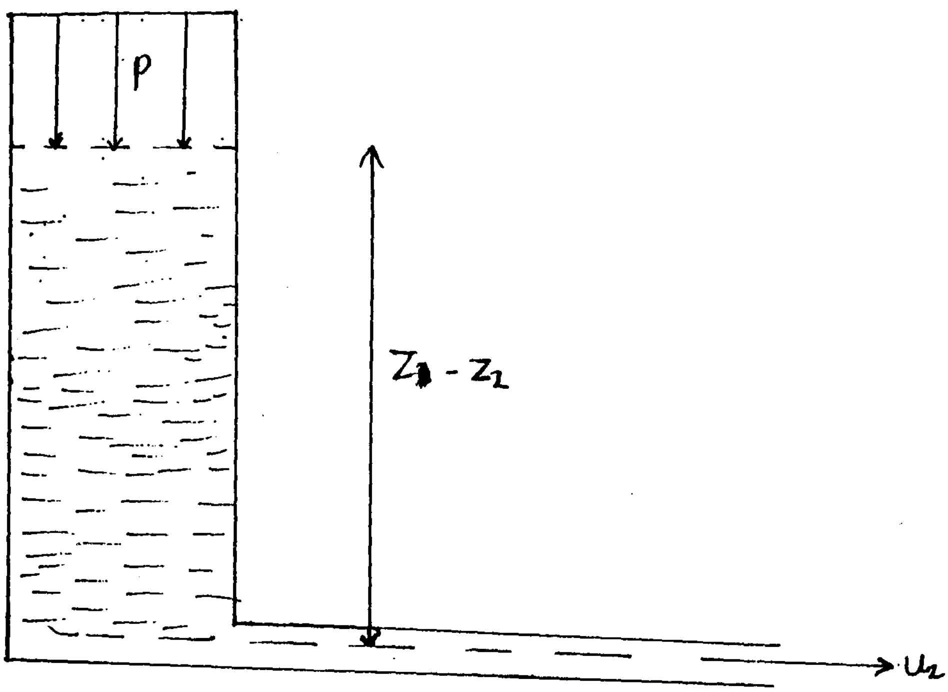


Fig: 3 Velocity in hose

Z_1 and Z_2 are changes in liquid height attained

From Bernoulli's equation taking note of friction losses

$$\frac{P}{\rho g} + \frac{u_1^2}{2g} + Z_1 = \frac{P_{atm}}{\rho g} + \frac{u_2^2}{2g} + Z_2 + h_f \quad ----(1.7)$$

Assumed pressure of 7 bar = $7 * 10^5$ N/m^2

$p - p_{atm} = 7 * 10^5$ N/m^2, $U_1 = 0$, $Z_1 - Z_2 = 1.26 * 10^{-2}$m

h_f = head loss

$$h_f = \frac{4fl}{d} \cdot \frac{u^2}{2g} \qquad ---(1\cdot 8)$$

From Darcy's formula

Where, f = friction factor

L = length of hose

$$\frac{U_2^2}{2g} + \frac{Ufl}{d} \cdot \frac{U_2^2}{2g} = \frac{p - p_{atm}}{\rho g} + (Z_1 - Z_2)$$

$$U_2^2\left(\frac{1}{2*9.81} + \frac{4*0.08*1.5}{0.012*2*9.81}\right) = \frac{7*10^5}{1000*9.81} + 1.26*10^{-2}$$

$$U_2^2(2.09) = 71.37$$

$$U_2 = 5.84 m/s$$

U = velocity

d = diameter

g = 9.81

ρ = density of fluid

3.1.5 Determination of exit velocity from the nozzle

From modified Bernoulli's equation

$$\frac{p}{\rho} + \frac{v_1^2}{2} = \frac{v_2^2}{2}(1-k) \qquad ----(1\cdot 9)$$

P = pressure build up in the system = 7 bars

V_1 = velocity in the hoses = 5.85m/s

K =loss due to conveyance coefficient

K = 0.5 for perpendicular rounded entrance

$$\frac{p}{\rho}+\frac{v_1^2}{2}=\frac{7*10^5}{1000}+\frac{(5.84)^2}{2}=717.11125$$

$$v_2^2(1-k)=1434.2225$$

$$v_2=38.85m/s$$

V_2 =?

3.1.6 Determination of quantity discharge per second

Q = A V A= area of the nozzle (red nozzle,dia = 7.5mm, standard specification) – – – –(2.0)

V= 5.84m/s

$Q = 4.418 * 10^{-5} * 5.84 = 2.58 * 10^{-4} m^3 /s$

=0.25 litre/sec

3.1.7 Determination of tank capacity

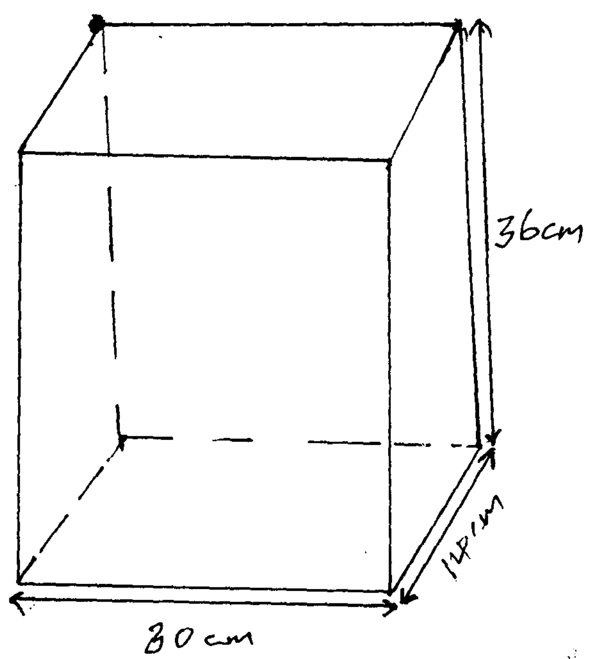


Fig: 4 Tank Capacity

V_t = volume of the tank

t_t = tank thickness = 2mm

$A = (L-2t_t)(b-2t_t)$

$V_t = A * h$ — — — — (2.1)

$V_t = (0.30 - 2(0.002))\,(0.14 - 2(0.002))\,(0.36 - 2(0.002))$

V_t = 15 litres

3.1.8 Cost analysis

This is the total cost of production for the fabrication of a Knapsack Sprayer, this is further divided into three parts:

i. material cost

ii. labour cost

iii. overhead cost

Material cost

This is based on cost of the material used for fabrication under current market prices.

The table below shows the quantity of material used and their prices. Cost of material deduced from the table is N 2, 600.00

Labour cost

Assuming a direct labour cost of 20 per cent of total material cost.

= 20/100 * 2,600 = N 520.00

Overhead cost

This include expensis incured apart from the material cost. This could also be referred to as uncertainty cost. Taking an overhead cost of 10 per cent of total cost of material

= 10/100 * 2, 600 = N 260. 00

Total cost of fabrication is the summation of all the three costs:

2,600 + 520 +260 = N 3, 380.00

TABLE 1

S/NO	MATERIAL	SPECIFICATION	QUANTITY	UNIT PRICE N K	TOTAL PRICE N K
1	Mild steel	(300*120)mm	½ sheet	600. 00	600. 00
2	Anti rust paint (black and red)	____.	1 litre each	150. 00	300. 00
3	Bolt and nut	M 14	2	20. 00	40. 00
4	Bolt and nut	M10	5	20. 00	100. 00
5	Ball valves	(5 * 10)mm	5	75. 00	150. 00
6	Super glue	___	6	20. 00	100. 00
7	Spring	(50 *10)mm	2	30. 00	60. 00
8	Lance, trigger, nozzle	Standard	1	1,150. 00	1,150. 00
9	Strainer (filter)	(50*40)mm	1	100. 00	100. 00
					2,600. 00

4.1.2 Discussion of results

The current cost of 15 litre capacity of Knapsack Sprayer (CP- 15) is N 6000. 00. But from the cost analysis, total cost of fabrication amounted to N 3,380. 00 about 44 per cent reduction in the cost of the ones sold in the market.

The difference between quantity discharged per second and that of experimental flow rate was due to some assumptions made during the calculation.

CHAPTER FIVE

5.0 CONCLUSION

With the pumping unit external, maintenance is now easy. Fatigue problem resulting from pumping has been reduced to the bearest minimum with a higher mechanical advantage greater than one less effort will now be applied in pumping. The operating pressure of $7 * 10^5 N/m^2$ should be maintained so as to ensure even droplet of the fluid.

5.1 Recommendation

1. Light stainless steel or plastic should be used in constructing the tank to avoid rust and reduce weight.
2. High precision equipment should be used in constructing the piston and the cylinders to reduce the clearance between them.
3. The pump should be air tight to prevent leakage
4. The sprayer should be motorised to prevent fatigue experienced during pumping.

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PLATE 1 Spraying with knapsack

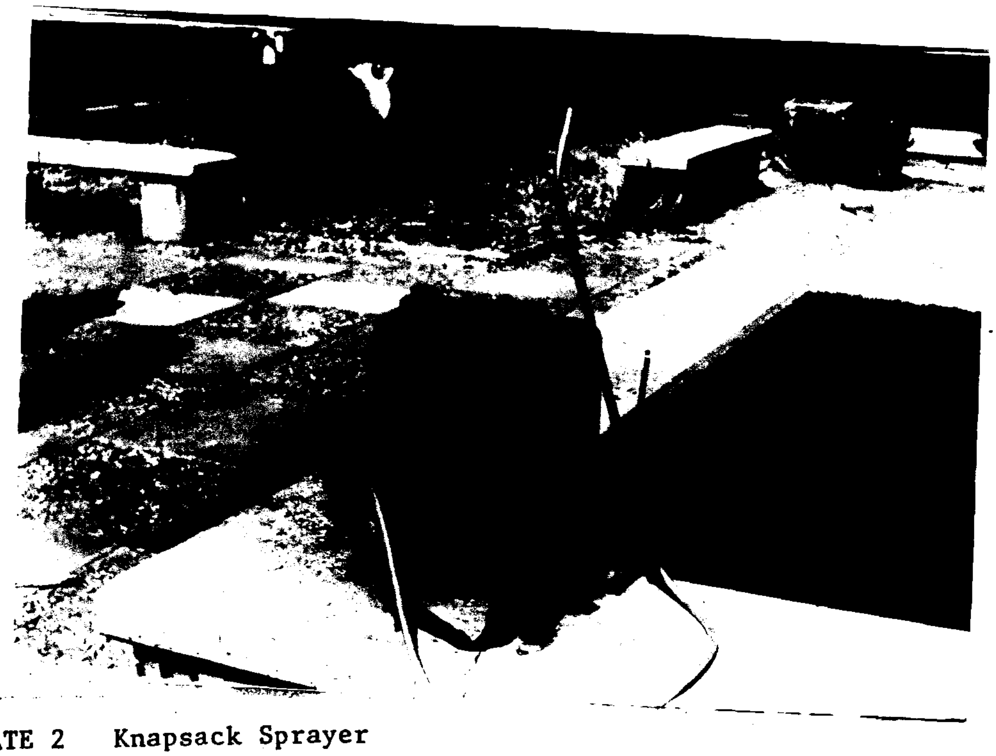

PLATE 2 Knapsack Sprayer