MECHANICAL CONTROL OF THE FLOATING TYPE AQUATIC WEED, SALVINIA MOLESTA (African Payal)

BY

M. R. SANKARANARAYANAN

THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agricultural Engineering

Faculty of Agriculture

Kerala Agricultural University

Department of Agricultural Engineering

COLLEGE OF HORTICULTURE

Vellanikkara - Trichur

1981

DECLARATION

I hereby declare that the thesis entitled" MECHANICAL CONTROL OF THE FLOATING TYPE AQUATIC WEED, SALVINIA MOLESTA (African Payal)" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title of any other University or Society.

Vellanikkara,
10 -12-1981.

SANKARANARAYANAN M.R.

CERTIFICATE

Certified that the thesis entitled "MECHANICAL CONTROL OF THE FLOATING TYPE AQUATIC WEED, *SALVINIA MOLESTA* (African Payal)" is a record of research work done independently by Shri. M.R. Sankaranarayanan, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to him.

Vellanikkara,
10 -12-1981.

DR. JOSE SAMUEL
Professor & Head
Department of
Agricultural Engineering,
(Chairman, Advisory Committee)

CERTIFICATE

We, the undersigned members of the Advisory Committee of Shri.M.R. Sankaranarayanan, a candidate for the degree of Master of Science in Agricultural Engineering agree that the thesis entitled "MECHANICAL CONTROL OF THE FLOATING TYPE AQUATIC WEED, SALVINIA MOLESTA (African Payal)" may be submitted by Shri.M.R. Sankaranarayanan, in partial fulfilment of the requirements for the degree.

(Dr. Jose Samuel)
Advisor and Chairman

(John Thomas)

(~~Jippu Jacob~~) (Dr. A.N. Ramaswamy)

(Luckins. C. Babu)

Vellanikkara,
-12-1981.

ACKNOWLEDGEMENTS

I am deeply indebted to Dr.Jose Samuel, Professor & Head, Department of Agricultural Engineering, College of Horticulture, Vellanikkara, Chairman of my Advisory Committee for his valuable advice, keen interest, constructive criticism and constant encouragement during the entire course of the research work and in the preparation of the manuscript.

I have greatest pleasure in expressing my sense of gratitude to the members of my Advisory Committee, Shri. John Thomas, Shri. Jippu Jacob and Shri. Luckins. C. Babu for their valuable suggestions and advice during the course of this investigation.

It is with great pleasure that I express my heartful thanks to all the staff members and students of the Department of Agricultural Engineering, especially to the staff of the Research Workshop, for their timely help during the conduct of this work.

I am grateful to the officer-in-charge and staff of The Research Station, Mancompu and Coconut Research Station, Kumarakam and M/S Malithra Industries, Kidangara, Changanassery, for providing me facilities to carryout the field trials of my research work.

I would like to thank the Principal, Officer-in-charge and staff of the Hydraulic Laboratory of the Engineering College, Trichur for giving permission to carry out some of the preliminary experiments in that Laboratory and for helping me with the loan instruments for the field tests.

Thanks are also due to the Kerala Agricultural University for granting me a Junior fellowship to undergo the post graduate course.

I am greatly indebted to Shri.D.R.Mahajan, General Manager, Telecommunications, Trivandrum and to Shri.T.M.R.Wariyar, Divisional Engineer, Telegraphs, Trichur for granting me permission and necessary leave for higher studies.

On a personal note, I am grateful to my family members whose love and affection had always been a source of inspiration for me during the higher studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

SYMBOLS AND ABBREVIATIONS USED

An	=	Area of nozzle
At	=	Area of throat
Cd	=	Coefficient of discharge
cm	=	Centimeter
cm^2	=	Square centimeter
cu. in	=	Cubic inch
cu. m	=	Cubic meter
Dn	=	Diameter of nozzle
Dt	=	Diameter of throat
Fig	=	Figure
Ft	=	Feet
g	=	Accelleration due to gravity
G.I	=	Galvanised iron
g/m^2	=	Gramme per square meter
Hd	=	Discharge head
Hn	=	Effective head to the nozzle
Hs	=	Suction head
H.P	=	Horse power
hr	=	Hour
hg	=	Hectare
H.Q	=	Headquarters
Kg	=	Kilogramme
lb	=	pounds
l.p.m	=	Litre per minute
lt	=	Litre

m	=	Meter
m^3	=	Cubic meter
M	=	Flow ratio
mm	=	Milli meter
mt	=	Minute
M.S	=	Mild steel
N	=	Head ratio
Pd	=	Discharge pressure
Pd1	=	Discharge pressure of Ist pumpset
Pd2	=	Discharge pressure of 2nd pumpset
Ps	=	Suction pressure
Psi	=	Pounds per square inch
Qn	=	Discharge through the nozzle
Qs	=	Secondary flow through ejector system
Qty	=	Quantity
R	=	Area ratio of ejector system
r.p.m	=	Revolutions per minute
Rs	=	Rupees
S	=	Nozzle - throat spacing
Sec	=	Second
Sq.m	=	Square meter
T	=	Tonnes
T/hr	=	Tonnes per hour
T/ht	=	Tonnes per hectare
Vn	=	Velocity of flow of water through nozzle

W.H.P = Water horse power

Wt = Weight

% = Percentage

η = Efficiency

Introduction

CHAPTER 1

INTRODUCTION

<u>Salvinia</u> <u>molesta</u> is a noxious floating type aquatic weed of common occurance throughout the world. The infestation is particularly severe in tropical and sub-tropical nations where the warm inland waters and the increasing number of man-made lakes and waterways foster the growth and spread of this weed. The Salvinia genus ranks one among the ten most widely spread aquatic weeds in India. While its presence has been noticed in more than sixty districts in the country, interestingly, the two states most affected by this weed are Kashmir in the north and Kerala in the south.

The species <u>Salvinia</u> <u>molesta</u>,locally known as "African Payal" has spread in enormous quantities during the last 25 years in Kerala. The weed has by now occupied the inland water surfaces of virtually all districts of this State. Being capable of prolific growth and rapid multiplication, the weed spreads like an extensive carpet over large areas of water bodies in the course of a few months. This in turn obstructs inland navigation, fresh water fishing and other hydrological concerns. In the Kuttanadu region and the kole lands of Trichur District where the infestation is the heaviest in the state, thousands of hectares of cultivable land have been invaded by this dreadful weed. Even the daily lives of people in this region, who depend on these waters for domestic consumption, have been affected.

Several technical literature have repeatedly chronicled the devastation brought by this disastrous aquatic weed. Total eradication of the weed is probably an utopian idea; and in most cases unnecessary. But the control, that is, reducing its presence to a manageable level and maintaining that state through periodic means is not only desirable but also imperative. Aquatic weeds can be controlled by several means employing manual, mechanical, chemical, or biological methods. Although, all of these methods have been attempted in the past with limited success, as of now manual control, that is, physical removal remains the only effective means of control for the Salvinia weed. An important reason for the present negative economic status of mechanical control methods is the lack of monetary returns from the harvested plants. Large scale collection of the weeds from the waterways by suitable mechanical equipment and their economic utilisation to defray the cost of collection is an appealing concept. This would result in weed-free waterways while providing an extensive vegetation resource, especially advantageous to developing countries where forage and fertilizer are in short supply.

The Department of Agricultural Engineering of the Kerala Agricultural University has evolved a novel design concept for the mechanical collection of Salvinia. The present project is an attempt, based on this design concept, to develop a prototype Salvinia Harvesting Machine and evaluate its performance characteristics under actual field conditions.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

2.1 General

2.11 Origin and distribution.

The weed Salvinia is a free floating non-flowering plant coming under the family Salvinaceae. Until recently, the species occurring in the fresh water bodies of Kerala and those in many Asian and African countries, was described as Salvinia auriculata Aubl. It has now been identified to be a distinct taxon named Salvinia molesta Mitchell. Although, locally known as "African Payal", this sterile water fern is actually a native of South America and is probably of horticultural origin (Mitchell, 1973 a).

Records show that Specimens of some of the species of Salvinia were present in the Botanic Garden at Rio de Janeiro, South America, in 1941 (Joy, 1978). As a weed Salvinia molesta was noticed widely when it invaded the Kariba Reservoir (Africa) in 1959. At one time, it was estimated that Salvinia occupied as much 1,000 sq.km(21.5 percent) of water surface in the lake (Mitchell, 1974 a). This might have been a possible reason to call this weed as African Payal (Varghese, 1974). Sculthorpe (1967) and Robson (1976) have chronicled the distribution of this weed in the tropical and sub-tropical regions of the world including Africa, Sri Lanka, India, Indonesia, Malaysia and even Australia. In a survey conducted with the help of a questionnaire, which received information from a total of 30 States/Union Territories, Varshney & Singh (1976) observed the presence of Salvinia as a troublesome aquatic weed in some 20 districts in the country. The survey also ranked Salvinia as one among the ten most widely spread aquatic weeds(Appendix I).

2.12 Introduction and infestation in Kerala.

Little is known of the precise mode of introduction of Salvinia or of the agents and environmental factors which facilitated its subsequent spread in this state and Cook and Gut (1971) reported that though there was lack of evidence, it was quite likely that the Salvinia in Kerala came from Ceylon (Sri Lanka) and was first noticed in Kerala as a pest around 1964. But according to George (1976, 1977) the plant, unknown in Kerala before 1953, is believed to have been brought to Trivandrum from Bangalore for botanical studies. It was possible that a few discarded plants, escaped or accidently introduced into the Chakkai Canal and Veli Lake near Trivandrum, survived and multiplied beyond all expectations. The weeds rapidly spread from here to other areas in the State by about 1960. Also, according to Thomas (1976, 1977, 1979), Salvinia was first noticed as a weed as early as 1956 itself during the course of an extensive survey of the vascular flora of Veli (Trivandrum) undertaken by the author. The weed was seen in paddy fields, small ponds, canals, and lakes in association with other free floating plants such as Eichhornia and Pistia.

Whatever might be the origin, during the last two and half decades *Salvinia molesta* has spread to most of the 50,000 hectares of paddy fields in the Kuttanadu region and about 10,000 hectares in the kole lands of Trichur District (Varghese, 1974, Joy,1978). The survey conducted jointly by the Kerala Agricultural University and the Calicut University during 1977-78 has also concluded that *Salvinia* is present throughout the low land areas of the state amounting to about 7150 sq.km(18.4 percent of the total area). The weed is generally absent or has not adversely affected the ponds and paddy fields in the northern districts and in the elevated regions like Pathanamthitta and Nedumangadu thaluks of the state(Calicut University, 1979, Thomas, 1976). The State Department of Agriculture has estimated that during the peak period of infestation between December to May the area of water surface covered by this weed in the whole state is around 2 lakh hectares(Mathew, 1980). Samuel (1980), on the other hand, has made a more conservative estimate in assessing the area requiring removal of the weed to be of the order of one lakh hectares for the entire state.

2.2 Biological Properties

2.21. Morphology

The plant body of *Salvinia molesta* consists of a slender horizontal stem which bears a pair of heart-shaped floating leaves and an apical growing point(Fig.I). From each node hangs a third finely dissected submerged leaf. *Salvinia molesta* differs markedly from other aquatic vascular plants in that it has no roots. It is the submerged leaf which absorbs water and nutrients performing the functions of the absent roots. In addition, it also acts as a stabiliser(Soulthorpe, 1967). *Salvinia molesta* is distinguished within the *Salvinia auriculata* group by the presence of long straight chains of sesile to subsesile male sporocarps, 1 mm. or less in diametre, containing mostly empty sporangia(Joy, 1978).

2.22 Reproduction

Salvinia molesta is notorious for its extremely high rate of vegetative propagation. The fragile stems are easily broken; even a violent disturbance of water by rapid currents or strong winds shatters the plant body into many fragments. Any of these detached fragments of the stem bearing one or more buds is capable of growing into an independent plant (Soulthorpe, 1967; Mitchell, 1976).

In fact, in all *Salvinia* species, fragmentation and regeneration are more prevalent than development of sexual propogules(Loyal & Grewal, 1966). Mitchell (1970) showed that *Salvinia molesta* (cited as *S.auriculata*) is incapable of forming viable spores and as such does not reproduce sexually.

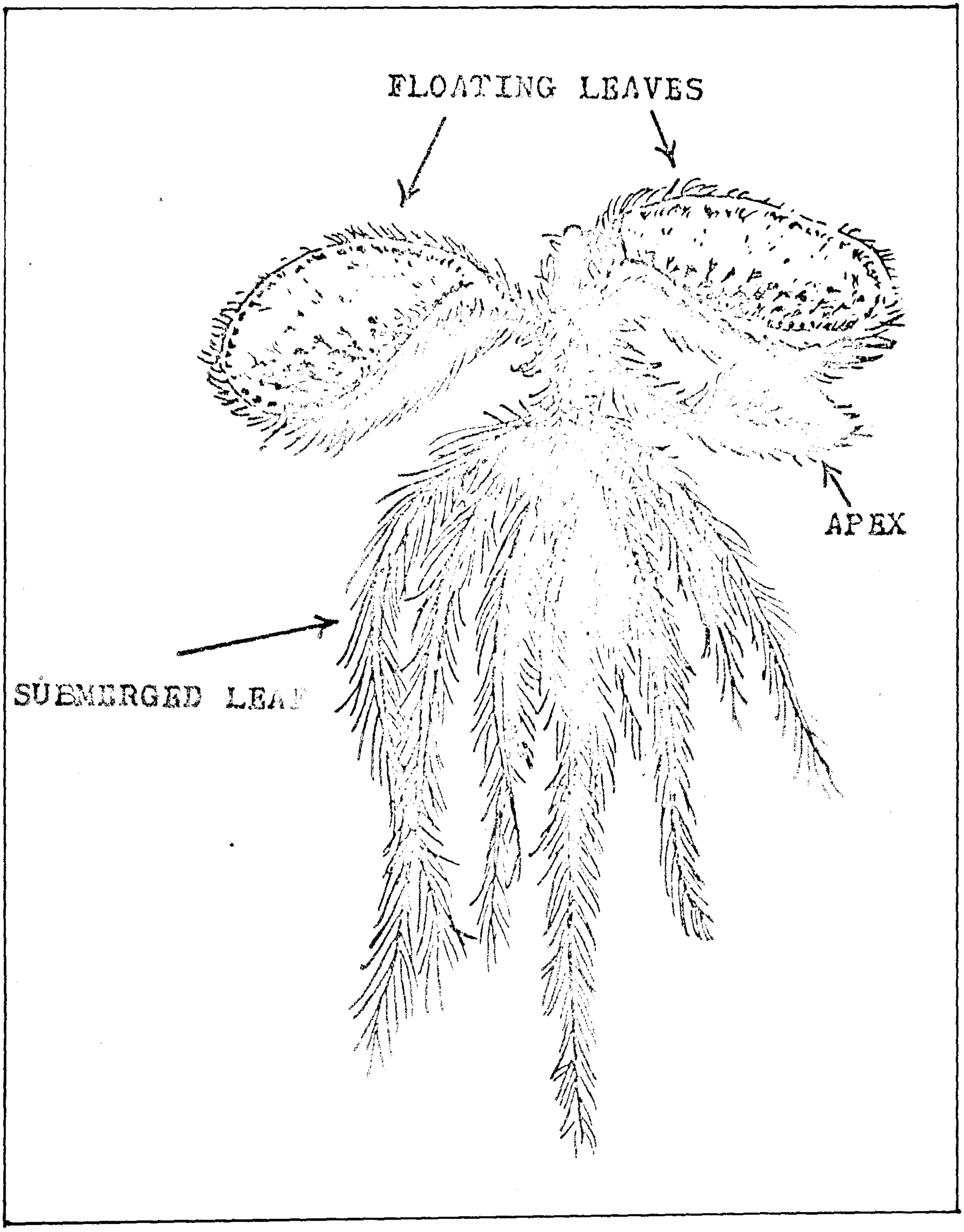


Fig.I. Termina[illegible] of a *Salvinia* plant (Anonymous)

2.23 Growth Phases

Salvinia molesta can survive for long periods under conditions unfavourable to its growth. The plant is able to survive fluctuations in water level and in the right conditions will recover rapidly from a prior period of adversity. Hattingh (1961) described three stages of development of *Salvinia* in lake Kariba; (1) Primary Stage, (2) Secondary Stage, and (3) Tertiary Stage. The Primary stage is generally to be found near the shore line where sufficient space is available for horizontal expansion. In this stage, the plant is characterised by long internodes and floating leaves which are more or less rounded and quite small; about 10 mm in diametre (Fig.2). Within a few weeks, the plant usually exhibits the Secondary stage in which the floating leaves become larger in size (about 23 mm in length and 38 mm in width) and partly folded into a keel-shape. The internodes still remain long. In the tertiary phase the terminal buds form compact in nature and almost vertical in orientation. The leaves are found to be acutely folded ones, broader than they are long, measuring about 23 to 25 mm in length and upto 38 mm in width. This is the "mat form" and normally the only stage to bear sporocarps. The transition from Primary to Tertiary stage takes place in as little as 2 to 3 weeks in a suitable habitat (Sculthorpe, 1967).

Cook and Gut (1971) distinguished four distinct phases

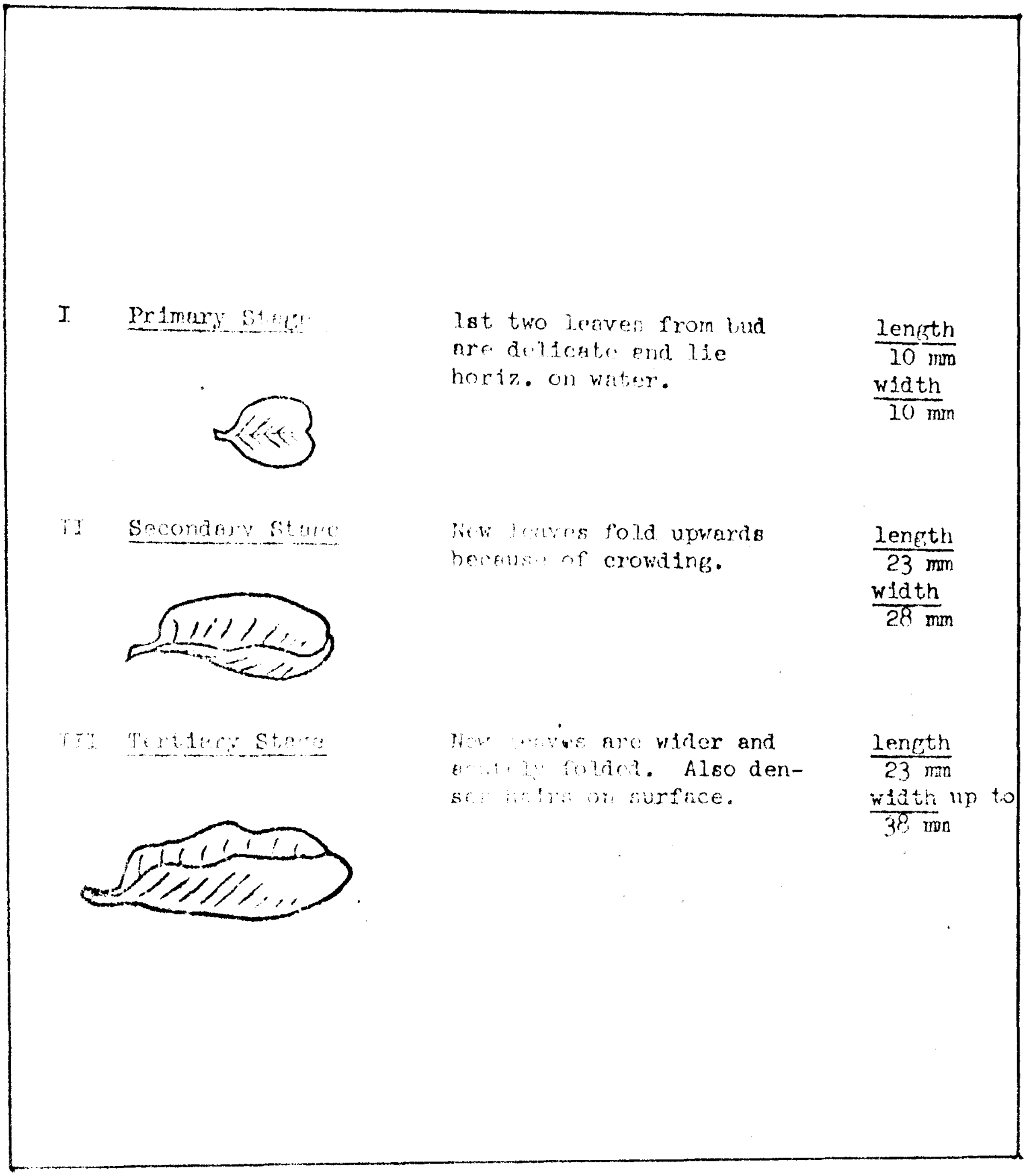


Fig.2. Three growth stages of Salvinia molesta (Hattingh, 1961).

during the growth of Salvinia in a loclity (Fig.3). During the first (initial) phase, the Salvinia is in the primary invading form which possibly includes all three stages discribed by Hattingh. But, when no more space is left for horizontal spread, the leaf alters its position to a more or less vertical one. The Salvinia then starts to grow vertically and to build up on its own dead material. This is the second growth phase during which the plants become very large. This phase also can not go on indefinitely. Due to the massive deposit of dead litter, the Salvinia weed is not able to obtain the large quantity of water needed for its growth. The habitat is thus changed and is now ready to be colonised by other plant species. The initial colonisers are mostly herbaceous plants which creep over the mats of Salvinia and bind them together. This is the third phase. The herbaceous plants also contribute litter which is deposited on the island, providing a suitable habitat for woody shurbs which will, in turn, be eventually replaced by trees. This is the fourth phase.

Most habitats in Kerala are either in the first or in the second phase of growth described by Cook & Gut. They do not get a chance to grow into the third phase as the weeds are periodically washed away by flood waters. However in isolated water bodies the third phase of growth is commonly seen. There have been little information of the weed having grown into fourth phase anywhere in Kerala. If the weed infestation is not

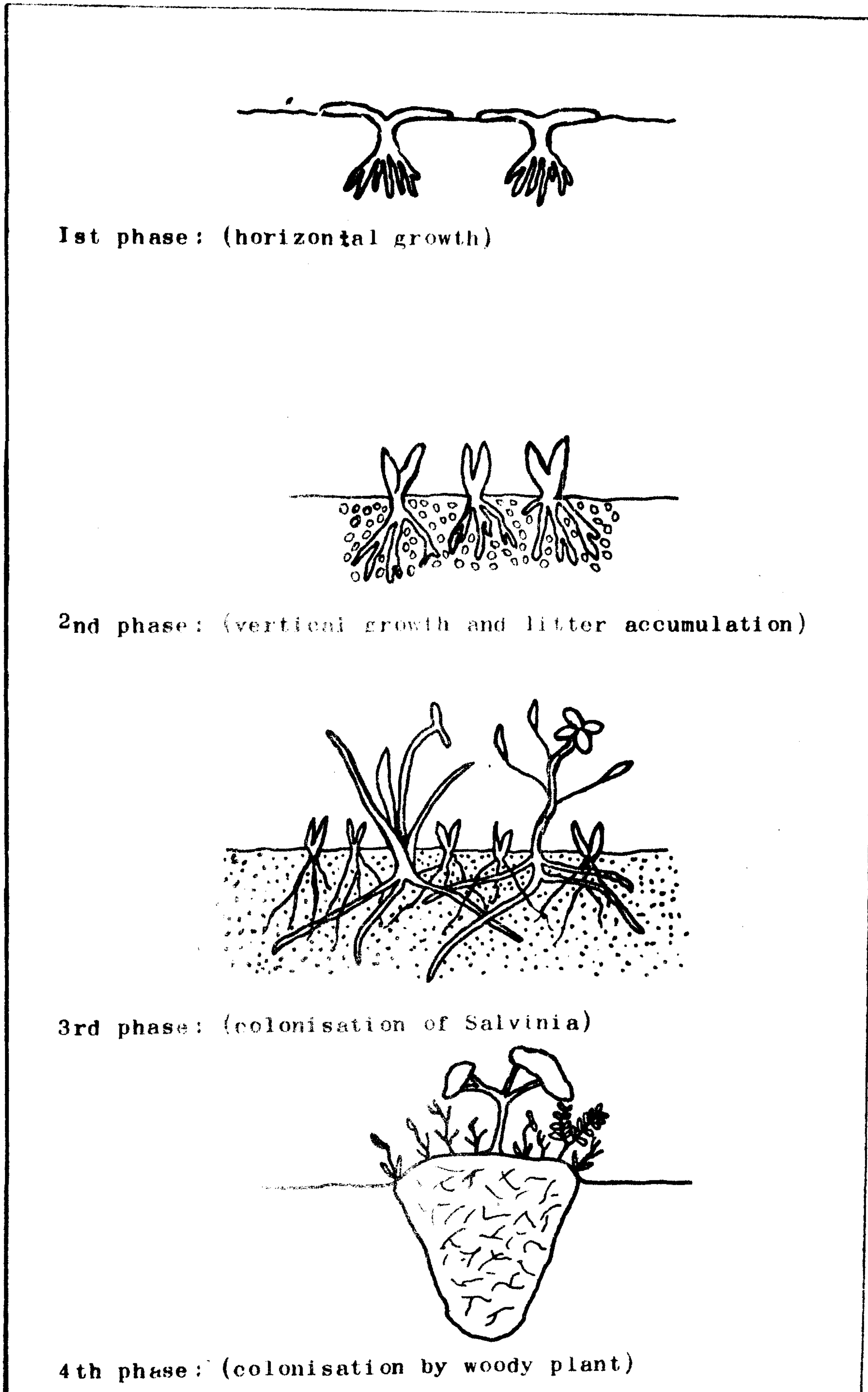


Fig.3. Four growth phases of Salvinia molesta
(Cook & Gut, 1971)

controlled effectively in the near future it is likely that even the fourth phase will have to be confronted in the state.

2.24 Growth rates of Salvinia

Growth rate in plants can be assessed by different means. The application of growth analysis techniques (Evans, 1972) and the concept of doubling rate are considered to be more appropriate for mobile plants like Salvinia than the method of net productivity (Penfound and Earle, 1948), commonly utilised in the case of attached plants (Mitchell, 1974 a). Several authors have utilised the doubling time technique in reporting the growth rate of aquatic weeds. Doubling time is the time taken for the material present to double itself. During the analysis of growth of Salvinia molesta, Mitchell (1974 b) found that the growth of the weed was exponential. Gaudet (1973) working with Salvinia minima and Salvinia molesta under standard culture conditions in laboratory, calculated doubling time in days for numbers of leaves using the formula;

$$\text{Doubling time } (T) = \frac{\log 2}{\frac{\log N_2 - \log N_1}{t}}$$

where N_1 is the initial number of leaves and N_2 is the final number of leaves and t is the observation time. The doubling time (T) of Salvinia molesta was found to be 4.6 days. But, the growth under field conditions was not as rapid and mean relative growth rates ranging between 4.85 and 5.61 percent per day in terms of leaf number were obtained. The relative growth rate was increased with increases in light intensity and nutrients. The optimum temperature for the growth was found to be 30°C for both species.

2.3 Mechanical Properties

It is essential to have a knowledge of the physical/mechanical properties of aquatic weeds, before attempting to design harvesting as well as processing equipments. Substantial improvements in the harvesting rates and utilisation and/or disposal techniques can be made possible by knowing these properties. In turn, it could lead to the acceptance of mechanical harvesting as an effective control measure for aquatic weeds.

Important physical/mechanical properties of aquatic weeds relevant to mechanical harvesting include moisture and matter contents, density characteristics, pressure-density relationships and strength characteristics.

In regard to water content, a typical figure of 92% by weight is believed to be present in all aquatic plants resulting in only 8% as the solid matter content (Little (Ed),1968). This low level of solid matter has been the major deterrent to the mechanical harvesting and commercial utilisation of aquatic weeds. The presence of air in the order of 70% or more by volume in the foliage of all free floating plants makes them sufficiently buoyant. A chemical analysis of Salvinia by Williams (1956) yielded the results as reproduced in Table I.

Table. I. Percentage matter content in Salvinia (Williams, 1956).

Element	Fresh matter %		Dry matter %
a) Moisture	89.30		
b) Dry matter			
1. Organic matter	3.92		56.72
2. Ash and Sand	4.63		
3. Nitrogen	0.92		
4. Potash (K2O)	1.156	10.7%	43.28
5. Phosperic Acid (P2O)	0.022		
6. Lime (CaO)	0.042		

A recent study by Thomas *et al* (1976) on *Salvinia molesta* based on samples collected from Trichur, Ernakulam and Kottayam Districts of Kerala also gave a value of 10.1 ± 0.21% of dry matter (oven dried) content in the weed. However, studies made by the Department of Life Sciences of the Calicut University, (Ignatious, 1979) and the Department of Agricultural Engineering of the Kerala Agricultural University, (Samual *et al*, 1980) indicated that Salvinia weed contains only less than 5% solid matter. This shows that the moisture content of fresh *Salvinia* would be in the order of 90 to 95 per cent. They also indicate the vast potential for reducing both the volume and weight of the harvested material by the expression of water and air in the course of any mechanical harvesting and subsequent processing. Livermore *et al* (1971) has reported that in the case of water-mil foil, it has been possible to reduce about 50% of the original weight by an application of pressure equivalent to 2 kg/cm^2. However, similar studies on *Salvinia* are not seen reported.

Another important physical property of aquatic weeds is their density characteristics. Two common methods of expressing density employed by the Biologists, are (1) Biomass and (2) Standing crop estimate (Sculthorpe, 1967). The biomass is defined as the total mass of the plants per unit area expressed on dry weight basis. The standing crop estimate, on the other hand, gives the weight per unit area of the harvested portion of the plant only. In regard to biomass of *Salvinia*, Zutshi and Vass (1976) found that it varied from 15 - 35 g/m^2 during the initial growth stage. The highest range of values reached was 266 - 324 g/m^2 on dry weight basis, while the ash content of the plant varied from 6 - 16%. Kaul and Usha-Bakya (1976) got similar values of bio mass for *Salvinia* (Table 2) in which the influence of growth stage was found to be most pronounced.

Table 2. Biomass values of Salvinia (Kaul and Usha Bakya, 1976)

Period	Light condition	Average biomass g/m^2
May 1973	Partial shade	33.0
	Exposed	30.6
Sept 1973	Partial shade	335.1
	Exposed	326.2

Samuel (1972) introduced a new term 'Spread Density' which was defined as the weight of the immediately harvested material per unit area. This term is perhaps more self-explanatory and relevant in mechanical harvesting. Preliminary experiments made in the College of Agriculture, Vellayani, Trivandrum by Samuel and Jacob (1977) showed that for ~~one~~ Salvinia weed which had completed horizontal expansion just to cover the water surface, the spread density was of the order of 3 kg/m^2. When there was no more room for horizontal expansion and secondary growth was about to start, the value went upto 7.5 kg/m^2. With secondary growth of creepers over the Salvinia canopy, the spread density was found to be upto 12.5 kg/m^2.

Bruhn et al (1971) and Abeaba (1972) have studied the mechanical properties of the aquatic weed, water milfoil (Myriophyllum spicatum) in detail. The relationship among the applied pressure, moisture content, dwell time (holding time) and density of the resulting material was investigated. The bulk density (lbs per cu: in) of the plant was derived as

$$\gamma_s = \frac{W_s}{V} = \frac{W - W_w}{V} = \frac{W\,(100-M)}{100\,V} = \frac{W\,[100-f(p,T)]}{100\,V}$$

where γ_s is the bulk density of solids (lb per cu: in), V the total volume of the sample (cu:in), W the total weight of the sample (lb), Ww weight of water in the sample (lb), Ws the weight of solids in the sample (lb), M the percentage moisture on wet basis = $\frac{W_w}{W}$ x 100 (%), p the pressure, (psi) and T the dwell time (sec). Consolidation tests were performed to determine the compression properties of the aquatic vegetation. The weight and volume of the harvested material were reduced by applying external pressure utilising a screw press. These tests provided a means of approximating the premeability values from the rate of flow of liquid for a given pressure gradient. The tests provided two other important physical properties also. They were (1) compression index, Cc which indicated the compressibility of the specimen and (2) the coefficient of consolidation, Cv which indicated the rate of compression under a given load increment. A value of 0.8 for Cc was obtained for the aquatic weed, *Myriophyllum spicatum*. This value was high compared to that of clay where the Cc value varied between 0.1 to 0.3. It appears that similar studies on *Salvinia* have not been conducted.

2.4 Economic effects of infestation

Floating mats of vegetation may be composed of either pure colonies of a single free-floating species or mixed sudd communities of free floating and emergent plants. They in turn produce far-reaching biological and economic consequences (Sculthorpe, 1967). Holm *et al* (1969) have discussed examples of difficulties caused by aquatic weeds in various parts of the world, while Little (1966, 1969) and Mitchell(1973) have listed the problems caused by the weeds in man-made lakes.

Though, actual estimates of losses due to aquatic weeds are not available, weed problems in India were officially recognised as early as in 1921 (Mukhopadhyay and Tharaphdar, 1976). The problems caused by common aquatic weeds in the country as a whole on the basis of an all India Survey conducted during 1973-74 were listed in order of importance by Varshney and Singh, (1976) as follows:

1. Covering of impounded waters
2. Hindrance to fisheries
3. Choking of flowing waters
4. Choking growth of cultivated plants
5. Making water unpalatable
6. Increased loss of water
7. Creating disease problems
8. Impediment to navigation
9. Hindrance to aquatic sports

In most areas in Kerala, Salvinia has become so well established that other floating plant populations have dwindled out considerably. The first and foremost of the manifold effects, is the direct mechanical hindrance to inland navigation (Thomas, 1979). Plate I shows one such situation commonly confronted in the water ways of Kerala. Any traveller by motor boat from Alleppey to Kottayam, which is a popular route, will be baffled by the sight of one of the crew frequently diving into the water and clearing weeds struck in the propeller (Jayakumar, 1980). Another serious problem caused

PLATE. I: INFESTATION OF SALVINIA RESULTING IN HINDRANCE TO INLAND NAVIGATION.

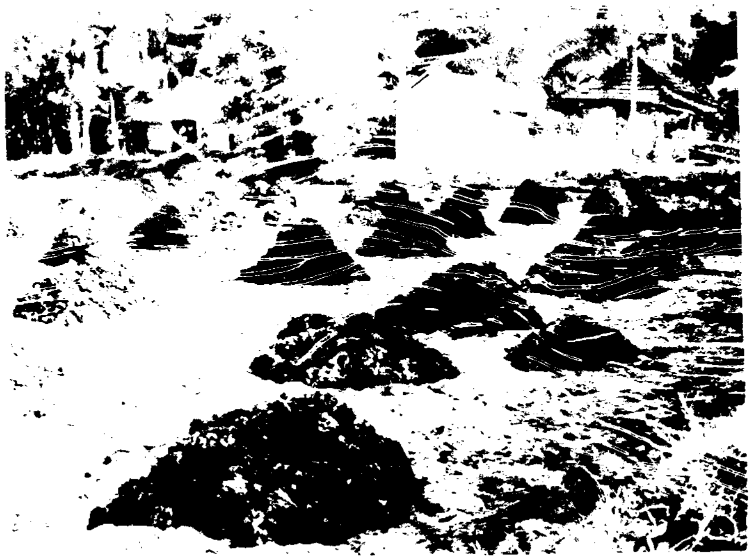
by the infestation of Salvinia is the severe crop failure in paddy fields of which several instances have been reported from Kuttanadu, the rice bowl of Kerala (George, 1977). If the fields are left fallow for some months, the unchecked spread of the weed may result in exhorbitant costs for its clearance or necessitate complete abandonment of the land. Reports also show that aquatic weeds may maintain a reservoir of pathogens that are harmful to rice plants(Joy, 1978). Fresh water inland fisheries have always been an important source of animal protein in less developed countries. The blanket of weed offers a direct threat to the establishment of commercial inland fisheries, because of the creation of a shallow-water environment which is both unsuitable for fish to breed-in and for fishing boats and nets to be moved about. Other important effects of excessive growth of Salvinia in Kerala have been those of making water unpalatable, promoting the menace of epidemic diseases, hindering hydroelectric and irrigation schemes and reducing recreation facilities.

2.5 Control measures for aquatic weeds

Manual, mechanical, chemical and biological methods are the usual techniques used for controlling aquatic weed growth in water bodies. Integrated control involves the employment of a combination of these methods. However, owing to the specific situation and the type of weed, even these alternatives are often found unacceptable thereby limiting the technology that is feasible. Since past attempts to eradicate Salvinia molesta have failed, the present emphasis is to control, that is, to simply check future growth and spread (Gaudet 1976). Changes in the recommended practices of aquatic weed control have been common and will undoubtedly continue (Welden et al 1973). It is rarely possible to tackle a particular aquatic weed problem in a routine manner. Each problem has to be treated as unique and all the local factors throughly investigated before a control technique is chosen.

2.51. Manual methods

In India, until the turn of the century, control of aquatic weeds occurring in inland ponds, tanks, reservoirs, lakes, canals, and waterways was mainly carried out physically, manual labour being almost exclusively used for the purpose, (Philipose, 1972). In general, raking, crushing, chaining and netting are the main approaches employed in dealing with aquatic weeds. These methods, however, have not been successful in the case of Salvinia because of its free floating and dispersed nature of occurrance. Hand picking, which is the simplest, is still the most widely used method in Kerala for the removal of Salvinia from paddy fields, ponds and isolated water bodies (Samuel & Jacob, 1977 & Joy, 1978). Plate 2 shows that in a drained paddy field the weed is first collected into small heaps, which are then joined together to form larger heaps. The small heaps may also be dragged along the mud supported on coconut leaf-tips to the boarder bunds where the material is finally disposed to be dried and destroyed in the sun.



a) Salvinia piled into small heaps

b) Sledging the heaps to [illegible]

PLATE 2: MANUAL REMOVAL OF SALVINIA FROM A PADDY FIELD

The present costs for manual collection and disposal of the Salvinia weed from different habitats in Kerala, ascertained from various sources are given in Table 3.

Table 3. Costs of manual collection and disposal of Salvinia from different habitats in Kerala

Sl. No.	Methods employed	Rate (Rs/m³)	Cost (Rs/hect)	Source of information
1	Encircling the weeds and pushing the mates to the adjoining navigation canal during low tides.	5/hour	500	Personal enquiry at Mancompu
2	Collecting into small heaps and dragging it on to paddy fields bunds engaging women labourer.	10/day	900	Personal enquiry at Kumarakam
3	Manual collection from water-ways and disposal from paddy fields.	0.75 to 1.00	750 to 1000	Dept. of Agrl. Engg. (1980)
4	Manual collection from water-ways and disposal at reasonable lead distance.	5.05	1000 to 1500	Mathrubhoomi (1981)
5	Manual collection from lake & clearing the banks and keeping and burning the material.	5.00 + 3.00	3700*	Cook, (1976)

*Air dried material

It may be noted that while the lowest cost of Rs.500 per hectare is for pushing the material to the adjoining canal which provides only partial control, the range of costs for collection and disposal of the weed at reasonable lead distance varies from

Rs.900/- to Rs.2700/-. The high cost is thus a serious deterrant to reclamation of the weed infested areas through manual control methods. The Kerala State Electricity Board succeeded in getting rid of Salvinia by manual removal in 1977 from the Kakki Reservoir but at a very considerable cost (Thomas, 1979). Floating booms made of bamboo poles tied with ropes and even nets are used for encircling a portion of the weed infested area and bringing the trapped weeds ashore. In the Kuttanadu region, the encircled Salvinia is dragged or pushed to the adjoining canal during low tides where they further multiply and block inland navigation and fresh water fishing for several months during the year. The final disposal is achieved only with the onset of the monsoon floods. During the floods the weed blankets move down the water course and reach the sea where they get destroyed easily in the saline water (Samuel, 1980). Manual methods have the advantage that they do not require technical expertise or costly equipment. But these methods remain to be time consuming, labour-intensive and prohibitive in cost.

2.52 Chemical methods

Chemical herbicides have been utilised against aquatic weeds in many areas of the world with moderate success(Sculthorpe,1967). Mclean (1922), Bose (1923) and Parija (1934) were the pioneers in the field of aquatic weed control by chemical means in India (Philipose, 1976). Some of the chemicals used for the control of aquatic weeds, especially against water hyacinth are 2, 4-D

(Shell weed killer) and MCPA (Methoxene). Patnaik (1972) used gramaxone (Paraquat) against Salvinia successfully. Control of Salvinia have been tried by several scientists during the latter half of the 1960's of which some work are still continuing. A notable result among these efforts was that of George (1976) who found that the use of non-toxic herbicides such as mixtures of mineral oils, uria and detergent were helpful in checking the increase of Salvinia. However, the wide-spread use of chemicals cannot be safely recommended as they create problems of pollution and are detrimental to the fish population as well as domestic use of the water. Thus, chemical control measures can be practised only in a limited way in small isolated water bodies.

2.53 Biological control

Biological control normally implies the use of competitive organisms to suppress a pest species. This method of making use of host specific pests in controlling the aquatic weeds has been used with some success since the latter half of this century. Several biotic agents have been evaluated and are available for aquatic weed control. Herbivorous animals like Grass Carp and Manatees, fishes like Tilapia and certain species of ducks are generally used for the biological control of aquatic weeds. Surveys in Trinidad, Guyana and Brazil were undertaken during the 1961 - 1963 period to study and identify the insects associated with Salvinia Spp. (Bennet, 1966). Some of these pests and insects were tried in Kerala also. But Roy (1978) reported that in preliminary trials in the field, the multiplication of the grass hopper, Paulinia, the most effective pest found for control of Salvinia in other areas of the world, has been drastically retarded by the attack of pedators like spiders. Although biological methods are quite attractive on account of its ecological and economical aspects, a complete control is often very difficult to achieve through such agents. What is at best attained is a natural balance between the biological agents and the weed. Moreover, the biological method is always a slow process (Joy, 1978). Thus, in the absence of an effective biological control agent or safe as well as economic methods of chemical control, investigations to reduce the cost of control through mechanical methods assume greater importance for the State of Kerala.

2.54 Mechanical control

Mechanical control of aquatic weeds is generally regarded as the cutting or dislodging of the plants often with subsequent removal of the resulting cut organic matter from the water body. Mechanical control may also include physical restraint of the floating aquatic material (Allan Deutsch (Ed) 1974). Ecologically speaking, the mechanical method which does not leave any plant residue in the water is considered to be the best means for controlling the growth of aquatic weeds. Various machines and equipment which are at present in use for the control, have in most cases been developed to meet local needs(Robson, 1974).

Soulthorpe (1967) has reviewed the various means employed in mechanical control of aquatic weeds, which include such techniques as mechanical cutting, dragging, mowing and rolling the weed materials. Robson (1974) has also reviewed some of the floating type harvesters used for the control of aquatic weeds. Several harvesters, however, have their basic operating characteristics similar. They consist of a barge with a cutting mechanism and a conveyer system for lifting the plants from the water. The machines also carry the materials ashore for disposal. Some harvesters, which suck up the weed, mash, partially dry and bale it on the barge itself, have been tried in the United States of America. Other harvesters like "saw boat" and "Kenny" also developed in the United States of America (Gangstad, 1976) crush and shred the harvested materials and deposit them back into the water. However, these machines would not be acceptable for the control of aquatic weeds which can reproduce vegetatively. Thus, several mechanical equipment have been tried to control aquatic weeds in the Western countries but they are mostly suited for rooted, submerged and emergent plants only. Appendix 2 provides the list of a limited number of firms world wide who construct and market specialised equipment for cutting, harvesting or otherwise controlling aquatic weeds. It is however, not known whether any of these machines have been effectively utilised against the floating type weed of the Salvinia species.

A noteworthy indigenous attempt for the mechanical control of aquatic weeds is the introduction of the "VARDHAMAN" Aquatic Harvester recently developed by the Central Institute of Fisheries Technology (CIFT), Cochin (Velu, 1976). The design know-how for commercialisation has been released to M/S Shree Vardhaman Industrial Engineering (Pvt) Ltd., Kolhapur, Maharashtra under licence through the National Research Development Corporation of India (N.R.D.C). The equipment (Fig.4) is reported to be capable of handling both submerged and floating type weeds effectively. The machine is claimed capable of clearing weed infested areas at the rate of 1.5 to 2.0 hectares per day of eight hours at a cost of 150 to 200 rupees per hectare with a crew of four persons. The estimated cost of the machine including the engine was reported to be Rs.84000/- (Kaimal, 1976). But the equipment has not yet been brought into public use for want of further modifications to handle specifically the _Salvinia_ weed. The cost of the 20 H.P equipment including modification was subsequently quoted at approximately Rs.1,50,000/- (Samuel and Jacob, 1977).

The State Committee for eradication of _Salvinia_ in Kerala has taken the initiative in encouraging local innovators in the development of mechanical equipment for harvesting the weed. One such project sponsored by the Committee was that proposed by a local innovator from Kottayam consisting of a conveyor system mounted on two country boats and operated by a 5 H.P diesel engine. The Committee had also sponsored a project for

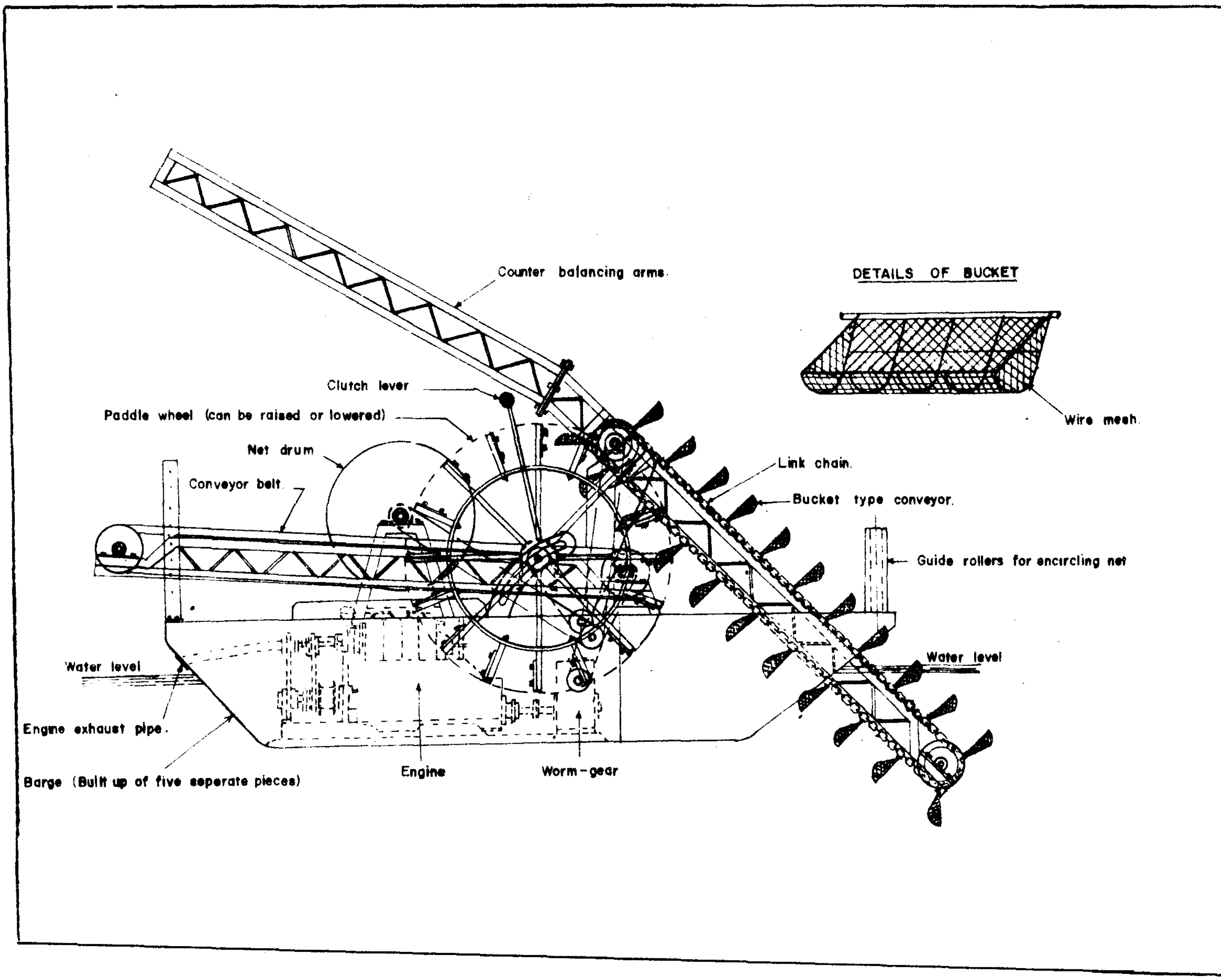


Fig.4. Diagrammatic representation of aquatic harvester (Velu, 1973).

developing a harvesting machine through the P.W.D of the State. But neither of these projects has progressed enough to demonstrate its potential usefulness over manual methods of collection.

As pointed out by Soulthorpe (1967), even mechanical control of aquatic weeds has its own limitations viz: (1) there is a risk of incomplete coverage of the infested area, (2) there is a chance for reinfestation of seeds or vegetative fragments that escape collection, (3) there is a need for frequent repetition of the treatment and (4) there is involvement of high costs for the labour and equipment utilised at present. The risk of incomplete coverage is mostly associated with the use of rakes and conveyor systems where there is a tendency for the floating weeds to flow around than be caught on the obstruction. Similarly, there is danger of regeneration and reinfestation only when the materials are broken up into fragments, due to the action of mechanical components, which subsequently escape collection. If the objective of any control programme is one of management of the weed and overcoming its ill effects rather than total eradication, then, as suggested by Velu (1976), two or three operations at suitable intervals would often keep the weeds under control. Any subsequent utilisation of the harvested material would also provide additional justification for such repetition of treatment. Development of more efficient machines, increased annual usage and multiple use of the selected equipment are again means of reducing the high cost of labour and equipment now involved in mechanical control methods. Samuel and Jacob (1977) have proposed a novel fluidisation technique to minimise the adverse effects of mechanical control measures wherein a suction type system is utilised for harvesting the Salvinia weed. The technique involves the use of a conventional irrigation pumpset in combination with a high capacity water jet pump to draw-in and pump out the weed-water mixture without allowing the weed materials either to clog the primary pumpset or to be broken up into fragments due to any mechanical obstructions within the system. The concept is further explained in the subsequent sections and forms the basis for the development and evaluation of a Salvinia harvesting machine attempted in this project.

It is true that no single size or type of machine can possibly be effective under all circumstances because of the different environmental and ecological conditions. But mechanical measures of weed control have the greatest attraction that the control obtained is very quick and that the weeds thus harvested and collected can be put to use for several agricultural or industrial purposes (Joy, 1978).

2.6 Utilisation

The idea of offsetting the cost of harvesting the aquatic weeds by finding some way of utilising the plant material has been the main impetus for the development of several weed processing systems (Livermore & Winderfinch, 1969). Sculthorpe (1967) has mentioned various methods of utilisation of the plants for horticultural, medicinal and other commercial purposes. Boyd (1972) & National Academy of Sciences (1976) have further reviewed these utilisation techniques for aquatic weeds. They include such specific uses as mulches in garden lands, for compost making and as live stock feed materials in agriculture and for purification of industrial waste, as packing material and as pulp for paper making in industry as well as in generating biogas for energy production. As in the case of other aquatic weeds, it has been found that Salvinia can be effectively utilised as an organic fertiliser. The trials at the College of Agriculture, Vellayani, indicate that compost made of Salvinia is rich in plant nutrients (Joy, 1978). Salvinia can also be used as a mulch in coconut or cocoa garden as is being practised in Ceylon (Menon, 1971). The use of this weed is already contemplated by some industries in Kerala as raw material for hardboards and as a packing material for delicate articles like glass wares (Thomas, 1979). It is stated that aquatic weeds might also one day provide a new source of energy for Kerala. Laboratory and pilot plant level studies have also brought out the tremendous potential for biogas generation from the harvested Salvinia weed mass (Samuel et al, 1980). In any case, the recovery of fuel from aquatic weeds even if on a small scale has interesting implications, especially for rural areas in the developing countries.

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

3.1 Objectives

The overall objective of this project was to carry out studies toward the mechanical control of the floating type aquatic weed "Salvinia molesta" (African payal) in Kerala.

The specific objectives were:-

1. to study the biological and mechanical properties of the weed Salvinia with a view to evolve design parameters for use in mechanical control and utilization techniques.

2. to assess the performance of an experimental harvesting machine designed to utilize the fluidization technique developed in the Kerala Agricultural University for mechanical collection of this weed.

3. to develop a prototype Salvinia Harvesting Machine along with essential accessory units and evaluate its performance towards economic viability and flexibility of applications, and

4. to investigate additional approaches to improve mechanical control as well as utilization of the weed.

Owing to time limitations, the study of biological and mechanical properties of the weed were largely limited to the review of literature. However, certain visual observations and additional measurements were made on these properties to the extent necessary. Efforts were concentrated on the second and third objectives because of their topical importance.

Consequently, investigations on the fourth objective had also to be restricted.

3.2 Concepts utilised

A simple and novel design concept is utilised in this project for the mechanical collection of Salvinia. This concept makes use of a high velocity water jet to fluidize and pump out the weed. The equipment consists of a low-cost high-capacity ejector device which, when used in combination with a medium or high head (pressure) centrifugal pump utilises the discharge of the said pump to suck an additional quantity of water through the device (Fig.5). The passage of pump discharge in the form of a high velocity jet of water causes the energy to be transferred to the stationary column of water present in the device. The movement of this otherwise stationary water with the jet, further results in drawing additional auantities of water through the suction side of the ejector. The quantity of water thus sucked into the ejector system may be several times the discharge capacity depending on the discharge pressure developed by the centrifugal pump. If now the suction mouth of ejector device is brought near to free floating weeds such as Salvinia, the induced flow of water would exert sufficient suction force to draw the weed materials also into the system. The weed, thus drawn-in is pumped out as a fluidized mass.

A significant feature of this simple technique is the

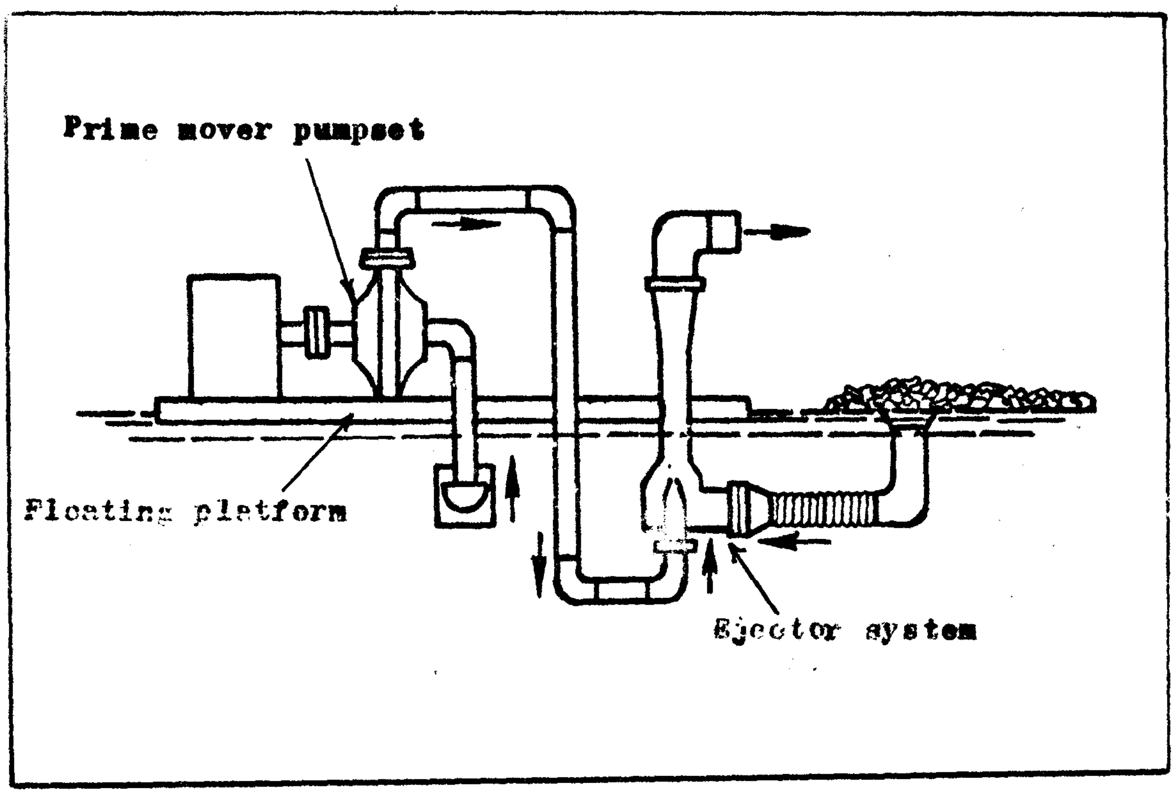


Fig. 5. Schematic representation of prime mover pumpset and ejector system.

fact that it does not allow the weed materials to be drawn into the centrigugal pump and clog its casing. The technique also allows the use of any locally available portable engine, power tiller or a tractor driven pumpset as the prime mover, which permits a reduction of the fixed costs of operation to be apportioned to the machine as a harvesting unit.

3.3 Preliminary studies

3.31. Experimental Salvinia Harvesting Machine.

In order to examine the applicability of the fluidization technique outlined in the previous section an experimental Salvinia Harvesting Machine was designed and constructed (Plate No.3). This machine consisted of three major compoments:

1. A light weight 5 H.P, 3600 r.p.m 'Greaves Lombardini' Diesel engine coupled to a 30-110 ft. head, 3600 r.p.m "TEXMO" pump which was used as the prime mover pump set.

2. A high capacity ejector device designed to suit the head capacity characteristics of the above prime mover (Appendix 3) which was used as the ejector system.

3. A specially designed small sized floating platform (Appendix 4) on which the prime mover pumpset and the ejector system were mounted.

The prime mover could be either mounted on shore or on the floating platform. In both cases, the ejector system was plamed below the water level. The delivery side of the prime

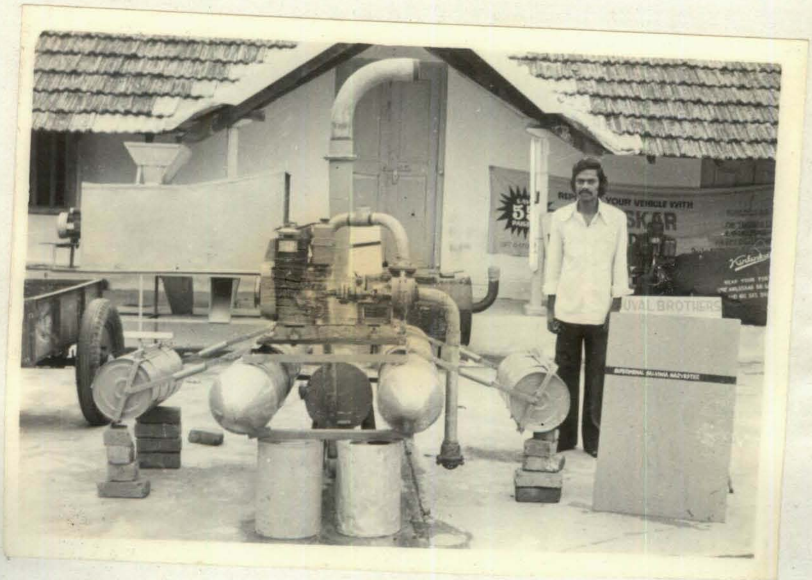


PLATE. 3. EXPERIMENTAL SALVINIA HARVESTING MACHINE ON DISPLAY.

mover was connected to the inlet of the ejector system nozzle, using standard pipe pieces and fittings. There was flexibility for operating the prime mover pumpset either independently or in combination with the ejector system.

In operation, when the centrifugal pump is started after priming, water is drawn through its (primary) suction pipe and delivered forcefully to the nozzle of the ejector system. The nozzle converts the high pressure water to a high velocity jet of water. This jet of water causes the stationary water in the ejector system to move with it. An induced flow of water is simultaneously created at the ejector (secondary) suction and a large volume of weed-water mixture is drawn in. The combined flow is then forced out through the delivery pipe of the ejector system.

3.32. Preliminary experiments:

The initial tests were conducted in a local pond (Reservoir) attached to the Panchayath Office at Mannuthy. In the first series of experiments, the prime mover pumpset together with the ejector system was operated as a shore mounted unit. The vertical ejector system which had a nozzle size of 23 mm diameter was placed in such a way that the suction chamber remained below the water level. A flexible pipe was used for inter-connection between the prime mover and the ejector system. The ejector system was operated at a lift of over one metre to reach above the height of the drum into which the water was being collected for measurement.

A 200 litre capacity oil drum was used for measuring the discharged water. A stop watch (Racer) was utilised to note the time for filling the drum. A total of three sets of tests were conducted in this series of which two sets of tests, each replicated thrice, were conducted to determine the primary flow alone and the combined (primary and secondary) flow from the pumping system. In a third set of tests, the secondary suction was allowed to draw the weed also into the system. Readings were taken on the time taken for the weed-water mixture to fill the 200 litre drum. After each test the weed material from the drum was taken out by hand and weighted immediately in a drip-dry condition.

In the second series of experiments, the prime mover and the ejector system were mounted on the specially designed floating platform. The prime mover was fixed to wooden planks on the platform. The ejector system was, as before, mounted, in a vertical orientation, using a hinge mechanism so that the suction chamber would be below the water surface. An important modification introduced in the float mounted experimental Salvinia Harvesting Machine, was that a 75 mm non-return valve replaced the 50 mm flap type foot valve used in the shore mounted unit. Accordingly, the entire suction line was also changed to 75 mm in size. In this machine, the length of the inter connection between the prime mover and the ejector system was considerably reduced which gave the additional advantage of reduced frictional losses between the centrifugal pump and the ejector nozzle. Observations on the performance of the floating platform were made, Two sets of tests were also conducted to separately assess the improvements in the primary flow and the secondary flow obtained from the unit. However, due to the absence of the weed in the pond during the second series of experiments, the extent of Salvinia collection possible from the machine could not be ascertained.

3.4 Main experimental programme.

3.41. Prototype Salvinia Harvesting Machine:

The preliminary studies made on the experimental Salvinia Harvesting Machine had given encouraging results. An assessment of the data showed that approximately 12% by weight of weed material can be pumped, by the adopted fluidization principle, for a given rate of pumping. This in turn indicated that prototype systems based on this technique could become economically viable. Accordingly, it was decided to develop a prototype Salvinia Harvesting Machine for final performance evaluation.

3.42. Design criteria:

The following design criteria were drawn up based on the inferences drawn from the preliminary experiments.

1. The machine may have a 10 H.P power source, similar to that of power tillers; generally accepted as a suitable size of power to provide sufficient output capacities in small scale operations.

2. The primary pump should develop higher pressures than that obtained in the preliminary experiments so that the ejector system can be designed for higher flow ratios.

3. The ejector system should avoid priming problems and at the same time provide various incremental heights of pumping.

4. The unit should fully utilize the self propulsion characteristics already observed.

5. The unit should negotiate narrow canals and at the same time should have sufficient stability.

6. The unit should be of low-weight and easily dismantlable to facilitate transportation and testing at various sites.

7. The machine should be made of locally available materials and capable of being fabricated in a small workshop.

3.43. Main components and Assembly.

Based on the design criteria listed above, a 10 H.P prototype Salvinia Harvesting Machine was designed (Appendix 3 & 4) and fabricated. The machine consisted of the following major components.

1. Two 5 H.P light weight diesel engine pump sets('Lombardini' Diesel Engine coupled with 'Texmo' pump) serving as the prime mover.

2. A floating platform of the catamaran type (Appendix 4) with stream lined frontal ends and telescopic stablizer floats on either side.

3. A horizontally disposed higher capacity ejector system (Appendix 3) which was a modified version of the original device utilised in the experimental unit.

The design procedure adopted for the prototype machine was similar to that of the experimental unit. A schematic of the component layout, and an isometric view of the prototype machine are shown in Figs. 6&7 respectively. The two prime mover pumpsets were connected in series (Plate 4) in order that the additive pressures of the individual pumps could be obtained for the complete system. Plate 5 shows the floating platform on which the prime mover pumpsets alone have been mounted. The constructional features of the floating platform, were the same as those in the earlier experimental unit. The pontoon however utilized larger sizes of cylindrical barrels of 80 lt. capacity to obtain adequate buoyancy and deck area with reasonable proportions(3.6m long and 0.85m wide) in the overall size of the unit. Another unique feature of the floating platform was its associated telescopic stabilisers on both sides of the main hull for additional lateral stability. The arrangement permitted frontal ends of the stabilizer floats also to be made conical in shape. A spring loaded bumper made out of G.I pipe (not shown in the figures) was provided at the front of the machine for added protection.

The prototype ejector system(Fig.8), which had a nozzle of size 20 mm, a throat of 75 mm and rest of the components with dimensions suitably proportioned, was mounted longitudinally, below the platform. The ejector system was pivoted in the centre

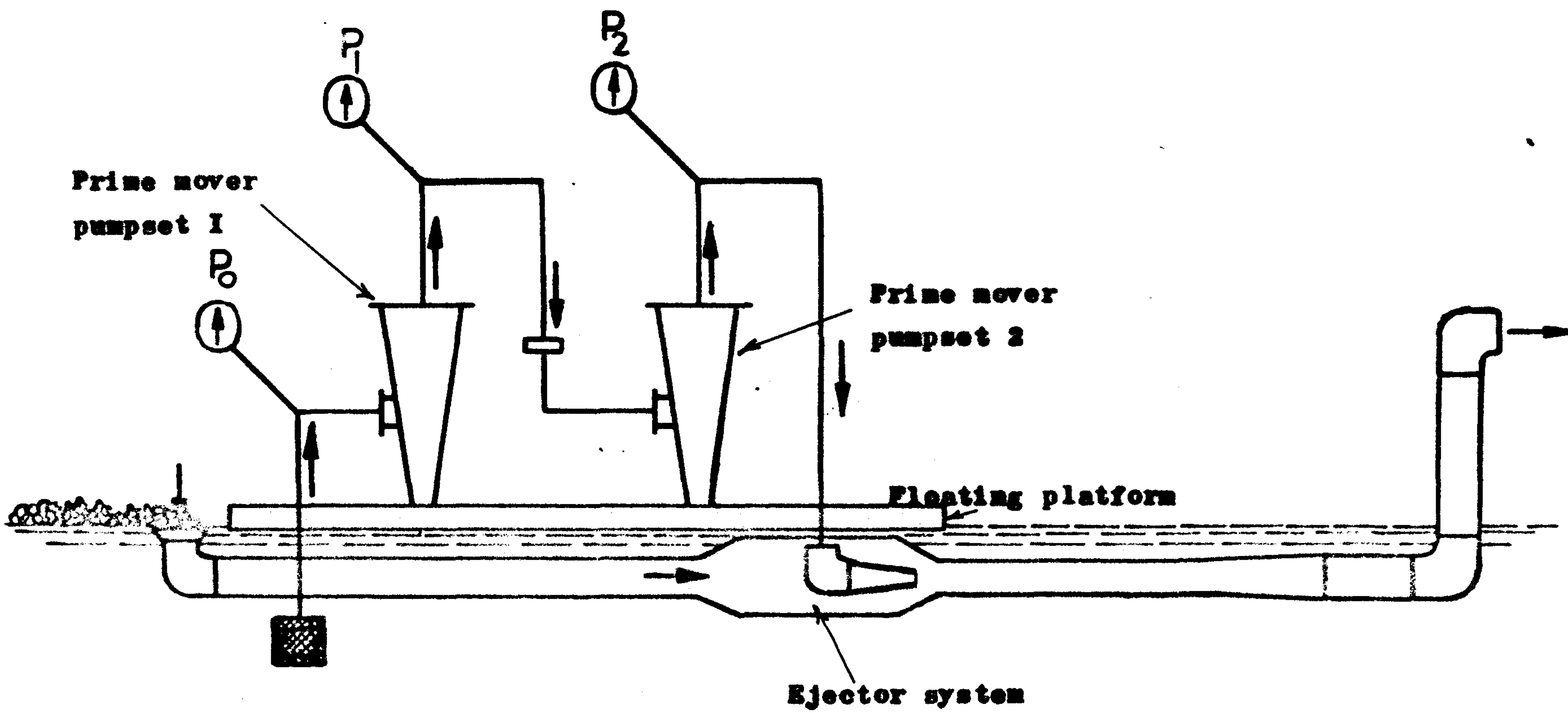


Fig. 6. Schematic of 10 H.P prototype Salvinia Harvesting Machine

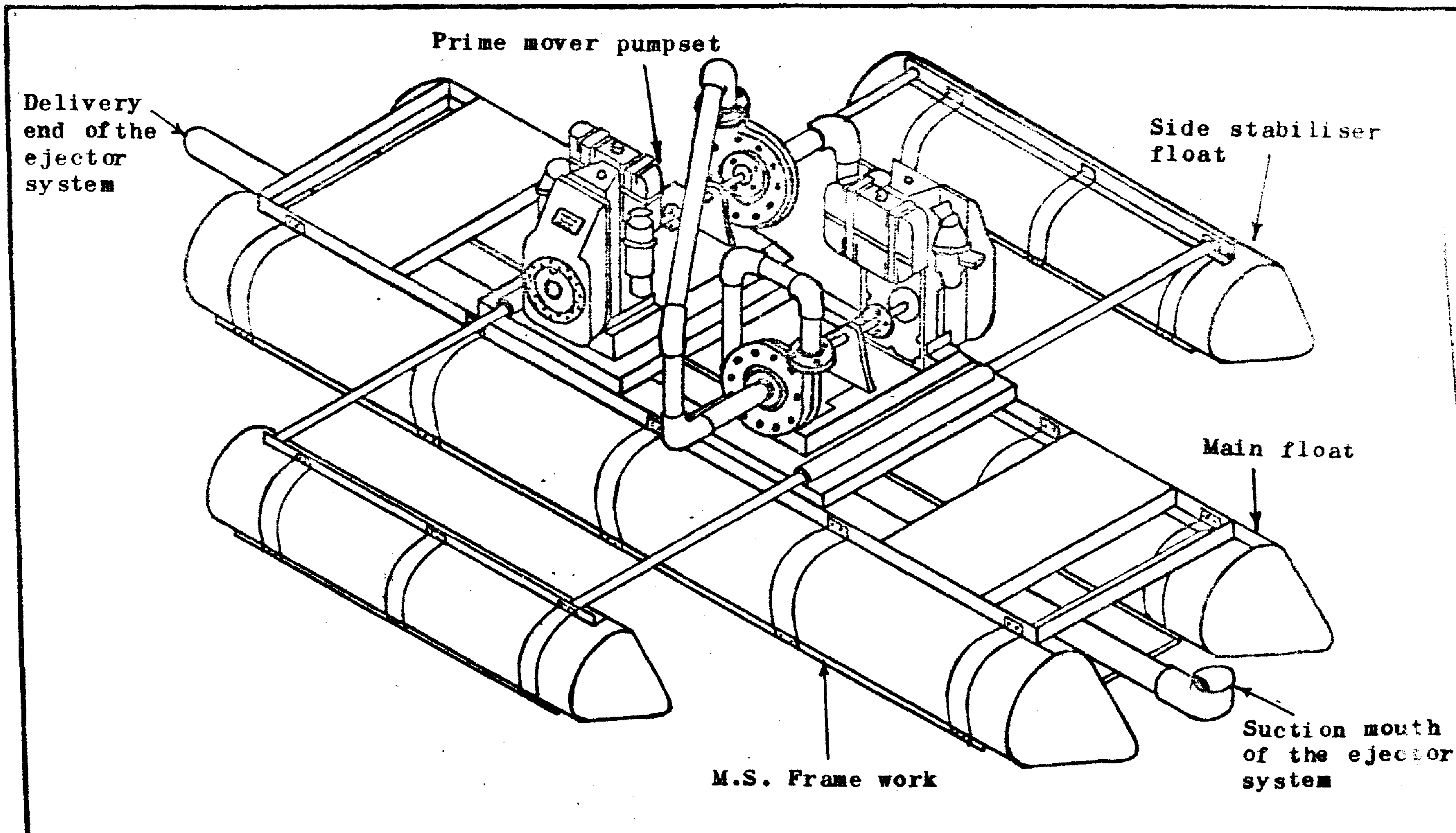


Fig. 7. Prototype Salvinia Harvesting Machine - Isometric view.

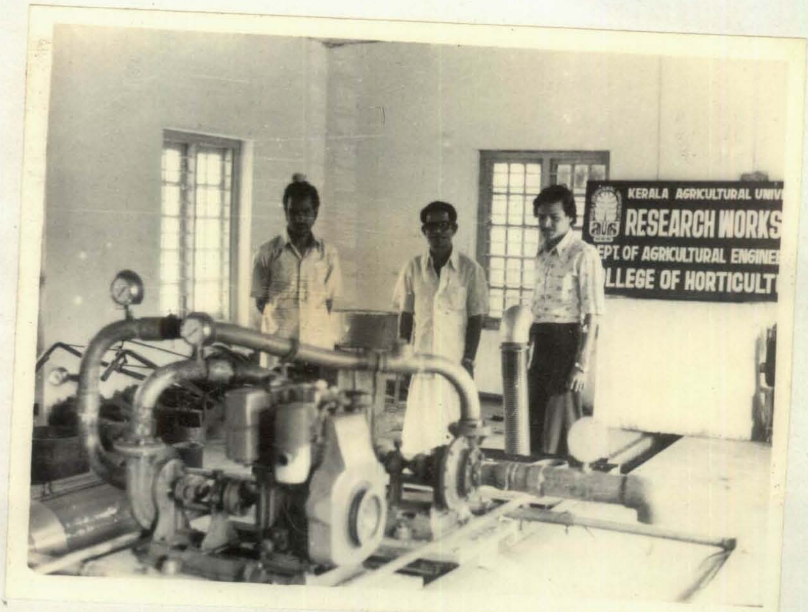


PLATE.4. SERIES CONNECTION OF THE PUMPSETS-PROTOTYPE SALVINIA HARVESTING MACHINE.

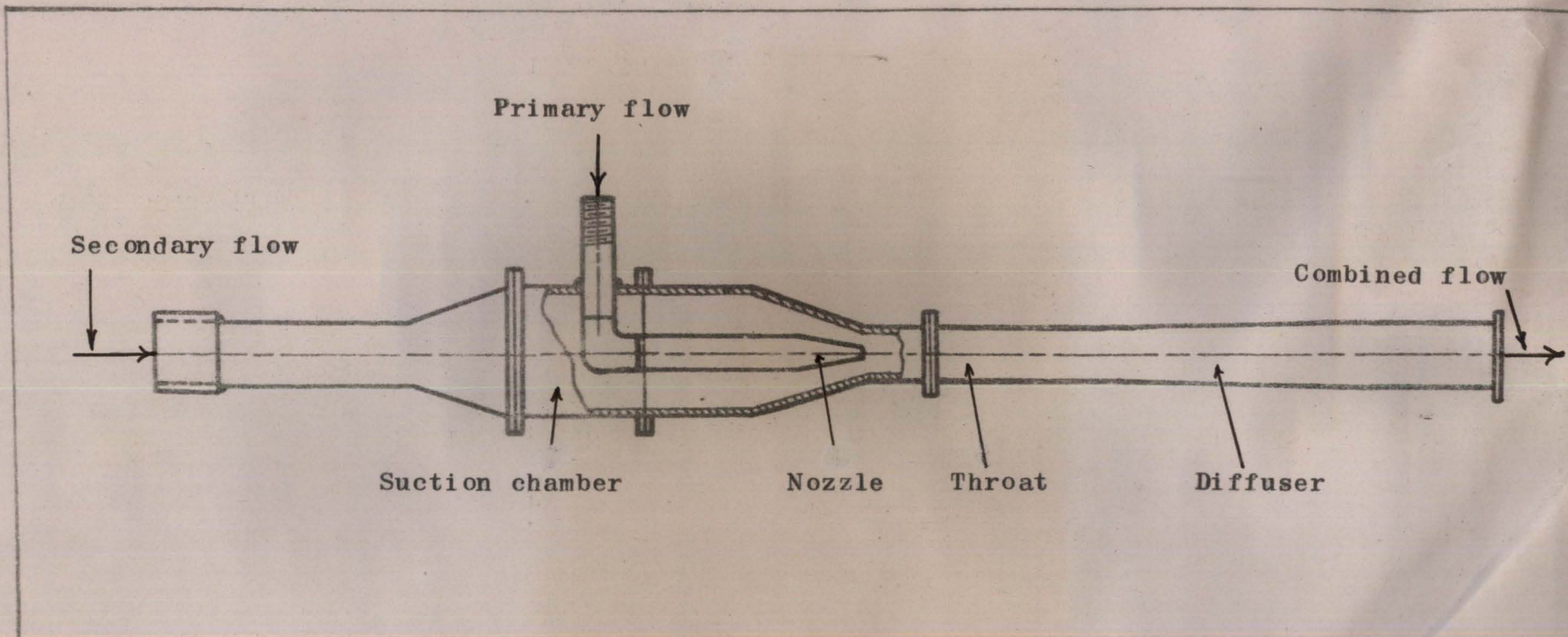


Fig. 8. Prototype ejector system

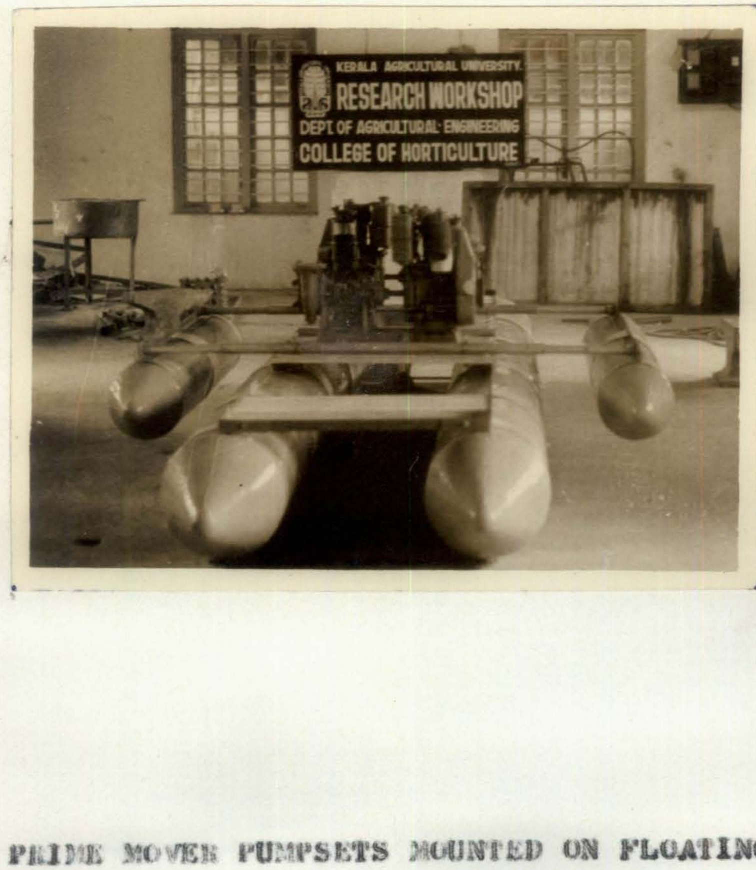


PLATE. 5. PRIME MOVER PUMPSETS MOUNTED ON FLOATING PLATFORM.

for ease of movement in the vertical plane. The entrance of the weed-water mixture was through a 100 mm elbow fitted at the end of the secondary suction. The elbow remained below the water level with its open end facing the surface of the water. The position of the elbow with respect to the water surface could be adjusted by a socket and rod arrangement. The discharge end of the ejector system was fitted with 100 mm flexible extension pipe and G.I bends to deliver the weed-water mixture to any desired height(Plate 6). Threaded connections were used for the extendable portions of both the suction and delivery ends of the ejector system so that they could be dismantled easily for inspection.

3.44. Accessory units.

In addition to the main harvesting machine, certain accessory units were also developed to provide greater swath width of collection and to facilitate filtering, loading and transportation of the harvested weed materials. They included a gathering arm, a filtering system and a floating fence.

1. Gathering arm: It was observed that at the suction mouth of the harvesting machine, the weed materials were drawn into the ejector system due mainly to the whirlpool that was formed. The influence radius of this whirlpool being limitted to between 30 and 50 cm. some external assistance was necessary to bring the materials continuously to this influence circle. The feeding was automatically accomplished when the machine was

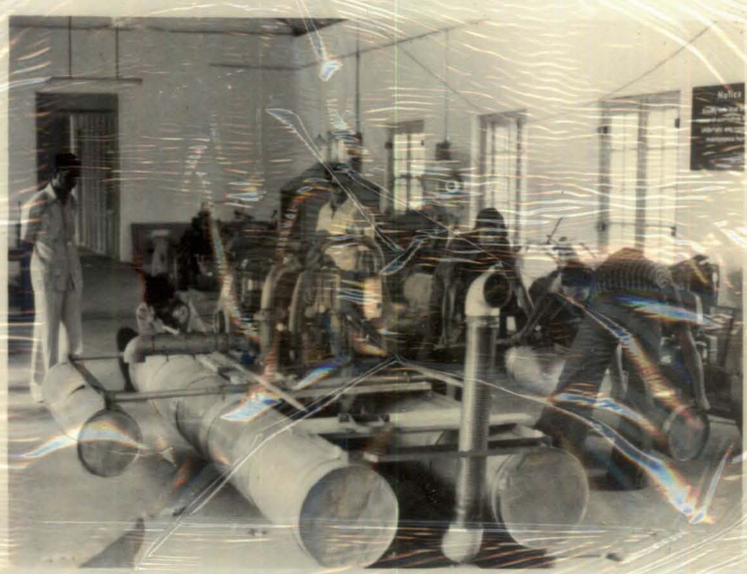


PLATE. 6. PROTOTYPE SALVINIA HARVESTING MACHINE WITH RAISED DISCHARG END OF EJECTOR SYSTEM.

operated as a mobile unit. But, on operating the machine as a stationary unit, the weed materials had to be fed to the suction mouth by encircling them with a rope and pulling the two ends of the rope towards the machine. When the weed materials present were scanty and highly dispersed, the collection rate became drastically low in the former method. It was thought that this situation could be improved if the materials from a wider swath width could be gathered as the machine moved forward. Accordingly, a gathering arm was designed and fabricated, a schematic of which is shown in Fig.9.

This was a V shaped angle iron frame which had an arm length of approximately 1½ metres each and a height of 30 cm. The space within the frame was covered by means of weldmesh of 12 mm size. The gathering arm was fitted to the front end of the machine. As the machine was propelled forward, the arm gathered the weeds from a swath width of approximately 2 m. The weeds thus gathered were found automatically being fed to the suction mouth of the ejector system. This in turn greatly improved the feeding process of the machine under conditions of scanty weed population.

2. Filtering system: The original filtering system consisted of a trapezoidal, perforated trough made of angle iron frame and fitted with wirenet. It had an open edge to which one end of a suitably sized perforated platform was hinged. When the weed materials were to be loaded to a country boat or unloaded to the adjacent shore, the unit was mounted in such a way to

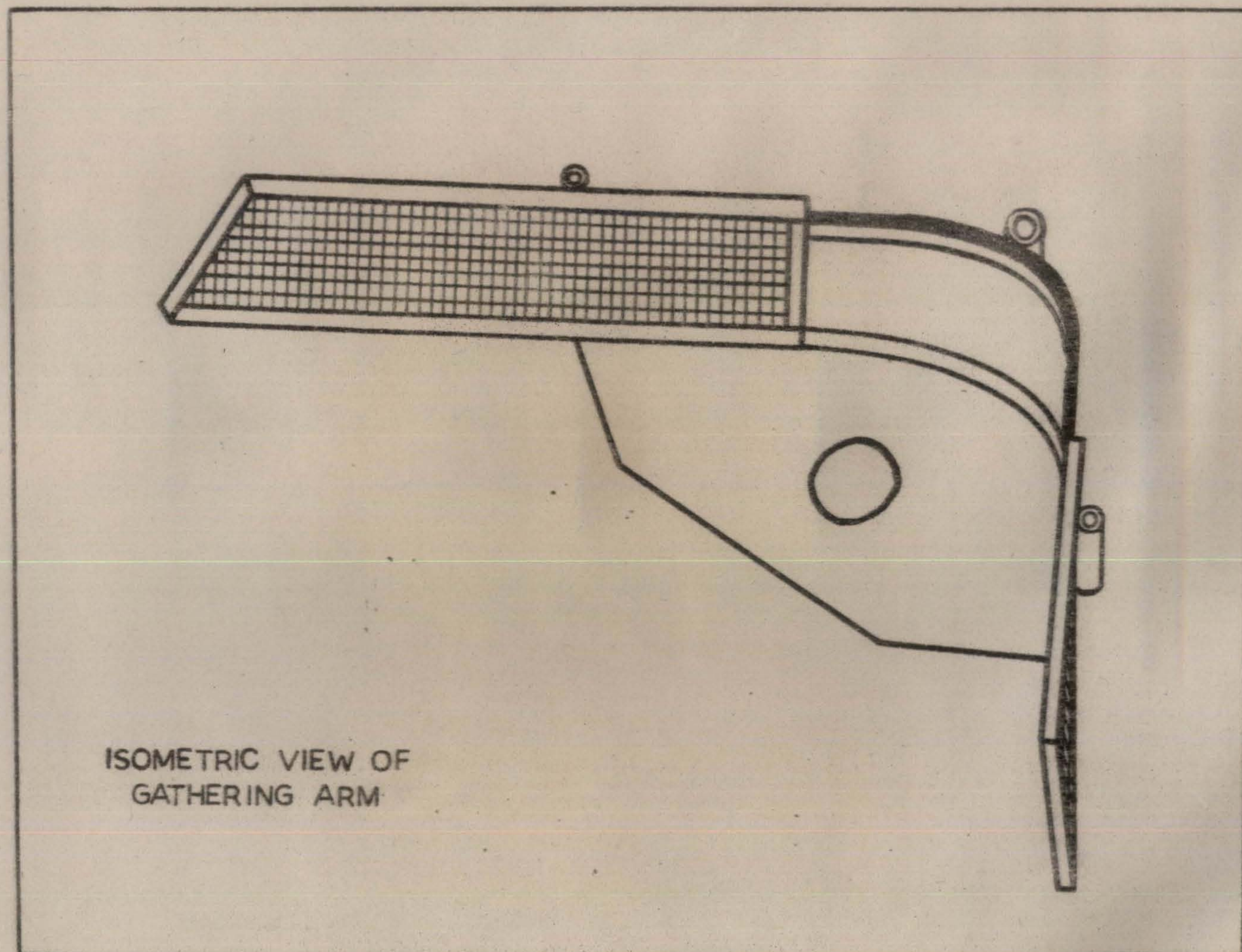


Fig. 9. Isometric view of gathering arm

face this open edge towards the boat or to the shore. When the weed-water mixture was pumped into this trough, the water drained off by gravity while the weed materials were retained. As more and more weed materials accumulated, they escaped through the open edge and slid along the slopping platform into the boat or to the shore in a drip-dry condition.

A modified version of the above filtering unit was developed while conducting field tests at Kumarakam. This modified filtering unit (Plate 7) enabled the pumping of weed-water mixture at zero head and eliminated the problems of inadequate filtering noticed in the previous unit. The unit mainly consisted of a U-shaped cylinderical filter section made up of flat iron frame and fitted with wirenet. The frame was extended vertically to form a rectangular enclosure keeping one of the sides open. The frame was also extended horizontally and floats were fitted at both ends. This enabled the filtering system to stay afloat as an independent filtering unit. It also permitted country boats to be easily attached or dis-engaged from under the filtering unit. After attaching the filtering unit to the country boat, the delivery pipe end of the harvesting machine was inserted to the bottom end of the filtering section. Thus, the weed materials could be pumped at zero head into the filtering section as opposed to the definite pumping head requirements of the original filtering system.

3. Floating fence: The floating fence (Fig.10) consisted of a

PLATE. 7.   MODIFIED FILTERING UNIT.

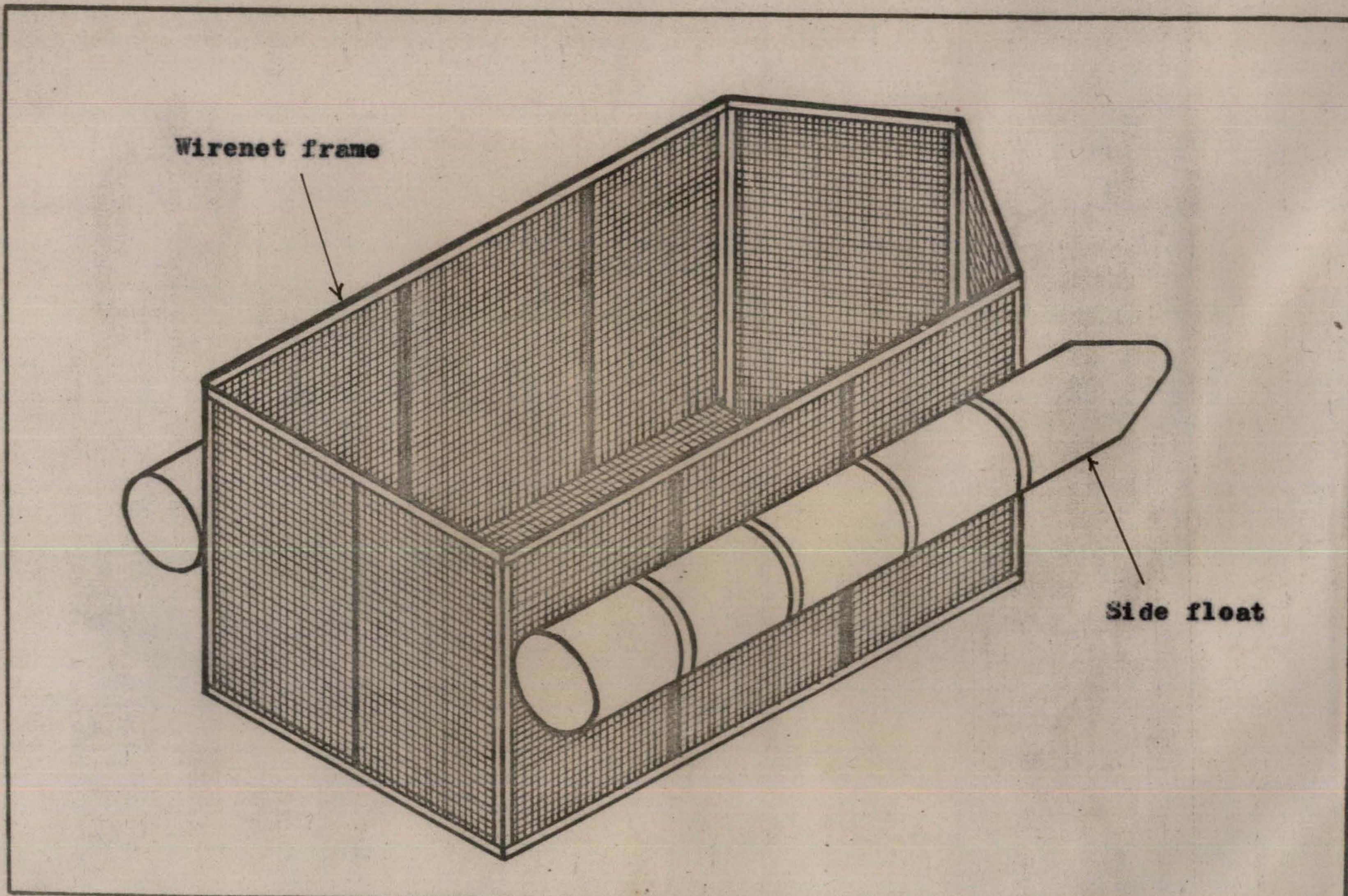


Fig.10. ISOMETRIC VIEW OF FLOATING FENCE

rectangular open top container (2.75m x 1.2m x 1m) made of flat iron and wirenet. The frame work was supported by floats mounted on either side. The fence, thus formed could hold the materials pumped into it as a floating island. The frontal ends of the fence as well as those of the floats were made conical in shape to reduce resistance in forward motion. The speciality of this type of unit was that large quantities of the weed could be collected virtually at zero head and hauled to a different site without the structure having to bear the weight of the weed-materials.

3.45 Test procedure:

The main experiments were in general devoted:

1. to study the general performance of the prototype floating platform.
2. to determine the performance features of the combination of the prime mover pumpset and ejector system such as the primary flow, secondary flow and pressure developed at various sections.
3. to study the physical properties of the Salvinia weed such as its spread density, bulk density etc. under actual field conditions.
4. to study alternative approaches to feeding, pumping and filtering of the weeds utilising the prototype harvesting machine and determine the suitability of each and
5. to study potential disposal and utilisation techniques for the weed.

The test procedure followed was in general similar to that explained in section 3.32. The main experiments were conducted in five stages at different locations shown in Table 4.

Table 4. Site locations at which the main experiments were conducted.

Stage	Site	Location and distance from the Headquarters
1	Local pond	Near H.Q, 3 Kms.
2	Chettupuzha kole land	Trichur kole land, 18 Kms.
3	Mancompu Rice Research Station.	Kuttanadu region, 275 Kms.
4	Kidangara water canals	Kuttanadu region, 275 Kms.
5	Kumarakam Coconut Research Station	Kuttanadu region, 275 Kms.

3.45.1 First Stage testing - at Local pond: The 10 H.P prototype Salvinia Harvesting Machine was first tested in the local pond. This testing was done mainly to assess the general performance characteristics such as stability, bupyancy and self propulsion features of the floating platform and the flow rates and pressures developed in the prime mover and ejector systems.

The machine was transported, using a 25 H.P 'Zeetor' tractor and trailor, with its major components dismantled into separate sub-assemblies. Plate 8 shows the machine components being unloaded from the trailor and the floating platform

a) Floating platform being unloaded from tractor-trailor

b) Floating platform being launched into the water

PLATE. 8. LAUNCHING OF SALVINIA HARVESTING MACHINE
IN LOCAL POND.

being first launched to the water. The ejector system was then fitted (Plate 9 a) underneath the platform. With the prime mover pump sets mounted on the platform and appropriate pipe connections provided, the machine was ready for operation (Plate 9 b). During the course of the tests there was only a scanty population of the weed in the pond as it had been manually cleared earlier. The machine could therefore be tested both with and without the gathering arm.

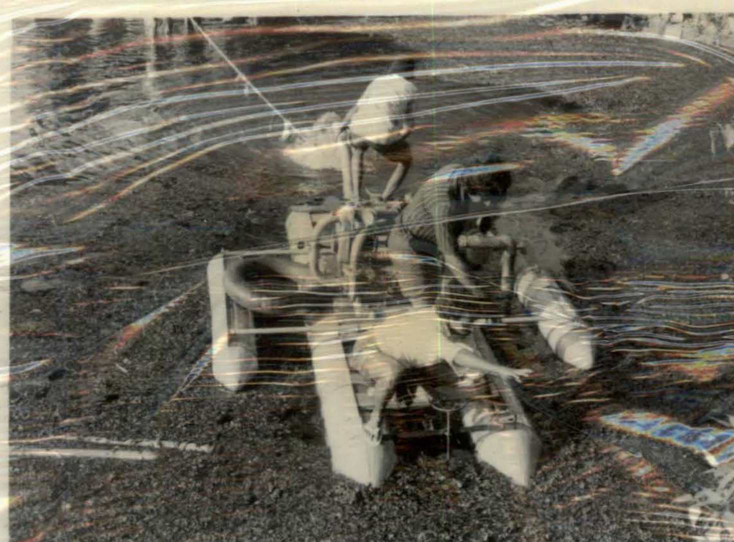
3.45.2 Second Stage Testing - at Chettupuzha: In order to assess the performance, in clearing weed-infested paddy fields, the machine was taken to a site at Chettupuzha, in the kole lands of Trichur. The field had standing water of more than 1 metre deep. The weed materials appeared to be in a packed condition at the windward corner of the field.

The series of tests conducted at Chettupuzha site consisted of 1. spread density measurements 2. bulk density measurements 3. pumping of Salvinia into country boat 4. pumping of Salvinia directly to the adjacent bank 5. pumping of Salvinia to the shore through the original filtering unit 6. pumping of Salvinia into floating fence under low head 7. pumping of Salvinia into floating fence at zero lift condition. 8. pumping of Salvinia into floating fence at near zero head condition and 9. pumping of Salvinia into a fermentation pond.

Test No.1. Spread density measurements:

For measuring the 'spread density' the weed population

a) Floating platform fitted with ejector system



b) The machine moving as a self propelled unit

PLATE. 9. TESTING OF SALVINIA HARVESTING MACHINE IN LOCAL POND.

was encircled by means of coir rope tied around poles fixed one metre apart in the field. The material present within this one square metre area was manually collected into a trough with perforated bottom and weighed by means of a spring balance. Samples were taken from three locations in the windward corner of the field having apparantly different spread densities.

Test No.2. Bulk density measurements:

In order to obtain measurements of bulk density values of the weed under actual field conditions, a rectangular cage of size 50 cm x 50 cm x 100 cm was constructed using M.S rods and wire net materials. The cage which had an open top was manually filled to its full height of 1 metre and weighed (Plate 10) by means of a spring balance after allowing sufficient time for the surface water to be drained off by gravity. Weight of the full cage minus that of the cage alone gave the weight of 0.25 cum. of the weed from which the bulk density was calculated.

Test No.3. Pumping of Salvinia into country boat:

Initially the machine was attached to an 8 tonne capacity country boat and moved forward by punting. The weed material pumped by the machine was collected into the boat through the original filtering unit. Fif. 11 shows a schematic of the test configuration in which the pumping height was fixed at about 1.25 metres. This lift was required for conveniently unloading the material through the filtering system into the boat.

PLATE. 10. WEIGHING OF SALVINIA WEED AT CHETTUPUZHA SITE.

Only a single test was performed in which the time taken to fill the boat was noted.

Test No.4. Pumping of Salvinia directly to an adjacent bank:

The actual operations of loading of Salvinia from the trough into the boat and finally unloading the same on to the shore by manual methods were found to be time consuming and tedious. Hence, attempts were made to pump out the weed materials directly to the shore by fixing a wire net fence along the bank and pumping the weed-water mixture over the net on to the bank. This experiment was in the form of an observational trial in which no measurements were taken.

Test No.5. Pumping of Salvinia to shore through the original filtering unit:

In this test, the machine was anchored near the shore along with the filtering unit. The weed materials were pushed manually to the suction mouth and pumping was made directly to the trough of the filtering unit. As the water was drained the relatively dry material was scrapped down the slopping platform of the filtering unit to the shore. The weed collected on the shore was weighed for test durations of one minute each.

Test No.6. Pumping of Salvinia into the floating fence at low head condition:

In this test the pumping of Salvinia was made directly into the floating fence, keeping the harvesting machine stationary. The height of pumping was approximately 80 cm. The test configuration of the equipment involved was as shown in Fig.12.

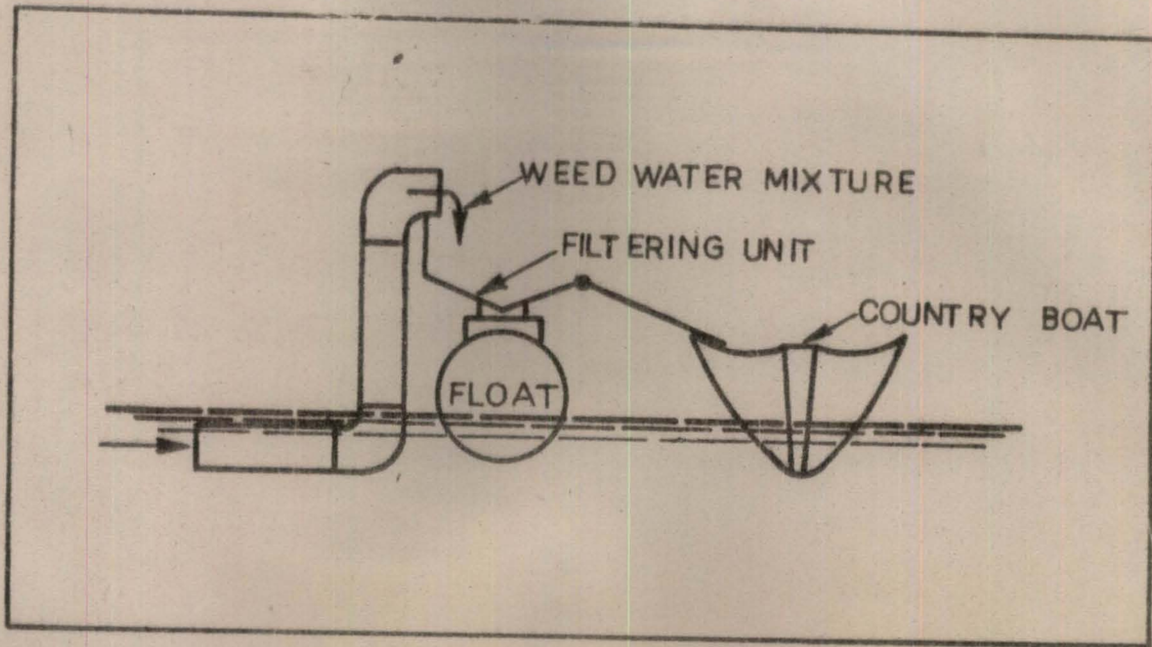


Fig. 11. Configuration of pumping of Salvinia into a country boat.

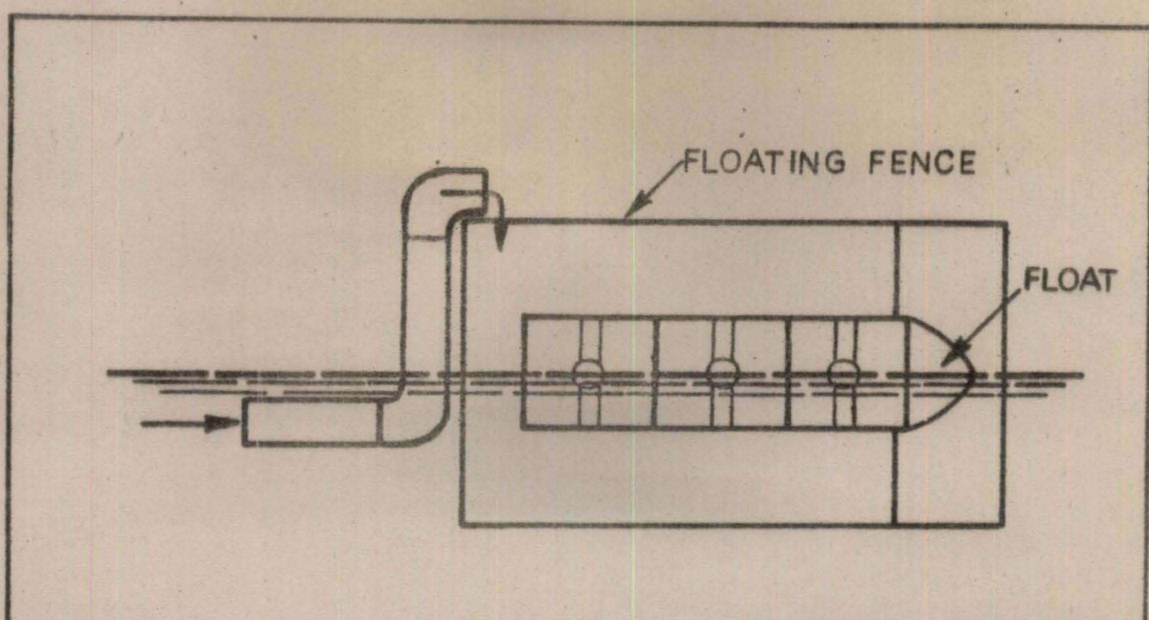


Fig. 12. Configuration of pumping of Salvinia at low head condition.

Repeated tests of one minute duration were made and the weed collected in each test was separately weighed.

Test No.7. Pumping of Salvinia into floating fence at zero lift condition:

The configuration used in this test was as shown in Fig.13. The zero lift condition was obtained by extending the discharge pipe of the previous test configuration vertically downwards to reach the water surface inside the floating fence. This way it was expected that increased discharge capacity could be obtained. Only an observational trial was conducted with this configuration.

Test No.8. Pumping of Salvinia into floating fence at near zero head condition.

The configuration of the system in this test was as shown in Fig.14. In order to obtain the required near zero head condition, an opening was made on the rear side of the floating fence. The horizontal discharge pipe of the ejector system was extended and inserted into this opening after removing the bends and vertical extension pieces (Plate 11). Thus, the discharge pipe remained at the water level, providing an essentially zero head condition.

Test No.9. Pumping and disposal of Salvinia into a field fermentation pond:

Extensive handling was involved in transporting and unloading the weed materials collected in the floating fence. It was felt that much of this handling could be avoided if the

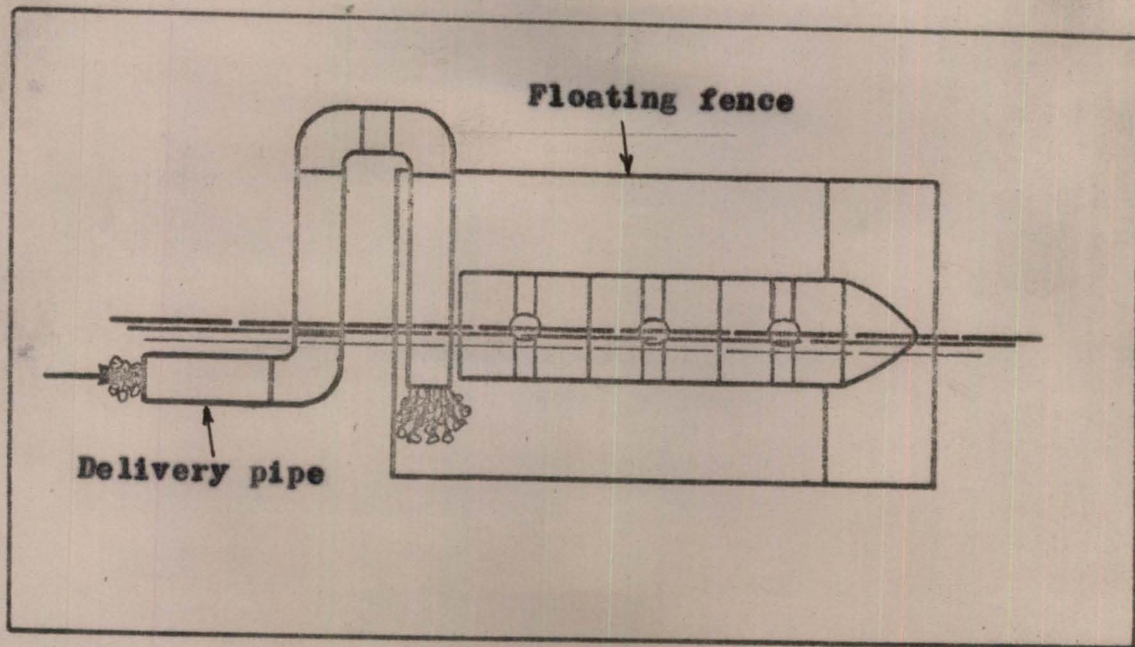


Fig. 13. Configuration of pumping of Salvinia at zero lift condition.

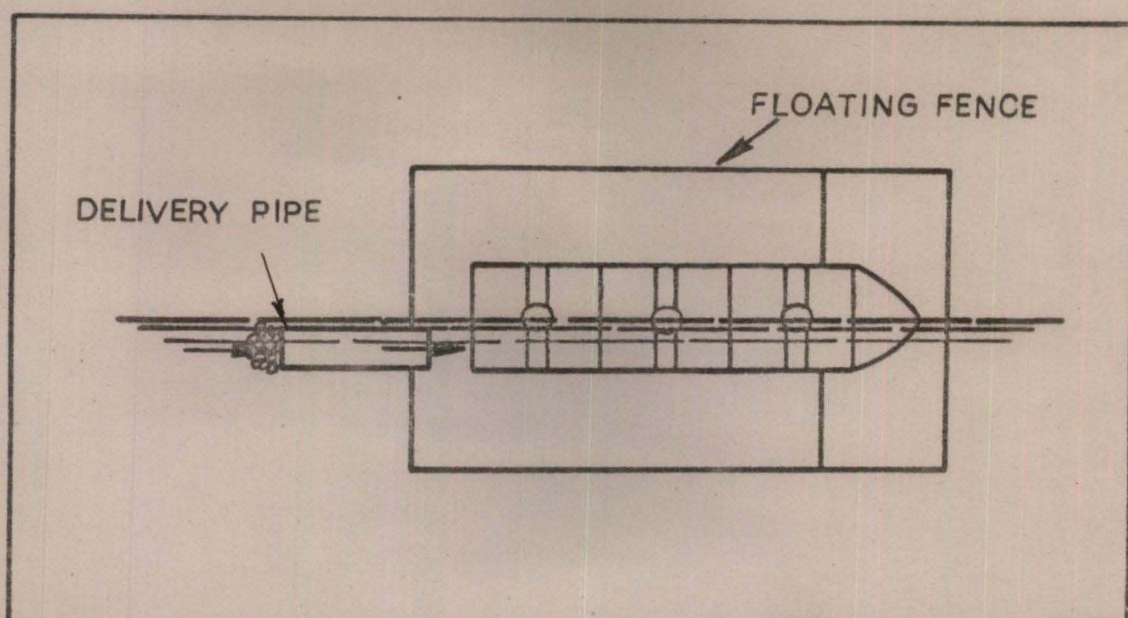


Fig.14. Configuration of pumping Salvinia at near zero head condition.

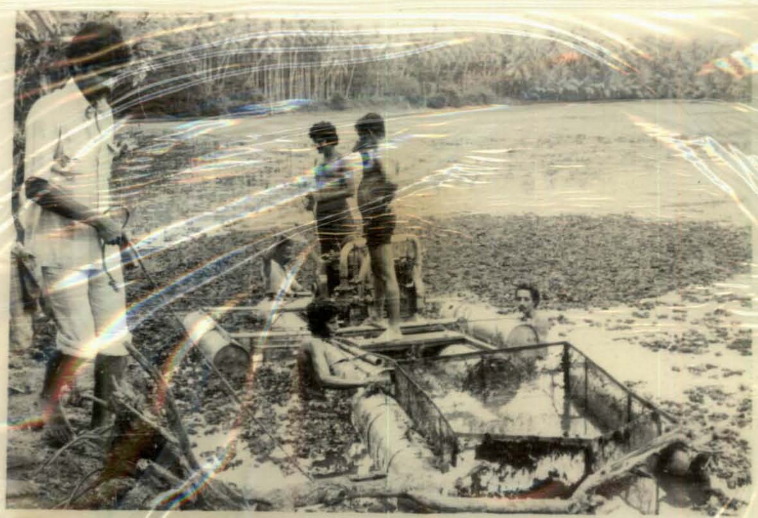


PLATE. 11. PUMPING OF SALVINIA INTO FLOATING FENCE.

material could be disposed in one corner of the field itself. This was accomplished by constructing a wirenet enclosure to serve the purpose of a field fermentation pond and pumping the weed materials into this enclosure. The enclosure was constructed in that corner of the flooded paddy field where the weed had naturally accumulated being blown by the wind. The machine was anchored near this fermentation pond and the weed was pumped into it virtually at zero head condition. As the weed-water mixture was pumped into the enclosure, the water was drained through the wirenet into the surrounding area while the weed materials remained inside the enclosure. For feeding the material to the stationary machine, the weeds were encircled by means of a rope and were gradually fed to the inlet of the machine by pulling the two ends of the rope together. The enclosure constructed was 16 m x 8 m x $1\frac{1}{2}$ m in size. The wirenet enclosure was later replaced by coconut cadjans and bamboo thatties with a view to economising on the cost of constructing such fermentation ponds.

3.45.3 Third Stage Testing - at Mancompu: After the field tests at Chettupuzha in the kole lands it was decided that the Salvinia Harvesting Machine should be further field tested in the Kuttanadu region also. The reasons for this decision were that (1) Kuttanadu region is one of the most heavily infested areas of the state (2) in this region different habitats and growth stages of the weed are encountered and (3) testing the machine in this area would yield additional information on the economics of its operation and the public reaction to its use under actual field conditions. The machine was therefore transported to Mancompu Rice Research Station using a 55 H.P "Hindustan" Tractor and trailor. At this site, the machine was tested again in a paddy field which was rather lightly infested by the weed.

3.45.4 Fourth Stage Testing - at Kidangara: The Salvinia Harvesting Machine was also tested at another site in Kidangara, 11 Km. from Mancompu. The shifting of the equipment was accomplished by operating it as a self propelled unit.

At Kidangara, an attempt was made to fabricate a second prototype Salvinia Harvesting Machine (Plate 12) utilising two country boats of approximately three tonne capacity each, to serve as the floating platform. Two additional pumpsets identical to those used in the original prototype harvesting machine were used in this set up. The ejector system was of the vertical type initially used in the 5 H.P experimental Salvinia Harvesting Machine. The throat size was kept at 75 mm and the nozzle was arbitrarily chosen to have a size of 25 mm which was already available. The ejector system was mounted between the boats and fitted with 150 mm PVC long radius bend at the delivery end. The whole machine was intended as a standby unit during demonstrations.

A public demonstration of the float mounted unit was also carried out at the Kidangara site. The machine was operated at zero head and the weed pumped into field fermentation ponds

PLATE. 12. COUNTRY BOAT MOUNTED SALVINIA HARVESTING MACHINE.

which were constructed with coconut cadjans and poles by the side of the canal adjoining the public road.

3.45.6 Fifth Stage Testing-at Kumarakam: The premises of the Coconut Research Station of the Kerala Agricultural University at Kumarakam consist of inter connected water channels of different sizes and bunds on which perennial crops are planted. The channels are severely infested by the Salvinia weed every year which inturn provided a favourable site condition for field tests. The station was therefore selected for the final series of tests with the Prototype Salvinia Harvesting Machine. The spread density values of Salvinia in each of the channels, which were to be cleared, were measured initially. The 'field fermentation pond' method of weed clearance was adopted. A suitable corner was selected for constructing the pond so that weeds from different channels could be gathered individually and fed to the Salvinia Harvesting Machine. The fence for the fermentation pond was constructed by wooden piles tied with coconut cadjans. The weed population in individual channels were then cleared with the machine. In each case, the area of the channel and the time taken for the clearing operation were noted. Additional tests were also carried out at Kumarakam to confirm earlier tests on the percentage of weed collected for a given rate of pumping. A country boat was utilised to collect the pumped weed-water mixture. The weed and water thus collected over a period of 60 seconds were manually separated. The weight of the weed and volumetric measurement

a) Filtering unit in operation

b) Closer view of filtering unit

PLATE. 13. COLLECTION OF SALVINIA INTO COUNTRY BOAT THROUGH MODIFIED FILTERING UNIT.

of the water were separately taken. The diesel consumption of each of the prime mover pump-sets was also noted.

Finally the modified filtering unit(Plate 13) which was constructed to facilitate automatic filtering and loading of Salvinia into country boats was tested at this site. The testing programme, which had extended to a period of over one month was concluded with a final demonstration of the equipment to the Vice-Chancellor of the Kerala Agricultural University.

Owing to time limitations, experiments relating to the formation of compost in the fermentation pond as well as on the utilization of the Salvinia weed for biogas production and hard board paper making could not be taken up.

3.5 Economic Analysis

In order to assess the economics of operation of the Salvinia Harvesting Machine, data regarding fixed and variable costs of the machine were either ascertained or calculated from direct measurements. The latter quantities included average spread density values, field capacity of the machine and fuel consumption rates. The operating cost of the machine was then calculated by Standard methods using the above values and appropriate assumptions on a per hectare basis as detailed in Appendix 5.

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Preliminary Experiments

4.11 Shore mounted unit.

The results of the preliminary experiments in which the prime mover pumpset was operated as a shore-mounted unit along with the vertical ejector system are given in Table 5.

Table 5. Pumping rates of shore mounted 5 H.P Prime mover pump-set with vertical ejector system at a static lift of over one metre.

Trial No.	Speed of prime mover (r.p.m)	Pressure (kg/cm^2)	Primary flow alone: Water collected (lt)	Time taken (sec)	Rate of pumping (l.p.m)	Primary flow + Secondary flow: Water collected (lt)	Time taken (sec)	Rate of pumping (l.p.m)
1	3300	2.0	200	27	440	200	11	1090
2	3300	2.1	200	25	480	200	10	1200
3	3300	2.05	200	28	430	200	10	1200
	Average rate of flow				450			1163

It may be seen from the table that the primary flow obtained was of the order of 450 l.p.m at a discharge pressure of 2.05 kg/cm2. It is to be noted that as per the head-capacity performance of the pump, calculated for 3300 r.p.m from the data supplied by the manufacturers, the best efficiency values were

440 l.p.m and a head of 24.87m. Again, the values determined for the pump for this speed, in the test conducted at the Engineering College, Trichur, were 460 l.p.m and 25m as shown in Fig.15. Therefore, with a primary flow of 450 l.p.m, we can reasonably assume that the pump was operating at its best efficiency point and that the nozzle design has given satisfactory performance. The combined flow which includes the primary flow from the prime mover pumpset and the secondary flow drawn-in by the ejector system was of the order of 1163 l.p.m. This in turn gave a capacity ratio(M) for the ejector system = (1163-450)/450=1.6. This value was lower than the designed capacity ratio of 2 explained in Appendix 3 A. The difference in performance is attributed to the low input head received by the ejector system on account of losses, in the conventional foot valve and excessive length of delivery pipe used for the prime mover pump.

The results of the test conducted on the rate of pumping of weed materials is shown in Table 6.

Table 6. Rate of pumping of weed materials with 5 H.P prime mover pump at a static lift of over one metre.

Trial No.	Speed of pumpset (r.p.m)	Pressure (kg/cm^2)	Time (sec)	Weight of weed (kg)	Rate of pumping (kg/mt)	of weed (T/hr)
1	3300	2.05	10	10	60	3.6
2	3300	2.10	10	15	90	5.4
3	3300	2.00	10	18.5	111	6.7
4	3300	2.00	10	17	102	6.1
			Average rate of pumping			5.5

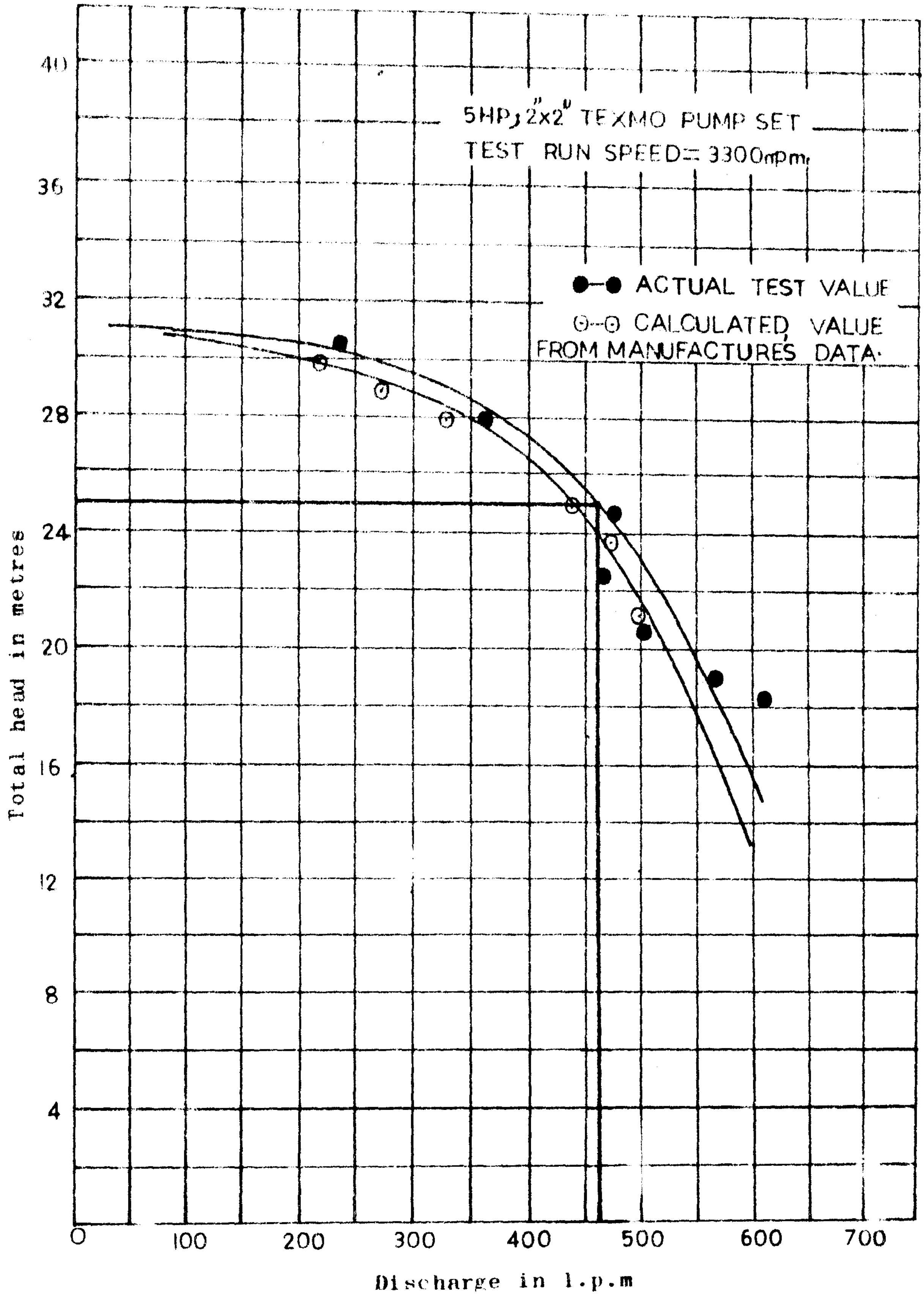


Fig. 15. COMPARISON OF PERFORMANCE CURVES OF PRIME MOVER PUMPSET

It may be seen from the table that the time taken to fill the 200 lt. capacity drum was a flat 10 seconds in all the four trials which was again identical to that obtained in Table 5. This indicated that whether it was water alone or the weed-water mixture that was pumped, the volume rate of flow was being maintained. The table also shows that the quantity of weed collection varied from 10 to 18.5 kg. within this 10 second period. This in turn indicates that there can be substantial influence on the rate of weed materials pumped by the methods of feeding provided at the inlet.

It is unfortunate that the volume of water remaining in the drum was not measured at the end of each test in this series. However, taking the bulk density (weight/volume) value of Salvinia from the table 12. to be 400 kg. per cubic metre, the volume occupied by the collected weed as well as the quantity of water remaining in the drum can be calculated. The calculated values are tabulated in Table 7. This table also shows the quantity of weed collected both as percentage of the weight rate of flow of the weed-water mixture and of the water alone in the mixture. The range of values obtained is from 5.4 to 12%. Table 8, shows the rate of collection of weed as a percentage of the weight rate of total flow and secondary flow obtainable from the system. The values obtained varies from 5.2% to 15.6%. Of the various percentages given in Table 7 and 8, the one based on the secondary flow if water alone were pumped by the ejector system appears to be of greatest interest. The range of percentage rate of collection

Table 7. Volume of weed and water in the weed water mixture along with percentage rate of collection of the Salvinia weed.

Sl.No.	Weight of weed in 200 lt. of weed-water mixture for 10 sec. time (kg)	*Calculated volume of weed in the mixture (lt)	Calculated volume weight of water in the mixture (lt/kg)	Percentage of collected weed	
				Based on wt. of weed water mixture (%)	Based on wt. of water alone in the mixture (%)
1	10.0	25.0	175.0	5.4	5.7
2	15.0	37.5	162.5	8.5	9.2
3	18.5	46.3	153.7	10.8	12.0
4	17.0	42.5	157.5	9.8	10.8
				Average	9.4

*Bulk density of weed = 400 kg/cu.m

Table 8. Percentage rate of collection of weed based on weight rates of total flow, and secondary flow from the ejector system.

Sl.No	Weight of weed collected (kg/sec)	Percentage of collected weed	
		Based on total flow of 19.4 lt/sec. from Table 5. (%)	Based on secondary flow of 11.89 kg/sec.from table 5. (%)
1	1.00	5.2	8.4
2	1.50	7.8	12.6
3	1.85	9.6	15.6
4	1.70	8.8	14.3
	Average	7.85	14.3

obtained on this basis is from 8.4% to 15.6%. Such a result was encouraging enough to go ahead with the fabrication and testing of the experimental Salvinia Harvesting Machine as a float mounted unit.

4.12. Float mounted unit.

The catamaran type floating platform was found to give adequate floatation as per design calculations. The unit was highly stable with the stabiliser floats extended and had only minimum rolling effects. The platform had sufficient deck area to accomodate the prime mover pumpset and ejector system. It also had space for the operator to conveniently start the engine as well as guide the platform during motion. The discharge of water from the ejector system in a horizontal direction was found to propel the platform due to the jet reaction on it. The hinge arrangement enabled the vertically oriented ejector system to operate at different heights of pumping. For obtaining the maximum possible discharge and consequently the highest forward speed it was considered desirable to keep the ejector system in a horizontal attitude. The position of extendable arms prevented the provision of conical shape to the frontal ends of the stabiliser floats. Some arrangement to circumvent this situation was considered desirable. It was also felt that the free board provided in the design did not provide sufficient margin of safty to allow for damage of a few individual drums or to accomodate additional weights in terms of materials or persons on the deck.

The results obtained in the two sets of tests conducted with the float mounted machine are consolidated in Table 9.

Table 9. Pumping rate of prime mover pumpset and vertical ejector system (mounted on a floating platform) at a static lift of over one metre.

Trial No.	Speed of prime mover (r.p.m)	Pressure (Pd) (kg/cm^2)	Primary flow alone (Ist set) Qty. of water (lt)	Primary flow alone (Ist set) Time (sec)	Primary flow alone (Ist set) Rate of pumping (l.p.m)	Primary+Secondary flow (2nd set) Qty. of water (lt)	Primary+Secondary flow (2nd set) Time (sec)	Primary+Secondary flow (2nd set) Rate of pumping (l.p.m)
1	3300	2.1	200	23.5	511	200	9	1333
2	3300	2.2	200	25	480	200	7	1714
3	3300	3.1	200	24	500	200	8	1500
			Average		497			1515

In this series the average rate of flow obtained from the primary pump and the combined flow obtained from the ejector system were 497 l.p.m and 1515 l.p.m respectively which were higher than those obtained in the previous series of experiments. The flow ratio in turn improved from 1.6 to 2.05 which was even a shade better than the designed capacity ratio of 2. This improved performance is attributed partly to the reduction in the friction losses in the primary pump suction and discharge line. It may also be due to the probable lower total head at which the ejector system operated as compared to its design head.

4.2 Main experimental programme

4.21 First stage testing-at local pond

4.21.1. Assessment of prototype floating platform: The platform had sufficient floation and could easily accomodate two operators in addition to the prime mover pumpsets and ejector system at a time. The freeboard at this condition was more than half the diameter of the main floats. The platform was capable of accomodating a maximum of eight persons at near full sinkage condition. The catamaran type design was found to be quite stable enabling the operators to move freely on the platform. The rolling and pitching effects were considerably minimised due to the stabiliser floats and the short overall length respectively. Because of the location of the suction pipe away from the longitudinal axis there was a tendency for yawing of the platform during forward motion which had to be corrected by means of paddles. When the prime mover pumps worked at full stream the machine could move as a self-propelled unit at more than walking speed utilizing the jet reaction of the discharged water. Directional control of the equipment was also easily possible by deflecting the direction of the discharged water either by paddles or by the use of a loosely fitted long radius bend at the delivery end of the ejector system.

4.21.2. Performance of the prime mover pump sets and ejector system: The data relating to the pressure developed by the prime mover pumpsets and the pumping rates obtained from the prototype machine are shown in table 10. The primary flow obtained was of the order of 507 l.p.m and the combined flow obtained from the system was of the order of 1957 l.p.m. Thus the addition of a second 5 H.P pumpset to the experimental machine (which had a 5 H.P pumpset as the prime mover) enabled the flow ratio to be raised immediately from 1:2 to 1:2.86. It is true that the series connection of the prime mover pumpset enabled the input pressure to the prototype ejector system to be of the order of 45 metres. Although this value is more than double the corresponding value for the experimental unit, the flow ratio did not increase from 1:2 to 1:4 which might normally be expected, but remained at less than 1:3. This reduction in the flow ratio is attributed to the decrease in efficiency inherent in ejector systems at higher flow ratios. It may be

Table 10. Pumping rates of Prototype Salvinia Harvesting Machine at a static lift of one metre.

Trial No.	Pressure developed (kg/cm²)			Speed (r.p.m)		Primary flow			Primary+Secondary flow		
	*Ps	Pd1	Pd2	Set.1	Set.2	Qty.of water (lt)	Time (sec)	Rate (l.p.m)	Qty. of water (lt)	time (sec)	Rate (l.p.m)
1	0.34	2.75	4.5	3600	3600	200	24.5	490	200	6.3	1905
2	0.33	2.7	4.4	3600	3600	200	23.0	521	200	6.0	2000
3	0.34	2.8	4.6	3650	3600	200	23.5	510	200	6.1	1967
							Average	507			1957

noted that substitution of the new area ratio of 0.07 for the ejector system into equation 1 of Appendix 3 yields a flow ratio of only 1:2.85 which has actually been obtained and even exceeded; thus verifying the design calculations. The improvement in performance over the designed flow ratio may in turn be attributed to two factors. One is that with an increased pressure of 4.5 kg/cm2 for the series connection of prime mover pumpsets, the actual input head received by the ejector nozzle would have been more than the design value of 40 metres. The second factor is that at a static lift of one metre, the jet pump would have operated at a lower total head than the design best efficiency head of 4 metres. This in turn justifies the assumptions made in the design calculations of the ejector system. Perhaps the performance could have been even better if pipe fittings of size 125 or 150mm were used on the discharge side of the ejector system which would have further lowered the total head for the pump for a given static lift.

4.21.3. Assessment of gathering arm and original filtering unit: The local pond had been cleared off the weed manually before the prototype machine was got ready for testing. Hence, data on maximum weed collection capacity of the machine could not be taken at this site. On the other hand, it afforded an opportunity to assess the performance of the gathering arm and the original filtering unit. The gathering arm already shown in Fig.9 was found to effectively deflect the scanty weed population present in the pond from a swath width of about 2 metres towards the suction mouth of the ejector system. Hardly any piece or fragment of the weed material could escape beyond the suction mouth into the passage between the central floats.

The weed-water mixture was pumped into the filtering unit, by the use of two long radius bends and a 40 cm vertical extension piece fitted to the delivery end of the ejector system. This in turn provided the required height of pumping. The wire net on the trough permitted the draining of water by gravity while retaining the weed material within the trough. Because of the on-rush of the weed-water mixture into the trough, there was no problem of clogging of the wire net. But, the forward propulsion of the unit was considerably affected as the energy of the discharged water was directly dessipated in the filtering unit which was integrally connected to the harvesting machine. Since there was no boat available at hand further tests on the performance of the filtering unit could not be conducted at this site.

4.22 2nd stage testing-at Chettupuzha

The results of test No.1 at this site relating to spread density measurements are given in Table 11.

Table 11. Spread density of Salvinia at Chettupuzha, kole lands.

Trial No.	Area covered (sq.m)	Weight of weed (kg)	Spread density (kg/m2)
1	1	30	30
2	1	20	20
3	1	25	25
		Average	25

The average spread density of 25 kg/m2 was more than 3 times the value obtained by Samual & Jacob, (1979) under still water conditions when the horizontal water surface was almost covered by the weed material. The variation between the two figures can, to a large extent, be accounted by the fact that at Chettupuzha the weed materials were in a highly packed condition owing to the strong winds prevalent at the site during the period of testing. It also shows the extent to which Salvinia can be packed by the action of strong winds.

In Test No.2, bulk density measurements were made by means of the wire net cage described in section 3.45.2. The results obtained are shown in table 12.

Table 12. Bulk density of Salvinia weed

Trial No.	Volume of cage (m^3)	Weight of cage (kg)	Weight of cage+weed (kg)	Weight of weed only (kg)	Bulk density (kg/m^3)
1	0.25	7	107	100	400
2	0.25	7	112	105	420
3	0.25	7	98	91	364
4	0.25	7	109	102	408
				Average	398 ≅ 400

The average bulk density value of 400 kg/m^3 makes the relative bulk density to be 0.4 and indicates the enormous bulk of the material to be handled whenever transported in an as-harvested condition.

In test No.3, a country boat was attached to the Salvinia Harvesting Machine and the weed was collected into the boat with the help of the original filtering unit. Since the filtering system was also attached integrally to the harvesting machine the latter could no longer be operated as a self propelled unit. The whole set-up was, however, made mobile by manual punting. In this method of collection, it took about one hour to fill the boat completely and it is presumed that about 6 tonnes of material were collected. This gave a harvesting capacity of approximately 6 tonnes per hour for the machine.

A few major disadvantages were noticed in this method of collection. Firstly, it was noted that the weed material being wet, did not easily slide on the platform between the trough and the boat and had to be manually pushed into the boat. Another disadvantage was that it took considerable labour to unload the weed material from the boat to the bank of the flooded paddy field. It was therefore, felt that the filtering unit should be improved to enable relatively dry material to be received into the boat and that this should as far as possible be accomplished automatically.

In test No.4, the harvesting machine was used as a stationary unit and the weed materials were directly pumped to the shore. The weed-water mixture flowing in very large quantities caused considerable soil erosion on the banks. It also upset the fencing that was provided to retain the weed material. The method of direct pumping of weed-water mixture on to the shore was thus found to be totally unacceptable.

In test No.5, the machine was again anchoured near the shore and the weed was pumped into the filtering unit from which it was directly unloaded to the bank by scraping it down the slopping platform. The results of three such trials, each of one minute duration, are given in table 13.

The average rate of collection obtained was of the order of 6 T/hr. This result further substantiated the earlier assessment of rate of collection into the country boat.

In test No.6, the weed-water mixture was pumped directly into a floating fence described in section 3.44. The results are given in table 14.

The average Salvinia pumping rate of 9.2 T/hr. obtained in this test was 50% more than that obtained in the previous test. The increased rate of pumping obtained can be partly attributed to the reduction in the height of pumping and the fact that the operators were by that time sufficiently experienced to provide consistant feeding of weed materials to the suction mouth of the ejector system.

In test No.7, visual observations were made on the pumping of Salvinia into the floating fence at zero lift condition. The extension of the discharge pipe by means of an elbow and short piece of flexible pipe did not seem to improve the pumping rate possibily because the reduction in the static lift was compensated by the frictional losses in the additional fittings utilised. No specific measurements were taken, since it was felt that a better way to obtain zero lift condition would be to remove all the bends and elbows and instead extend the horizontal discharge pipe of the ejector system directly into the floating fence.

Table 13. Rate of pumping of Salvinia to the bank through filtering unit, at a static lift of 1.4 metres.

Trial No.	Speed Set.1 (r.p.m)	Speed Set.2 (r.p.m)	Discharge pressure (kg/cm^2)	Time taken (sec)	Weed collected (kg)	Rate of collection (kg/mt)	Rate of collection (T/hr)
1	3600	3600	4.56	60	102	102	6.1
2	3600	3600	4.50	60	94	94	5.6
3	3600	3600	4.45	60	110	110	6.6
					Average		6.1

Table 14. Rate of pumping of Salvinia into floating fence at a static lift of 70 cms.

Trial No	Discharge pressure (kg/cm^2)	Speed Set.1 (r.p.m)	Speed Set.2 (r.p.m)	Time taken (sec)	Weed collected (kg)	Rate of pumping (kg/mt)	Rate of pumping (T/hr)
1	4.5	3600	3600	60	148	148	8.9
2	4.55	3600	3600	60	156	156	9.4
3	4.45	3600	3600	60	153	153	9.2
					Average		9.2

In test No.8 the above alterations were made and an essentially zero head condition for pumping of Salvinia was obtained. The results of this test are given in Table.15.

The average pumping rate of 18 T/hr. obtained was the highest among all the previous tests and was almost 100% more than that obtained in Test No.6. The increased rate of pumping obtained can be attributed to the combined effect of several favourable factors. It is known that low area ratio ejector systems have relative flat head-capacity characteristics. As compared to test No.6, the removal of two bends would have caused a further reduction in the total head by atleast 1.20 metres(0.70m static lift + 0.25 metre friction head for each bend). This in turn would have substantially increased the secondary flow rate and consequently the quantity of weed drawn-in. The fact that drastic changes in the direction of the flow could be avoided, consequent to the removal of the bends, would have further influenced in increasing the proportions of the weed in the weed-water mixture. In this test, the operators had also made every effort (a) to provide uniform feeding and (b) to make proper adjustment of the position of the suction mouth of the ejector system from the water level both of which, it appears, had a profound influence on the performance. Since the discharge pipe from the ejector system was operating at zero lift, it was not possible to measure either the volume of water in the weed-water mixture or the secondary flow of water alone, in this test. However, taking the maximum percentage of 15.6 in the rate of pumping of Salvinia obtained in Table 8 (this percentage was further substantiated in the results of tests at Kumarakom) the

Table 15. Rates of pumping of Salvinia into floating fence at near zero head condition.

Trial No.	Discharge pressure (kg/cm^2)	Speed Set.1 (r.p.m)	Speed Set.2 (r.p.m)	Time (sec)	Weed collected (kg)	Rate of collection (kg/m)	Rate of collection (T/hr)
1	4.45	3600	3600	60	264	264	15.8
2	4.50	3600	3600	60	317	317	19.0
3	4.50	3600	3600	60	320	320	19.2
					Average	307	18.0

secondary flow of the system could be estimated to be (307x100)/15.6 = 1968 l.p.m. This in turn show that the flow ratio had changed from 1:3 to 1:3.88 for the ejector system. Thus, the test convincingly shows that the Salvinia pumping capacity of the ejector system is sensitive to changes in the total head. Therefore, it is felt that for best performance the ejector system should be operated perferably at zero lift with no drastic changes in the directions of flow. Further, the feeding rate and positioning of the suction mouth should be optimal.

In test No.9, which was the final test conducted at the Chettupuzha site, efforts were directed to clear the weeds present in the entire paddy field and concentrate the weed material into a field fermentation pond. During the course of this work a triangular shaped weed infested area of 5,100 square metres was cleared in eight and a half working hours over a period of two days. This in turn afforded a chance to directly assess the field capacity of the machine in terms of hours required to clear a unit area which worked out to be 8.5 x 100 x 100 ÷ 5100=16.7 hours/ht (0.06 ht/hr). Assuming that the spread density was of the order of 250 T/ht., this meant that the machine had achieved an average pumping rate of 14.97 T/hr. Plate 14. shows the fermentation pond filled with Salvinia easily supporting the weight of a person standing over the material. The testing work was concluded at this site as there were no more weeds left in the paddy field.

4.23 3rd stage testing-at Mancompu:

The Salvinia Harvesting Machine including the accessories

PLATE 14. HEAP OF SALVINIA COLLECTED IN A FIELD
[illegible]

such as the gathering arm, filtering unit and the floating fence was transported in a dismantled condition to Mancompu using a tractor and trailor. It was observed that the entire equipment could be unleaded and reassembled at the site in a matter of one and a half hours time. The machine along with the accessories was moved to the testing site as a self propelled unit. Measurements of only one trial was taken in two days of working with the machine at this site. Salvinia was pumped into a fermentation pond constructed similar to the one at the Chettupuzha site. An area of 17x78m=1326 square metres was cleared off weeds within a duration of 44 minutes. This gave a field capacity of 0.18 hects/hour which was considerably higher than that obtained at the Chettupuzha site. But, it may be noted that the infestation was very light in this particular field. Assuming that the spread density of infestation at this site was approximately 1/3 of that at the Chettupuzha site, the machine performance would work out to, 15 T/hr. which is again consistant with the corresponding figures obtained at Chettupuzha.

4.24 4th stage testing-at Kidangara.

After the testing programme at Mancompu, the harvesting machine was shifted to another site at Kidangara nearly 11 Km. from Mancompu. The shifting of the machine was accomplished by operating it as a self propelled unit. It took about 2¾ hours to reach the proposed testing site. From this distance and the time taken, the speed of the self propelled unit was calculated as approximately 4 kilometres per hour. During this period the oil consumption by the engines was noted as 4 litres each. Hence, total diesel consumption rate of the machine was estimated to be at 2.92 lt/hr.

The testing work at Kidangara was mainly confined to assessing the performance of a second prototype harvesting machine constructed to serve as a standby unit during public demonstrations. It was observed that the use of the country boats made the unit rather unwieldy with excess length than that was required. The output from the ejector system was noticeably lower than that obtained in the first prototype harvesting machine, mainly because of the miss-matched nozzle and the relatively large pumping height employed. Consequently, the populsion speed obtained from the system was also appreciably lower than that of the float mounted unit. In general, experience with the country boat mounted unit indicated that the nozzle design should be precise to obtain satisfactory performance in the ejector system and that such harvesting units do not permit attachment of loading boats easily.

The demonstration work of the float-mounted unit, pumping Salvinia at zero head condition into temporary field fermentation pond, was well received by the public. Large crowds assembled throughout the day to witness the demonstration of this novel equipment.

4.25 5th stage testing-at Kumarakam

The spread density measurements, from each of the seven channels from which Salvinia was cleared, are given in table 16.

It may be seen from the table that the average spread density values varied from 11.60 to 20.16 kg/m^2,m in the field channels amounting to a site average spread density value of

Table 16. Spread density of Salvinia in field channels at Kumarakam.

Sl. No.	Plot No.	Spread density measurements. Weight in kg of sample collected from $\frac{1}{2}m^2$ area				Average spread density (kg/m^2)
		Sample 1	Sample 2	Sample 3	Average	
1	A	10.00	9.75	10.50	10.08	20.16
2	AI	8.50	9.25	8.00	8.58	17.16
3	A2	7.25	5.75	4.50	5.80	11.60
4	A3	9.00	8.50	8.25	8.25	17.50
5	A4	8.00	6.00	5.75	6.58	13.16
6	A4/2	8.25	8.75	9.50	8.83	17.66
7	A6/2	7.25	8.75	9.00	8.33	16.66
				Site average		16.20

16.2 kg/m^2 or 162 T/ht. In as much as the weed occupied the entire water surface in these channels under still water conditions (not subjected to wind action) the above figure rounded to 160 T/ht may be taken as a representative value for the completed first phase of growth of Salvinia under the Kuttanadu condition.

The results obtained in regard to weed clearance tests from individual field channels are given in table 17. It may be noted from the table that the harvesting capacity of the machine varied from 13.4 to 19.6 T/hr. giving a mean value of 16 T/hr. This result is somewhat lower than the highest average harvesting capacity of 18 T/hr. measured at the Chettupuzha site. Considering the fact that while at the Chettupuzha site the tests were of short duration and the feeding rate better controlled, the test duration were longer and the feeding rate was less controlled at Kumarakam the two values may be taken as consistant. The more conservative figure of 16 T/hr. may thus be taken as a representative value for the harvesting capacity of the 10 H.P prototype machine for continuous working.

During the course of the above tests, measurements were also taken to obtain an idea of the extend to which the weed materials were packed by manual pushing. The values obtained are given in table 18.

Table 17. Results of weed clearance tests at Kumarakam

Trial No.	Secondary pressure (kg/cm^2)	Speed of pumpset Set.1 (r.p.m)	Speed of pumpset Set.2 (r.p.m)	Plot No.	Plot measurements Length (m)	Width (m)	Area (m^2)	Time taken (mt,sec)	Average spread density (kg/m^2)	Harvesting capacity (hr/ht)	(ht/hr)	(T/hr)
1	4.30	3600	3600	A	154.3	4.70	725.21	62,30	20.16	14.25	0.07	14.27
2	4.45	3600	3600	A1	39.7	4.60	182.62	9,30	17.16	8.67	0.12	19.60
3	4.45	3600	3600	A2	136.5	4.50	614.25	23,50	11.60	6.51	0.15	17.81
4	4.50	3600	3600	A3	136.5	4.20	573.30	44,40	17.50	12.98	0.08	13.40
5	4.50	3600	3600	A4	136.5	4.25	578.00	29,30	13.16	8.50	0.12	15.29
6	4.50	3600	3600	A4/2	77.7	4.60	318.57	22,00	17.66	11.50	0.09	15.36
7	4.50	3600	3600	A6/2	55.6	3.90	245.00	16,35	16.66	12.82	0.08	16.27
								Average	16.20	10.75	0.10	16.00

Table 18. Spread density values under manual pushing and packing.

Trial No.	Area covered sq.m	Weight of weed kg.	Spread density kg/m^2
1		27.1	54.2
2	½	10.0	20.0
3	½	8.5	17.0
4	½	18.5	37.00
		Average	32.00

The table indicates that there can be wide variation in the extend to which the material can be concentrated in a given area. The mean value of 32 kg/m^2 is again higher than the mean value of 25 kg/m^2 obtained at Chettupuzha site. It was also observed that under manual pushing, the material can be packed one over the other while only a single layer packing occurs under wind pressure.

The results of the fuel consumption tests carried out at Kumarakam are shown in table 19.

Table 19. Diesel consumption test data of two 5 H.P pumpsets.

Trial No.	Total hours of pumping Salvinia	Diesel consumption (lt)			Rate of Diesel consumption (lt/hr)
		Set.1	Set.2	Total	
1	1 hr., 38 mt	2.52	2.54	5.06	3.1
2	2 hr., 5 mt	3.10	3.15	6.25	3.0
			Average		3.05

The average value of 3.05 lt/hr. for the two pumpsets amounting to 1.525 lt/hr/set compares favourably with the values of 1.46 lt/hr. obtained at Kidangara and 1.4 lt/hr. obtained in the test conducted at the Engineering College, Trichur for a single pumpset. This is particularly so in view of the slightly lower speed at w ich the latter tests were carried out.

The modified version of the filtering unit was field tested at this site. It was observed that the unit could stay afloat as an independent filtering unit and that it permitted the country boats to be easily attached to or disengaged from it. With this filtering unit the weed material could be pumped at near zero head condition and the pumped weed-water mixture provided sufficient agitation at the bottom of the U-shaped filter section permitting the water to be drained off without allowing the weed materials to clog the perforations. The weed accumulating in this section gradually gained height and automatically fell into the hull of the country boat. The material thus collected was in a drip-dry condition and was spread inside the boat manually. When the boat was fully loaded the filtering unit could be easily ditached and made ready for loading the second boat. The floats provided in the filtering unit however were found inadequate to comfortably support the weight of the material which accumulated in the filtering section. It was felt that with the above aspect taken care of and with the frame work strengthened the unit may serve well as an automatic system for filtering and loading the harvested Salvinia into country boats.

The results of tests conducted to reconfirm the flow rates from the prime mover pumps and ejector system obtained in earlier tests are shown in table 20. In this test, there was absence of one bend in the discharge line and a reduction of approximately 50 cms in the pumping height as compared to the test originally conducted with the same machine in the local pond. But the primary and secondary flow rates obtained in both these tests seem identical. (Also see table 10). This indicates that the differences in the set up did not make an appreciable change in the capacity of the ejector system while pumping water alone. On the other hand, the results of tests conducted on the rates of weed collection and proportions of weed in the weed-water mixture are shown in Table 21. This table indicates that the average rate of collection obtained at a static lift of 50 cms is of the order of 12.6 T/hr. which is higher than the average of 9.2 T/hr. obtained at Chettupuzha at a lift of 70 cms with two bends in position. It may however be noted that, in the present test, a 90° change in the direction of flow was avoided by replacing one of the bends with a straight pipe. Also, it has been demonstrated earlier that when both the bends are removed (causing a further reduction of 70 cms in the pumping height that is at zero lift) the rate of weed collection had improved to an average of 15.7 T/hr. in long duration tests at Kumarakam and 18 T/hr. in short duration tests at Chettupuzha. Therefore, it would seem that the pressure head losses in the long radius bends (involving two 90° changes in the direction of flow for the weed-water mixture) have influenced the rate of

Table 20. Pumping rate of prime mover pumpset at Kumarakam at a static lift of 50 cm.

Trial No. 6	Secondary pressure (kg/cm^2)	Speed Set.1 (r.p.m)	Speed Set.2 (r.p.m)	Primary flow: Time taken (sec)	Primary flow: Water (lt)	Primary flow: Rate of pumping (l.p.m)	Primary and Secondary flow: Time (sec)	Primary and Secondary flow: Water (lt)	Primary and Secondary flow: Rate of pumping (l.p.m)
1	4.5	3600	3600	30	245	490	30	980	1960
2	4.5	3550	3600	30	256	412	15	492	1980
3	4.5	3600	3600	30	257	514	15	502	2008
					Average	505			1983

Table 21. Rate of pumping of Salvinia at Kumarakam at a static lift of 50 cms.

Trial No.	Secondary pressure (kg/cm²)	Speed Set.1 (r.p.m)	Speed Set.2 (r.p.m)	Time taken (sec)	Water (lt)	Weed (kg)	Rate of weed&water: Weed (kg/mt)	Rate of weed&water: Weed (T/hr)	Rate of weed&water: Water (l.p.m)	% of weed collection based on second: flow from Table 20
1	4.5	3600	3600	30	780	98.0	196	11.7	1560.0	13.3
2	4.5	3600	3600	30	672	112.0	224	13.0	1344.0	15.7
3	4.5	3550	3600	30	708	113.5	227	13.5	1416.0	15.1
						Average	216	12.6	1440.0	14.7

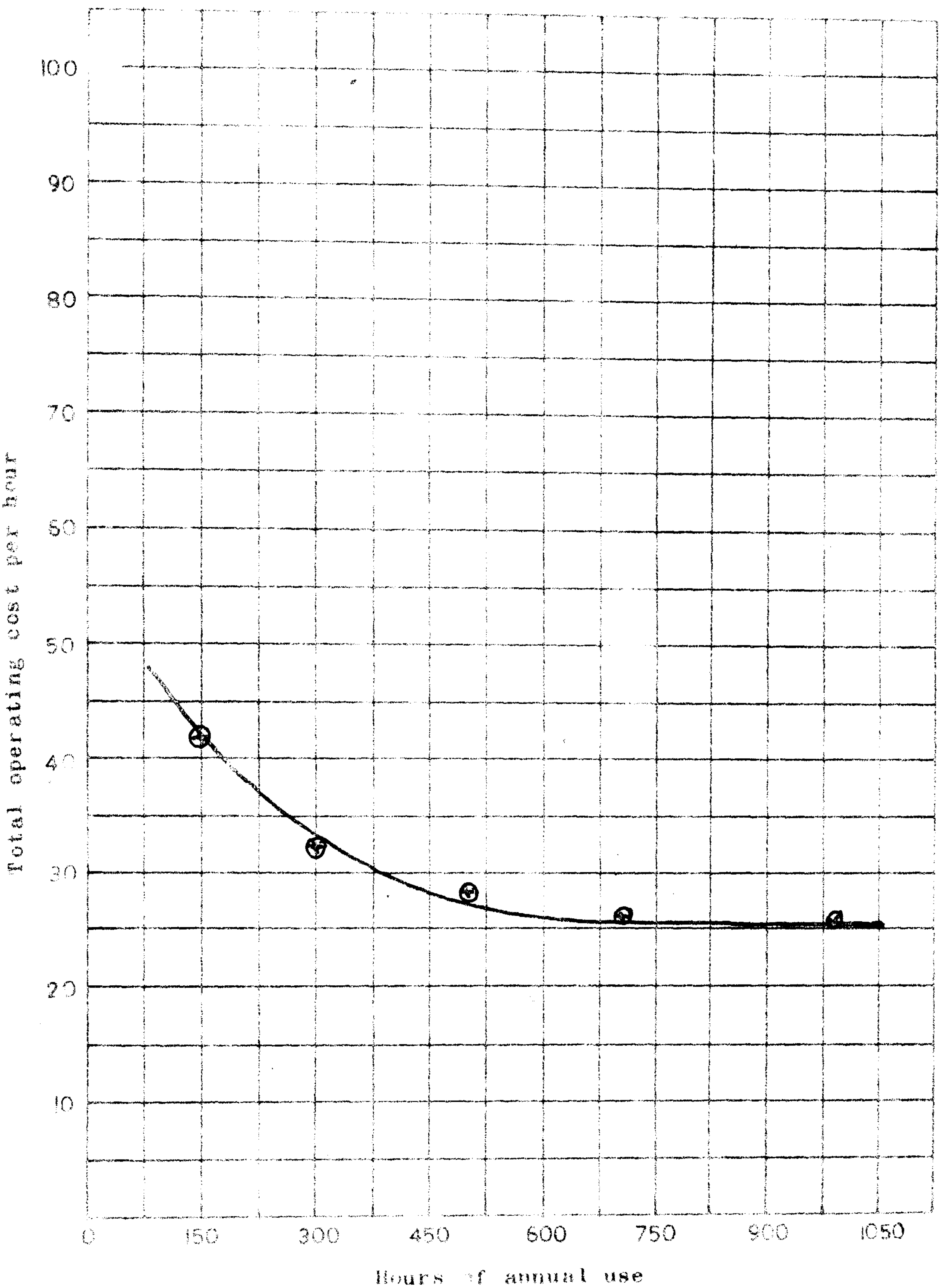


Fig.10. COST ANALYSIS OF SALVINIA HARVESTING MACHINE

pumping of the weed in the weed-water mixture much more than the rate of pumping of water alone through the ejector system.

The percentage of weed collection in each of the tests has been calculated in relation to the secondary flow obtained when water alone was being pumped. This percentage is also given in the table 21 which has an average value of 14.7 and a maximum value of 15.7. These values are comparable with the corresponding values obtained in the table 8.

4.5. Economic analysis

The operating cost for the Salvinia Harvesting Machine has been worked out on the basis of assumptions and calculations detailed in Appendix 5. The total costs in terms of rupees per hour as well as rupees per hectare, for a range of 100 to 1000 hrs. of annual use, are plotted in Fig.16. As can be expected, the total cost of operation decreases with increasing hours of annual use. In the Kuttanadu region the Salvinia problem is prevalent for over 6 months during the year. As such even with a very conservative figure of 500 hrs. of annual use, the cost of operation of this machine amounts to only approximately Rs.30 per hour or Rs.300 per hectare under heavy infestation conditions. This compares very favourably with the reported rates of Rs.900 to 2700 for manual collection and destruction of the weed.

Summary and Conclusions

CHAPTER V

SUMMARY AND CONCLUSIONS

The possibilities of mechanical control of Salvinia molesta locally known as African Payal were investigated in the present project. The study was concentrated on the development and evaluation of a prototype Salvinia Harvesting Machine which utilised a novel design concept evolved in the Department of Agricultural Engineering. The concept consisted of a fluidization technique in which the weed materials are pumped by means of the combination of a conventional centrifugal pump and an ejector system. The prototype machine, finally developed and evaluated in the study was composed of two 5 H.P pumpsets and a high capacity ejector system mounted on a catamaran type floating platform. The machine was capable of harvesting the Salvinia weed either as a stationary or as a self propelled unit. Certain accessory units for the prototype machine and disposal techniques for the weed were also developed and evaluated as part of the project.

The present study yielded the following principal results and conclusions:

1. The bulk density of Salvinia at the beginning of the second stage of the first phase of growth was found to be of the order of 400 kg/cum.

2. The spread density values of Salvinia which specified the fresh weight of weed per unit area were collected for

different habitats and growth stages. Considerable variation was found in these values depending on the stage of growth and degree of packing caused by wind pressure or physical manipulation. The values obtained are summarised in Table 22.

Table 22. Spread density of Salvinia under different habitats and degrees of packing.

Sl. No.	Degree of packing	Approximate spread density (T/ha)
1	Light infestation(no artificial packing, does not completely occupy the water surface) - Ist stage.	80
2	Severe infestation(completely occupies the water surface) - 2nd stage.	160
3	Severe infestation and packing under wind pressure - 2nd stage+wind action.	240
4	Severe infestation and packing by manual pushing - 2nd stage+manual action.	320

3. Preliminary studies were made with an experimental Salvinia Harvesting Machine consisting of a 5 H.P centrifugal pump and a vertically oriented ejector system as a shore mounted unit. Measurements of the primary and secondary flow from the above combination used showed that the assembly achieved the designed performance of flow ratio of 2, at static lift of over one metre and an estimated head ratio of 0.167.

4. Experiments to collect Salvinia through the ejector system were successful which verified the feasibility of the

fluidization technique. The collection of weed materials within a range of 8 to 16 per cent by weight of the secondary water alone indicated that a prototype system based on this principle could possibly become economically viable.

5. The specially designed and fabricated experimental floating platform was found to be stable. It was also observed that the reaction of the discharged water from the ejector system enabled the unit to move as a self propelled machine.

6. The 10 H.P prototype Salvinia Harvesting Machine, comprising of two 5 H.P pumpsets connected in series, a matching horizontally oriented ejector system and a suitably sized catamaran type floating platform, was found to have sufficient floatation and stability. When operated as a self propelled unit directional control was easily obtained by using a loosely fitted long radius bend to the vertical extension of the delivery end of the ejector system.

7. At a static lift of one metre and a primary flow of 507 l.p.m, the secondary flow obtained from the ejector system was of the order of 1450 l.p.m. The flow ratio of 1:2.86 thus obtained was equal to or even higher than the corresponding design flow ratio. The improvement in performance was attributed to the possible higher input head received by the ejector nozzle and lower operating total head for the ejector system than the design values.

8. The gathering arm was found to effectively deflect the

weed material and concentrate them on the suction mouth of the ejector system, when the weed population was scanty in the infested areas.

9. The prototype Salvinia Harvesting Machine in conjunction with the filtering unit was found capable of harvesting and collecting the weed at the rate of approximately 6 to 8 T/hr. at a static lift of 1.40 m. into a country boat. However the performance of the filtering unit was not satisfactory enough to have automatic loading of the weed from its trough to the country boat. The material collected in the boat was relatively wet. Unloading of the weed from the boat to the shore by manual method was also tedious and time consuming.

10. The pumping of weed-water mixture directly on to the shore was found to be impracticable due to the erosion of soil it caused on the banks.

11. An average weed pumping rate of 9.2 T/hr was obtained into a floating fence by reducing the static lift of pumping from 1.40 m to 70 cm and by improving the feeding method.

12. The prototype machine gave in short duration tests the highest average pumping rate of 18 T/hr when the weed-water mixture was pumped directly into the floating fence at near zero head condition. Under this test condition, the estimated secondary flow was the order of 2000 l.p.m giving a flow ratio of 1:4 for the ejecter system.

13. In a long duration tests at the Chettupuzha site the machine pumped the weed material into a field fermentation pond at an average rate of approximately 15 T/hr. The fermentation pond technique had the advantages that it did not involve any immediate handling and transportation of the freshly harvested weed and that it permitted the pumping of weed at near zero head condition.

14. The pumping capacity of approximately 15 T/hr was confirmed even while harvesting the weed under light infestation condition at the Mancompu site.

15. An average speed of 4 Km/hr was obtained when the machine was moved as a self propelled unit from Mancompu to Kidangara.

16. The use of country boats as floating platforms was found to be cumbersome in the operation of a prototype Salvinia Harvesting Machine.

17. In long duration tests held at Kumarakam, the average weed pumping rate obtained was of the order of 16 T/hr. This area had a severely weed infested water surface having an average spread density of 162 T/ha. This in turn gave a harvesting capacity of 10 hrs/ha for the machine in field conditions which are typical of Kuttanadu region.

18. The modified version of the filtering unit was found to perform the functions of automatic filtering and loading of Salvinia into a country boat successfully. The design also

permitted the pumping of the weed-water mixture at zero lift condition and convenient engagement of country boats to the unit for loading purposes.

19. The tests at Kumarakam further confirmed the results of the preliminary experiments that the proportion of the weed obtainable was of the order of 15 per cent by weight of the secondary flow, when pumping water alone. Considering the fact that Salvinia is lighter than water having a relative bulk density value of only 0.4, these results compare favourably with the proportion of 20 percent of solids normally obtained in dredging works (Cornick, 1960).

20. The economic analysis of harvesting costs with the prototype machine amounted to Rs.280/- per hectare which compares favourably with the reported cost of Rs.900/- to Rs.2,700/- incurred for manual collection and disposal of the weed. Mechanical harvesting of Salvinia by this machine is therefore considered economically viable. It also has the added advantages, as compared to the biological and chemical control methods, that the harvested material can be put to other uses such as compost making, hard board paper manufacture or bio-gas production.

References

REFERENCES

1. Abeaba, F.O; Bruhn, H.D; Koegel, R.G and Livermore, D.F (1972). Some fundamental principles of dewatering aquatic vegetation. Transaction of A.S.A.E 16, 430 - 434.

2. Allan Deutsch (Ed) (1974). Some Equipment for Mechanical Control of Aquatic Weeds. International Plant Protection Centre, Oregon State University, Oregon/U.S.A.

3. Anonymous. Study of Salvinia, Problems & Control methods.

4. *Bennet, F.D; (1966). Investigations on the insects attacking the aquatic ferns, Salvinia spp: in Trinidad and Northern South America. Proc. 8th. Weed Centr. conf. 19 : 497 - 504. (quoted by Mitchell (Ed), 1974)

5. *Bose, J.C (1923). The spread of the water hyacinth. Trans. Bose Res. Inst (244) : 786 - 795 (quoted by Philiphose, 1976)

6. Bruhb, H.D; Livermore, D.F; Abeaba, F.O (1971). Processing characteristics of macrophytes as related to mechanical harvesting. Trans. Am. Soc. Agric. Engrs. 14, 1004 - 8

7. *Boyd, C.F (1972). A bibliography of interest in the utilisation of aquatic plants. Econ. Bot. 26. (quoted by Mitchell D.S (Ed), 1974)

8. Calicut University (1979): Ecological Survey on African Payal (1978 - 79). Unpublished report communicated as per letter No.43168/NCA-3-78/AD dated 27-12-1979 of the Under Secretary, Agrl (NCA), Dept. Govt. of Kerala TVM. to the Registrar, K.A.U.

9. Cook, CDK (1976). Salvinia in Kerala, India and its control. In (Varshney, C.K (Ed, 1976) 113 - 116

10. Cook, CDK and Gut, B (1971). Unpublished Report on the Salvinia (African Pyle) problem in Kerala. Botanischer Garten Der Universitat, Zurich, Switzerland.

11. Cornic, H.F (1960). Dock and Harbour Engineering Vol.III. Charles Griffin & Company Limitted, London p.p. 320.

12. Department of Agricultural Engineering, K.A.U, (1980). A Note on mechanical control and utilisation of aquatic weeds. Submitted to High Power Committee on Salvinia eradication, Govt. of Kerala.

13. *Evans, G.C (1972). The quantitative analysis of plant growth Oxford, Blackwell Sci. Publ. 734 p. (quoted by Mitchell (Ed), 1974).

14. Gangstad, E.O (1978). Weed Control Method for River Basin Management. C.R.C. Press INC, Florida

15. *Gaudet, J.J (1973). Growth of a floating aquatic weed, Salvinia, under standard conditions. Hydrobiologea 41: 77 - 106. (Quoted by Mitchell (Ed) (1974) & Mitchell (1976).

16. George, K (1976). Studies on the control of some important aquatic weeds of Kerala Salvinia, Ludwigia and cyperus. In (Varshney, C.K (Ed) 1976)

17. George, K (1977). The Salvinia weed problem in Kerala - Factors affecting growth and methods of control. In Programme & Abstracts of papers, Weed Science Conference and Workshop in India. Paper No: 180., 115 - 116

18. *Hattingh, E (1961). Problems of Salvinia auriculata Aubl and associated aquatic weeds on Kariba Lake. Weed Research I, 303 - 306 (quoted by Sculthorpe, 1967)

19. *Holm L.G; Welden, L.W and Black burn, R.D (1969) Aquatic Weeds Science 166, 699 - 709. (quoted by Mitchell (Ed) 1974)

20. Ignatious D. Kemikkara. (1979). Preliminary work reports pf Ph. D Studies. Calicut University, Botany Dept.

21. Jayakumar, T.G (1980). Save Kuttanadu from weeds. Indian Express - Sunday Standard Daily; 2-3-1980; Madras.

22. Joy, P.J (1978). Ecology and Control of Salvinia (African Payal): The molesting weed of Kerala. Kerala Agricultural University, p.p. 80

23. Kaimal, P.N.R (1976). Aquatic Weed Harvester. Publication of Central Institute of Fisheries Technology, Cochin.

24. Kaul, V; and Usha Bakaya (1976). The noxious, floating, lemnid-Salvinia aquatic weed complex in Kashmir. In (Varshney, C.K (Ed), 1976)

25. King, R.C (Ed), (1967). Piping Handbook. Mc Graw - Hill Book Company, New York.

26. *Little, E.C.S (1966). The invasion of man-made lakes by plants. Man-Made Lakes, Academic Press London, 75-86

27. *Little, E.C.S (1969). Weeds and man-made lakes. Man-made lakes, The Accra symposium University Press, Ghana, 284 - 91

28. Little, E.C.S (Ed), (1968). Handbook of utilisation of aquatic plants. F.A.O. United Nations, Rome p.p. 123.

29. *Livermore, D.F and Winderfinch, W.E (1969). Mechanical removal of organic production from water ways. Eutroplication: causes, consequences, correction. National Academic of Sciences, Washington, 494 - 519 (quoted by Mitchell (Ed), (1974)

30. Livermore, D.F; Bruhn, H.D and Pollock, B.W (1971). Processing characteristics of sub surface mactophytes of Modison, Wisconsin Lakes. Hydrobiologia Vol. 12.

31. *Loyal, D.S and Grewal, R.K (1966). Cytological study on sterility in Salvinia auriculata Aubet with a bearing on its reproductive mechanism. Cytologia, 31, 330 - 8 (Quoted by Sculthorpe, (1967).

32. Mathew (1980). Estimate of African Payal infestation in Kerala; Direct information from Departments of Agriculture, Vikas Bhavan, Trivandrum.

33. P.I.B. Paper Report (1981): Project for the removal of African Payal. Mathrubhumi Malayalam Daily; 13-4-81.

34. *Mc Lean, K (1922). Water hyacinth, a serious pest in Bengal. Agric. J. India, 17: 23 - 40 (quoted by Philipose, (1976).

35. Menon, M.V.K (1971). The threatening weeds. Science Today, 6 (2) 33 - 38

36. *Mitchell, D.S (1970). Autecological studies of Salvinia auriculata. Ph. D. Thesis, University of London. (quoted by Mitchell (Ed) (1974).

37. *Mitchell, D.S (1973a). The Kariba weed: Salvinia molesta. Brit. Ferngaz. 10: 251 - 2 (quoted by Joy, P.J (1978).

38. *Mitchell, D.S (1973b). Aquatic weeds in man-made lakes. (Geophysical Monograph Series, 17: 606 - 611) (quoted by Joy, P.J (1978).

39. Mitchell, D.S (1974a). The development of excessive populations of aquatic plants. In (Mitchell D.S (Ed), (1974)

40. Mitchell, D.S (1974b). Environmental management in relation to aquatic weed problems. In (Mitchell, D.S (Ed), (1974)

41. Mitchell, D.S (1976): The growth and management of eichhornia crassipes and Salvinia spp: in their native environment and in Alien situation. In (Varshney, C.K (Ed), (1976)

42. Mitchell, D.S (Ed), (1974). Aquatic Vegetation and its use and control. UNESCO Paris p.p. 135.

43. Mukhopadhyay, S.K and Taraphdar, S.K (1976). Aquatic weed problems in West Bengal and control through herbiades. In (Varshney, C.K (Ed) (1976)

44. National Academy of Science (1976). Making aquatic weeds useful: Some prospectives for developing countries. Washington, D.C

45. *Pariga, P (1934). Physicalogical investigations on water hyancinth (Eichhornia crassipes) in Orissa with notes on other aquatic weeds. Indian J. Agri. Sci. 4: 399 - 429 (quoted by Philiphose (1976).

46. *Patnaik, S (1972). Observations on control of Pestia stratiotes in fish ponds by gramoxone' Proc. Indian Acad. Sci (B), 75(1): 15 - 22 (quoted by Philiphose, (1976)

47. *Penfound, W.T; Earle, T.T (1948). The biology of the water hyacinth. Ecol. Monogr. 18, 447 - 72 (quoted by Mitchell (Ed), (1974)

48. *Philiphose, M.T (1972). Aquatic Weed Control in India. Silver Jubilee Souvenier of the Central Inld Fish Res. Inst. Barrackpore. p.p. 49 - 55. (quoted by Philiphose, (1976).

49. Philiphose, M.T (1976). Fifty years of aquatic weed control in India. In (Varshney, C.K (Ed) (1976)

50. Rameswar Bhattacharyya (1978): Dynamics of Marine vehicles. John-Willey & Sons, New York, p.p. 497

51. Robson (1974). The control of aquatic weeds - Mechanical control. In (Mitchell, D.S (Ed), (1974).

52. Robson (1976). A review of the distribution of aquatic weeds in the Tropics and sub Tropics. In (Varshney C.K (Ed), (1976)

53. Samuel, J (1972). Control of floating type aquatic weeds. A proposed programme of research seminar presented in the Division of Agrl. Engg. IARI, New Delhi, Nov.72

54. Samuel, J (1975). Water Jet pumps for low left application. Ph. D. Thesis, Indian Agricultural Research Institute, New Delhi.

55. Samuel, J (1980). Development of Salvinia Harvesting Machine. Paper presented at the Seminar, held at the College of Agrl. Vellayani, Kerala, Dec. 1980.

56. Samuel, J (1981). Project proposals for control and utilisation of Salvinia molesta(African Payal) in Kerala State. Proposed by Dept. of Agricultural Engg. Kerala Agrl. Uty., Trichur.

57. Samuel, J and Jippu Jacob (1977). Prospects for mechanical control of Salvinia in Kerala. Paper presented in the symposium on Rice Research at the Rice Research Stn., Pattambi, Kerala, Dec. 1977

58. Samuel, J; Roy Sukumaran and Kabir Rawther (1980). Note on Biogas production from African Payal.

59. Sculthorpe, C.D (1967). The Biology of aquatic Vascular plants. Edward Arnold Ltd., London p.p. 610

60. Thomas, K.J (1976). Studies on the aquatic vegetations of Trivandrum (Kerala). In Varshney C.K (Ed) (1976)

61. Thomas, K.J (1977). Impact of aquatic weeds on the changing pattern of ecosystem. Proc: All Indian symp: on Environ. Biol. Univ. Kerala. and UGC. P. 17

62. Thomas, K.J (1979). The extend of Salvinia infestation in Kerala (S.India). Its impact and suggested methods of control. Environmental conservation, Switzerland 6 (1)

63. *Thomas, C.T; Devassia, P.A; Kunjikutty, N and Nandakumar, N (1976). A preliminary study on the chemical composition of African Payal (Salvinia molesta Mitchell) (unpublished) (quoted by Joy,(1978)

64. Varghese, P.C (1974). African Payal, Kalpadenu, Jan-Feb. 1974, KAU, TVM

65. Varshney C.K (Ed) (1976). Aquatic weeds in S.E Asia: Reg. Semin. on Nox: Aqu. Veg. Trop. and sub-Trop. Dr. W. Jank. D.V. Publishers, The Hague.

66. Varshney, C.K and Singh, K.P(1976). A survey of aquatic weed problem in India. In (Varshney, C.K(Ed) (1976)

67. Velu, M (1976). Development of mechanical equipment for eradication of aquatic weeds. In (Varshney, C.K (Ed),(1976)

68. Weldon, L.W; Blackburn, R.D and Harson, D.S(1973). Common aquatic weeds. Dover publications, INC, New York,p.p.43.

69. *Williams, R.H (1956). Salvinia auriculata Aublet. The chemical eradication of a serious aquatic weed in Ceylon. Trop. Agric. Trin. 33 : 145 - 157. (quoted by Joy, (1978).

70. Zutshi, D.P and Vass, K.K (1976). Ecology of macrophytic vegetation of Kashmir Lakes. In (Varshney, C.K (Ed), (1976)

*Original not seen

Appendices

APPENDICES

1. Ten most common aquatic weeds in India.

2. List of some of the important world wide firms manufacturing aquatic weed harvesters.

3. Design of ejector systems.

4. Design of floating platforms.

5. Assumptions and calculations to determine operating cost of Salvinia Harvesting Machine.

APPENDIX - I

TEN MOST COMMON AQUATIC WEEDS IN INDIA*

I Free floating

1.Eichhornia Crassipes(Water hyacinth)**

2.Salvinia spp:(Waterfern, African payal)

3.Pistia Stratiotes(Water lettuce)

4.Lemnoids(Fregbit)

II Rooted floating

1.Nymphaea Stellate(Water lilly)

2.Nelumbo nucifera(Lotus)

III Submerged

1.Hydrilla Verticuilata (Elodea)

2.Vallisneria spiralis (Vallisneria)

IV Emergent

1.Typha sp: (Cattails)

2.Scirpus (Bus rush)

*Source: Varshney & Singh, (1976)

**Bracketed names indicate the local/popular names.

APPENDIX - 2

LIST OF SOME WORLD WIDE FIRMS MANUFACTURING AQUATIC WEED HARVESTERS.

1. Air-Lee Industries, INC
   3306 Commercial Avenue
   Madison, WI 5374/USA.

2. American Water Weed Harvesting Co.
   6538 West 70th Street,
   Shrevepert, LA 71109/USA.

3. Aquamarine Corporation,
   Box 616, Waukesha, WI 53186/USA.

4. Krinke & Kruger GM BH
   POB 142, Hubertus Strasse 15
   3012 Langenhagen-Hannover/W.Germany.

5. Robba Limited,
   Charlwoods Road, East Grinstead,
   East Susse RH 192 HU/England.

6. John Wilder(Engineering)Ltd.,
   36 St: Mary's Street,
   Willingford, Berks/England.

Source:-Allan Deutsch (ed), (1974).

APPENDIX - 3

DESIGN OF EJECTOR SYSTEMS

A. Experimental ejector.

The basic components of the experimental ejector system consisted of a vertically disposed jet device having a jet inlet fitted into a suction chamber(Fig.17). The suction chamber in turn was connected to a flexible suction pipe having a conical inlet, and a throat section (mixing chamber) fitted with a diffuser and bended discharge end. The detailed design procedure followed was in accordance with Samuel (1975) and is briefly described below:

Step I: In order to match the device with the prime mover pumpset, the head capacity characteristics of the prime mover pumpset was determined. This experiment was carried out at the Hydraulics Laboratory of the Government Engineering College, Trichur. The pumping heads were measured by using locally available pressure gauges and discharge capacities were determined by the direct weighing method. The data collected during the test are given in Table No.23.

Step 2: From the head-capacity characteristics (Fig.18) the actual best efficiency point was determined. This value was compared with that of the performance characteristics curves supplied by the manufacturer(Fig.19) and was found almost identical (Fig.15). The best efficiency values for the discharge, Q and head, H for the pumpset were taken to be 460 l.p.m and 25.0 m respectively. An allowance of 20 percent(5.0 m)

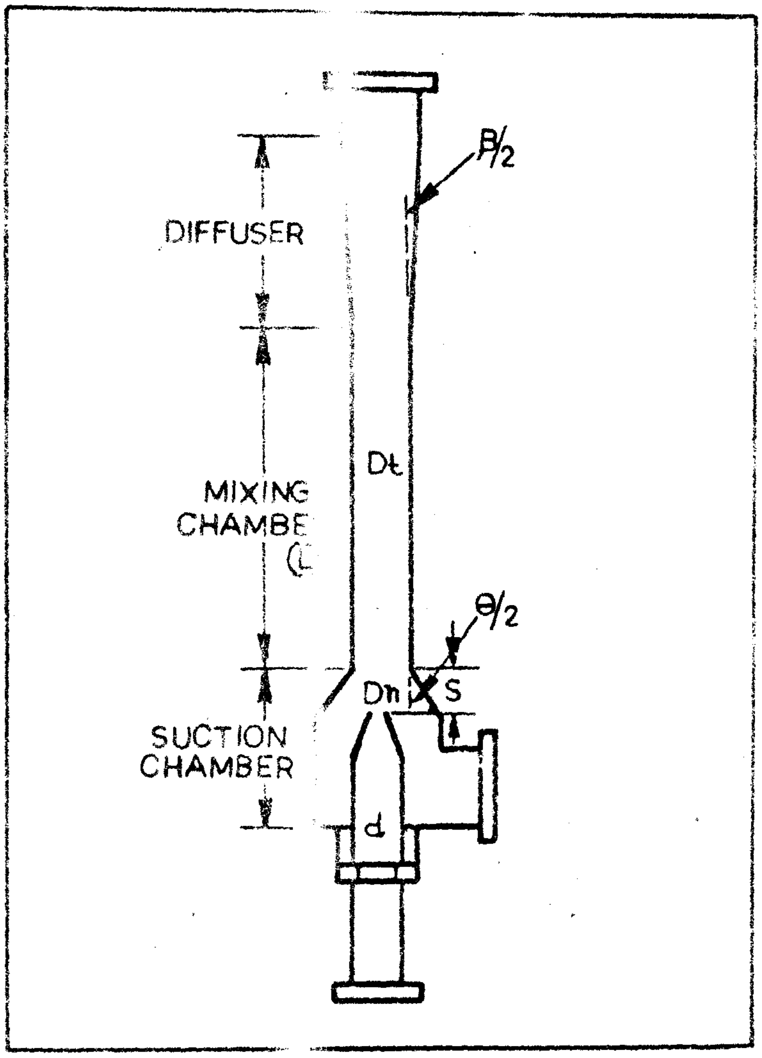


Fig. 17. Nomenclature of ejector system.

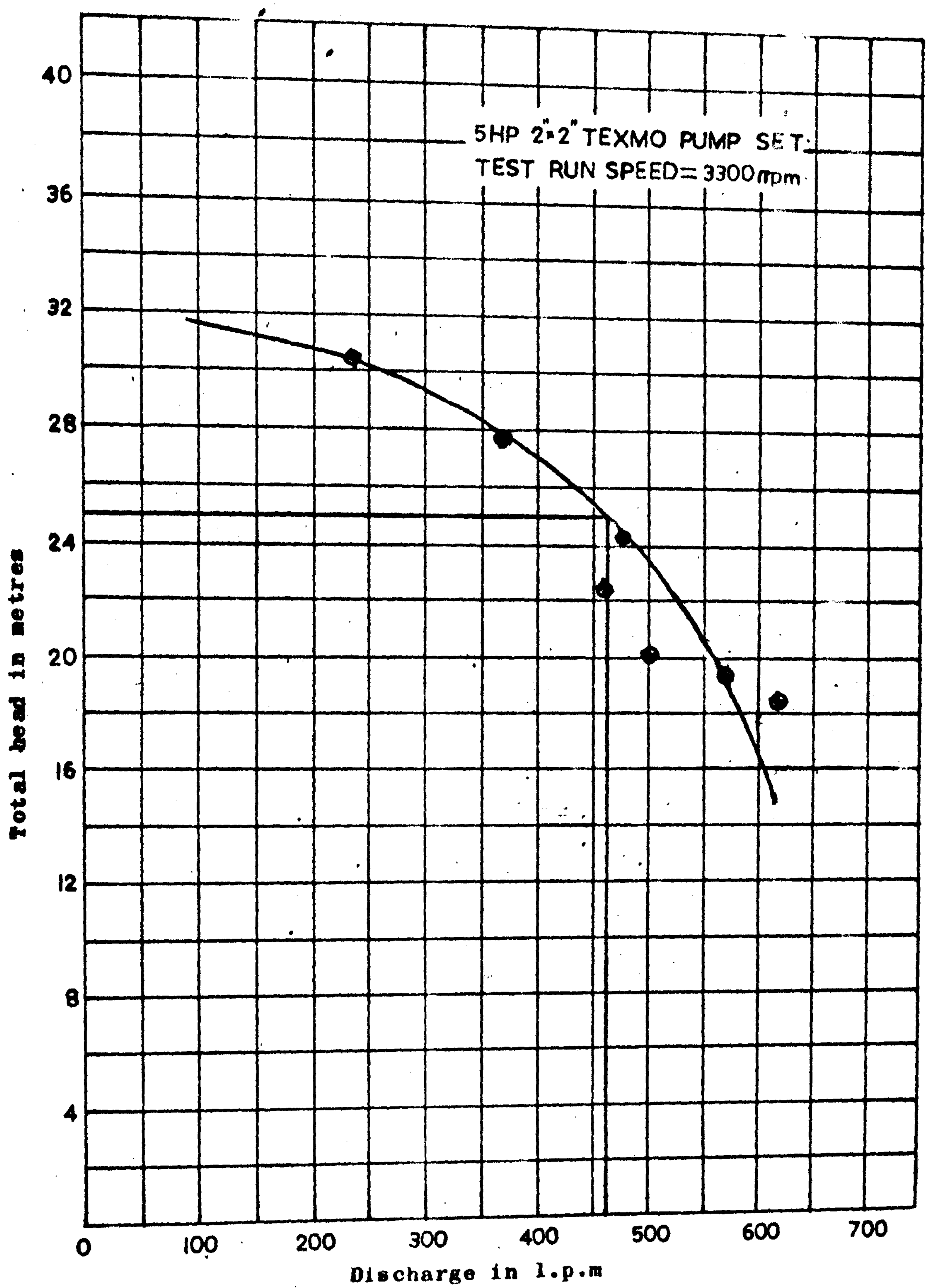


Fig. 18. HEAD-CAPACITY CURVE OF 5 H.P TEXMO, TL-5 PUMPSET (TEST AT ENGG. COLLEGE, TRICHUR)

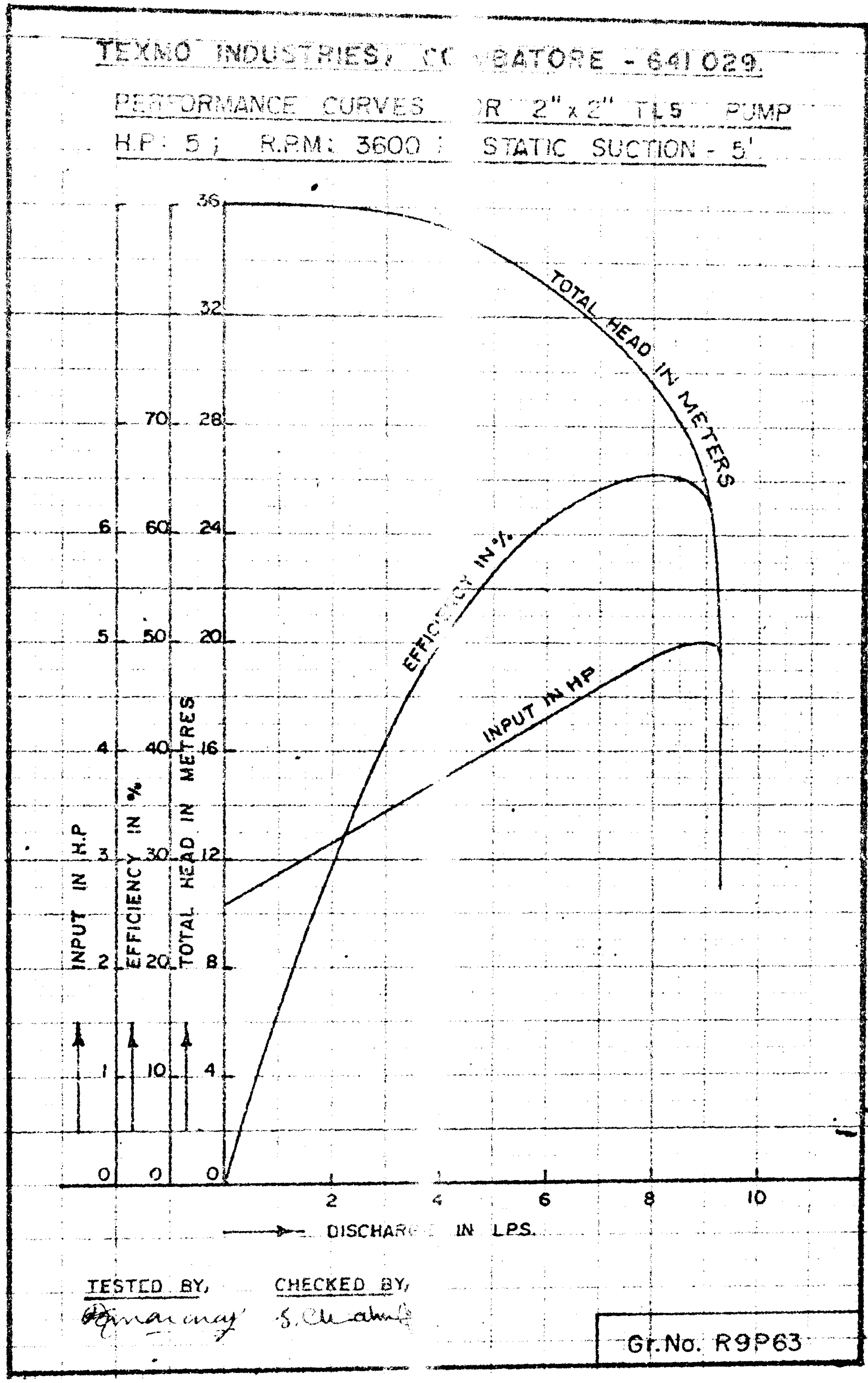


Fig. 19. Performance curves of prime mover pumpset at 3600 r.p.m (Manufacturer's data)

Table No. 23 Performance characteristics of the Diesel engine pumpset

Sl. No.	Speed (r.p.m)	Suction head (m)	Delivery head (m)	Total head (m)	Time for a flow of 1000 lt. of water (sec)	Discharge (l.p.m)	W.H.P	Fuel consumption in 20mt. (c.c)	Fuel consumption rate (lt/hr)	Input H.P	Overall efficiency (%)
1	3300	5.6	12.75	18.35	98.25	610.70	2.490	475	1.425	19.61	12.70
2	3300	3.8	15.25	19.05	106.00	566.00	2.396	480	1.440	19.81	12.10
3	3300	2.8	18.25	21.05	121.00	495.87	2.319	455	1.365	18.70	12.35
4	3300	2.5	20.25	22.75	132.00	454.50	2.298	425	1.275	17.54	13.10
5	3300	2.3	22.25	24.55	126.50	474.30	2.588	480	1.440	19.81	13.06
6	3300	2.4	25.25	27.65	164.50	364.74	2.240	415	1.245	17.13	13.08
7	3300	2.0	28.25	30.25	254.00	236.20	1.588	355	1.065	14.65	10.83

of the total head was given for system losses at this point. Hence, the effective head, Hn and capacity, Qn available to the ejector system were taken to be 20 metres and 460 l.p.m respectively for design purposes. From these two parameters, the critical diameter 'Dn' of the nozzle of the ejector system was determined as follows:

$$Qn = Cd \times An \times Vn$$

Where Qn is the discharge through the nozzle, Cd the Coefficient of discharge, An the area of the nozzle and Vn the velocity of flow through the nozzle.

$$\text{Hence } An = \frac{Qn}{Cd\sqrt{2g\ Hn}}$$

substituting values in consistant units and assuming, Cd=0.95

$$An = \frac{460 \times 100 \times 100}{1000 \times 60 \times 0.95\sqrt{2 \times 9.81 \times 20}}$$

$$= 4.08\ Cm^2$$

$$\text{But } An = \frac{\pi Dn^2}{4}$$

$$\text{Hence } Dn = \sqrt{\frac{4An}{\pi}}$$

$$= 2.28\ cm$$

$$= \text{Say } 23\ mm\ (\tfrac{7''}{8})$$

================

Step 3 The nozzle was fabricated with 10 gauge sheet metal (Fig.20). The cone angle was taken as 16° and the nozzle length was calculated as 10 mm in order to weld it to a piece of Standard 50 mm 'B' class G.I pipe. A 50 mm G.I coupling was provided on the suction chamber through which the nozzle was inserted. The pipe of the nozzle assembly was externally threaded to a suitable length. The provision of threads on the pipe, along with a check nut enabled the adjustment of the nozzle-throat spacing, S for optimum performance.

Step 4 The main characteristics of the ejector system can be defined by the following ratios:

1. Flow ratio, $M = \frac{Qs}{Qn} = \frac{\text{Secondary flow (through ejector suction)}}{\text{Primary flow (through nozzle)}}$

2. Head ratio, $N = \frac{Hd-Hs}{Hn-Hd} = \frac{\text{Total head of ejector system}}{\text{Net input head to the ejector system}}$

The following emperical design equations were utilised:

$$M = \frac{1}{\sqrt{R}} - 1 \quad \text{------------} \quad (1)$$

$$N = 1.5R \quad \text{------------} \quad (2)$$

$$\eta = M \times N = (1.5R)\left[\frac{1}{\sqrt{R}} - 1\right] \quad \text{----} \quad (3)$$

where R = An ÷ At = Nozzle tip area ÷ Throat area, Hd is the discharge head of the ejector system, Hs the suction head, Hn the effective input head to nozzle, and η the efficiency of the ejector system.

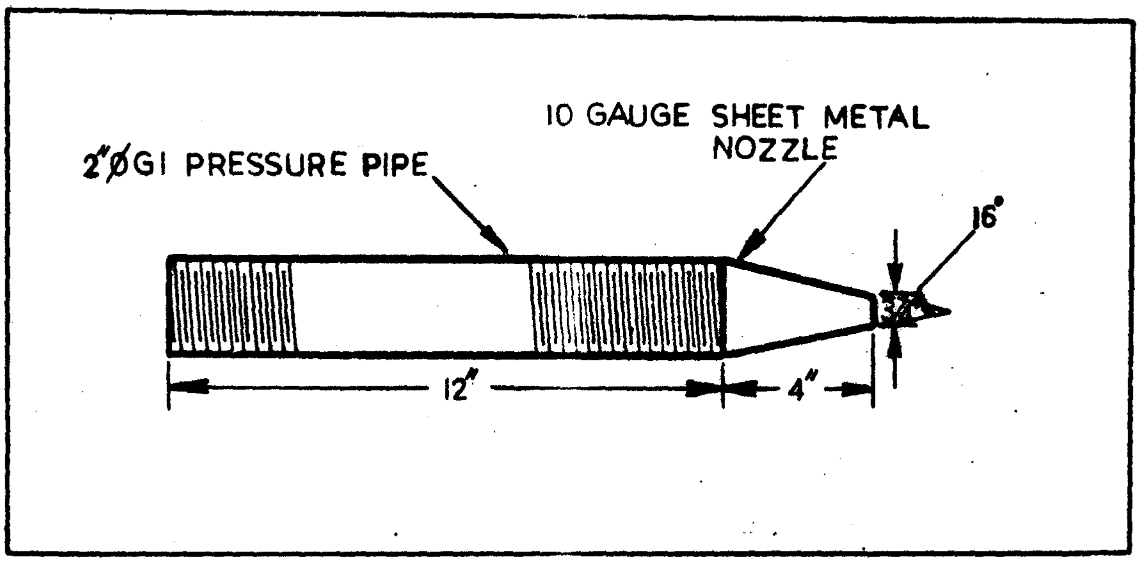


Fig. 20. Nozzle assembly.

Assuming Hs is 1 Metre and Hd is 2 Metres(to include sudden contraction and friction losses in the suction line, atleast one metre of static lift, and friction and velocity head losses in the discharge line, respectively) and substituting the values

$$N = \frac{2-(-1)}{20-2} = \frac{1}{6}$$

$$R = \frac{N}{1.5} = \frac{1}{6 \times 1.5} = \frac{1}{9} = 0.11$$

$$M = \frac{1}{\sqrt{R}} - 1 = 2$$

The throat diameter 'Dt' can now be calculated from the relation

$$Dt = Dn \times R^{-\frac{1}{2}} \quad - - - - - (4)$$

$$= 23 \times 0.11^{-\frac{1}{2}} = 69 \text{ mm}$$

$$= \text{Say, } 70 \text{ mm } (2\tfrac{3}{4}")$$

<u>Step 15.</u> The remaining geometric sizes in Fig.17 were selected as follows:

Throat length = 5 Dt = 350 mm

Nozzle spacing = 0.75 Dt = 52.5 mm

Throat entry profile = 90°

Diffuser angle = 7°

The expected efficiency of the above ejector system was obtained from the equation (3).

$$\eta = M \times N = 2 \times \frac{1}{6} \times 100 = \underline{33\%}$$

Since a ready made jet pump casing of throat size 75 mm was available, an insert of 70 mm diameter was introduced into the available unit. Other parameters like throat length, diffuser angle etc. of the available jet device were found to be matching with the designed values. Thus the combination of the fabricated nozzle and the available jet pump casing were fitted together to form the ejector system for the experimental Salvinia Harvesting Machine.

B. Prototype ejector:

The prototype ejector system (Fig.8) was designed to match the two 5 H.P prime mover pump sets which were to be connected in series.

Step 1. In view of the series connection of the prime mover pump-sets the best efficiency head of the combination was taken as 50 metres at 3300 r.p.m or 60 metres at 3600 r.p.m. The best efficiency discharge capacity in turn would be 460 l.p.m at 3300 r.p.m and 500 l.p.m at 3600 r.p.m, respectively.

Step 2. Assuming a higher system loss, for the combination to be $33\frac{1}{3}$ % on account of the series connection, the effective head, Hm and capacity, Qm available to the ejector system were taken to be 40 metres and 500 l.p.m respectively for design purposes.

$$A_n = \frac{Q_n}{C_d\sqrt{2g\ H_n}}$$

and $$D_n = 2\sqrt{\frac{A_n}{\pi}}$$

substituting the values for Q_n = 500 l.p.m and H_n = 40 metres, C_d = 0.95 and g = 9.81 m/sec^2.

$$A_n = \frac{500\times100\times100}{1000\times60\times0.95\ \sqrt{2\times9.81\times40}}$$

$$= 3.13\ cm^2$$

$$D_n = \sqrt{\frac{4\times3.13}{\pi}}$$

$$= 1.99\ cm \quad \underline{\underline{\text{Say 20 mm}}}$$

<u>Step 3.</u> The nozzle was fabricated with a 16° cone angle and a base diameter of 50 mm and was welded to a nipple of the same size. The opposite end of the nipple was in turn fitted to an elbow to introduce the nozzle to the suction chamber in a direction parallel to the secondary flow.

<u>Step 4.</u> Slightly increased values of H_s = 1.5 meters and H_d = 2.5 meters were assumed for prototype ejector system in view of the higher flow rates to be expected.

Accordingly $$N = \frac{H_d-H_s}{H_n-H_d}$$

$$= \frac{2.5-(-1.5)}{40-2.5}$$

$$= \underline{\underline{0.107}}$$

$$R = \frac{N}{1.5} = \frac{0.107}{1.5}$$

$$= \underline{\underline{0.0713}}$$

$$M = \frac{1}{\sqrt{R}} - 1 = 3.85 - 1 = \underline{\underline{2.85}}$$

$$Dt = Dn \times R^{-\frac{1}{2}} = 7.34 \text{ cm, } \underline{\underline{\text{say } 75 \text{ mm}}}$$

<u>Step 5.</u>

Throat length = 5 Dt	=	375 mm
Nozzle spacing = 0.75 Dt	=	55 mm
Throat entry profile	=	90°
Diffusion angle	=	7°

The expected efficiency of the ejector system will be $M \times N = 2.85 \times 0.107 = \underline{\underline{30.5\%}}$.

The components of the ejector system were made out of 18 gauge M.S. sheet and jointed by means of flanges at various sections. A size of 46 cm x 20 cm was chosen for the suction chamber. The ejector suction and discharge pipe sizes were chosen as 100 mm for convenience in handling and fitting of pipe connections. The suction line was extended by means of flexible pipe to reach the frontal end of the floating platform. The suction mouth consisted of a 100 mm elbow fitted to this flexible pipe. The discharge end was made up of two 100 mm long bends and vertical extension pieces of 75 cms and 40 cms each which were alternatively used depending on the pumping height required. The ejector system was mounted underneath the floating platform, below the water surface.

APPENDIX - 4

DESIGN OF FLOATING PLATFORMS

A. Experimental floating platform:

Preliminary experiments in harvesting Salvinia by means of the combination of a centrifugal pump and an ejector system as a shore-mounted unit encountered several difficulties which indicated the need for mounting the unit on a floating platform. Accordingly the design of such a floating platform was attempted.

1. Design criteria

The design parameters and requirements considered were that the platform should have

1. Sufficient floatation (buoyancy)

2. Adequate roll stability

3. Sufficient deck area

4. Appropriate length-width ratio

5. Manoeuvrability

6. Low resistance to forward motion

7. Reasonable transportability

II. Nomenclature of motions

The different kinds of motions that a floating platform or ship may experience (Rameswar Bhattacharyya, 1978) are illustrated in Fig.21, where

1. a = surging : motion backwards and forwards in the direction of travel
2. b = swaying : athwartship motion
3. c = heaving : motion vertically up and down
4. d = rolling : angular motion about the longitudinal axis
5. e = pitching : angular motion about the tranverse axis
6. f = yawing : angular motion about the vertical axis

III. Selection of hull type

Based on the design requirements and motion considerations explained above, a catamaran (twin hull) type design was selected for the floating platform because of the large deck area and transverse stability it can provide. For lightness of weight and easiness of transportation, it was also decided to make the hull out of individual metal drums of 20 litre capacity(28 cm in diameter and 36 cm in length) which weighted 2.5 kg. each

Buoyancy calculations:

a)total weight to be carried by the floating platform:

1. Weight of the prime mover pumpset = 75 kg(measured)

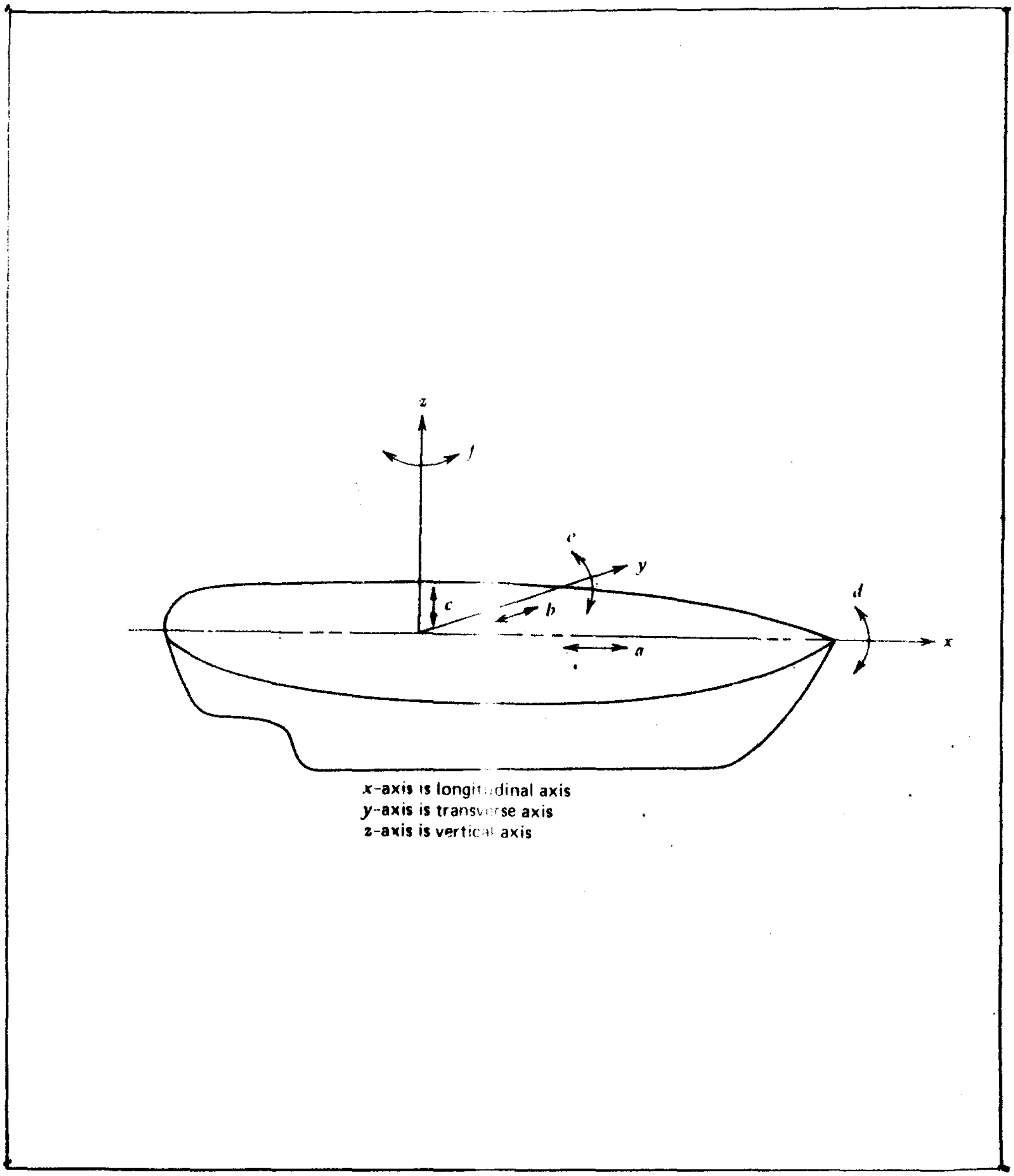


Fig. 21. Dynamic motions of floating platform & ship

2. Weight of the vertical ejector system = 10 kg (measured)

3. Weight of the moving water through the ejector system = 10 kg (assumed)

4. Weight of the inter connecting M.S frame work of the hull = 25 kg (measured)

5. Weight of the operator = 50 kg (assumed)

6. Self weight of the drum = $2.5x$ kg (measured)
   (x = No. of drums to be used)

Total weight = $(170+2.5x)$ kg

b) free-board

The free board of the floating platform was taken as ½ diameter of the hull section, i.e. 7 cms. The number of drums, was calculated as follows:

Displacement of hull section per drum = $\frac{\pi}{4}\sqrt{D^2 - h\ 0.017D^2 + 1.7Dh - h^2}$ according to King (1967) when the height of the free board (h) is from ¼D to ½D.

Equating for total weight

$170 + (2.5 \times x) = 18.8 \times x$

$x = 10.4$, Say 10 Nos.

IV Stability considerations

In order to provide sufficient stability, the above drums were arranged in two rows of 5 drums each at a distance of 40 cm apart to form the twin hull arrangement. Individual drums were bolted to a 25 mm x 25 mm angle iron frame work at the top and the bottom by means of 20 gauge metal straps. It would have been desirable to space the two hulls still further apart to provide greater roll stability. But the spacing selected was a compromise to enable the machine to negotiate narrow water canals. To further improve its floatation, rolling and pitching characteristics two stabiliser floats made up of 2 drums each were also provided on either side of the main hull. A simple hinging and locking mechanism provided to the stabiliser floats enabled them to be folded over to the deck area or spread out to the water surface.

V Other considerations

The prime mover pump set and the ejector system were mounted centrally on the platform. The symetrical construction of the floating platform and mounting of equipment was expected to improve the yawing (manoeuvrability) characteristics. The frontal ends of the two hulls were made conical in shape to help to reduce the resistance to forward motion. A schematic diagram of the resulting experimental floating platform is shown in Fig.23. With the stabiliser floats in a folded position and the ejector system dismantled, the entire machine could be easily accommodated in a Kubota Powertiller Trailer.

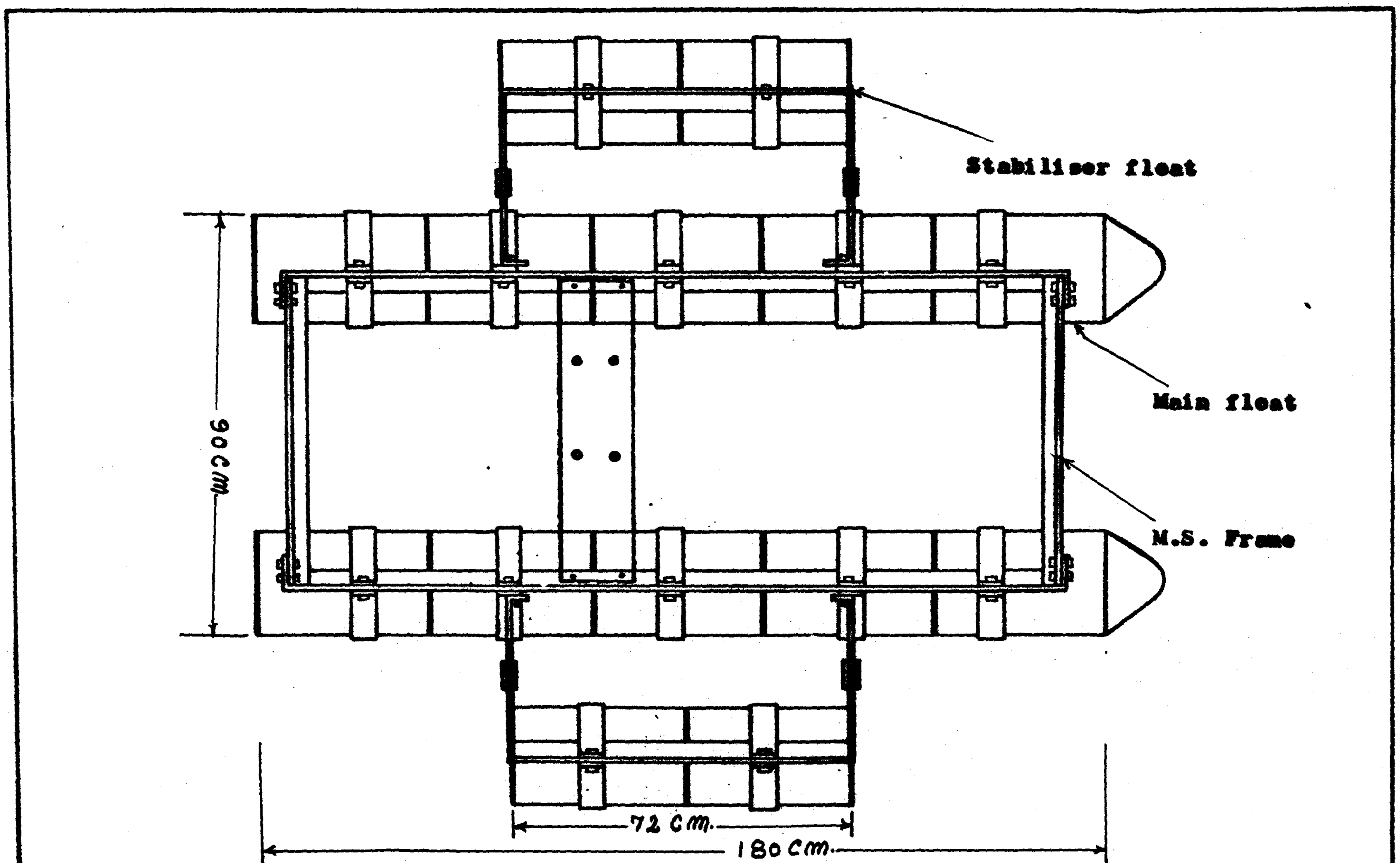


Fig. 22. Schematic of experimental floating platform.

B. Prototype Floating Platform

The prototype floating platform was designed mainly as a scaled up version of the experimental floating platform. It was observed that the free board provided for the experimental unit was not adequate and did not have sufficient factor of safety to take care of contingencies of a few drums getting damaged and the unit losing some of its buoyancy. The extendable arm arrangement did not permit the provision of a conical shape to the stabiliser floats. These major limitations were over-come by providing a free board of half the diameter and a telescopic arrangement for the stabiliser floats in the prototype floating platform.

Buoyancy consideration

a) total weight to be carried by the floating platform:

1.	Weight of prime mover unit having two pumpsets	= 150 kg
2.	Weight of horizontal ejector system	= 15 kg
3.	Weight of moving water	= 10 kg
4.	Weight of inter-connecting M.S frame work of the hull and pipe connections	= 30 kg
5.	Weight of two operators	= 110 kg
6.	Weight of 8 Nos. of 20 lt. capacity stabiliser floats	= 30 kg
7.	Self weight of x number of 60 lt capacity drums of 8 kg each	= $8x$ kg
	Total	= $(345+8x)$ kg

b) free-board

The free board of the floating platform was taken as about half diameter of the hull section i.e. 20 cm. From these requirements the number of drums (x) was calculated as follows:

Displacement of hull section per drum = 40 lt

Hence (345 + 8x) = 40

x = 10.7, Say 10 Nos.

Stability considerations:

In order to provide sufficient stability the 10 drums of 80 lt capacity (38 cm diameter and 68 cm height) were arranged in two rows of 5 drums each at a distance of 85 cm. apart to form the twin hull arrangement. Individual drums were bolted to a 38 mm angle iron framework at the top and the bottom by means of 20 gauge metal straps. The side stabiliser floats were telescopically fitted over the platform; and the position of the side floats was so arranged that they would also contribute to the floatation requirements when the main hull would sink more than half of the dameter of the hull section. The telescopic arrangement helped to adjust the width of the platform for negotiating narrow water canals.

Other considerations:

The ejector system was centrally hinged and positioned just below the water surface providing freedom to be tilted in the vertical plane. This enabled the adjustment of the depth of the suction mouth from the water surface. The pumpsets were mounted cross-wise on the floating platform for convenience in providing inter connections. The frontal ends of both the central hull and the stabiliser floats were made in conical shape. Pipe sockets were provided on both sides of the rectangular frame of the platform to connect the filtering unit to the main hull. Orthographic projections of the resulting floating platform fitted with the prime mover pumpsets and the ejector system forming the prototype Salvinia Harvesting Machine are shown in Figs. 23 to 25. The floating platform could be easily accommodated in a tractor trailer.

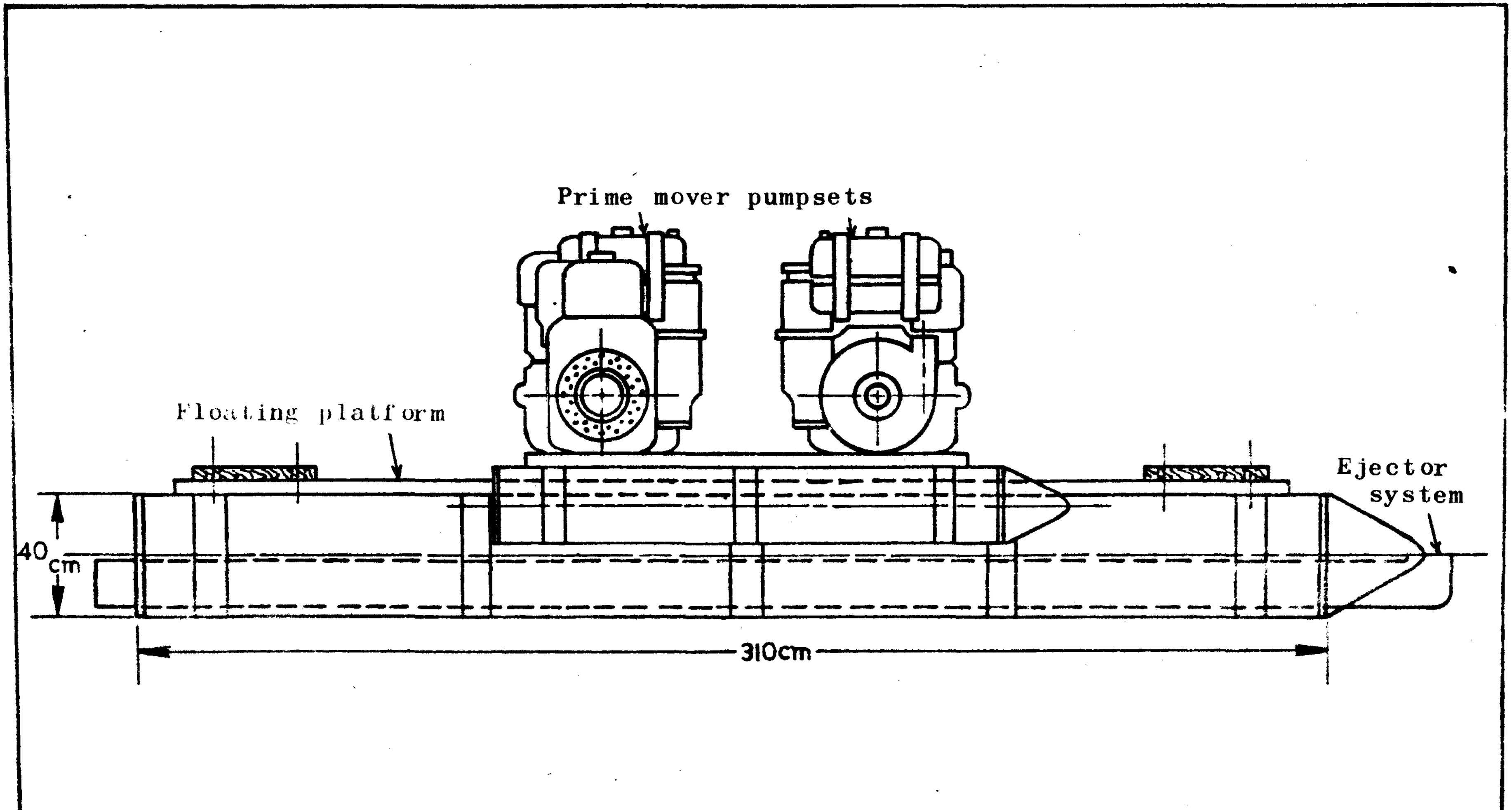
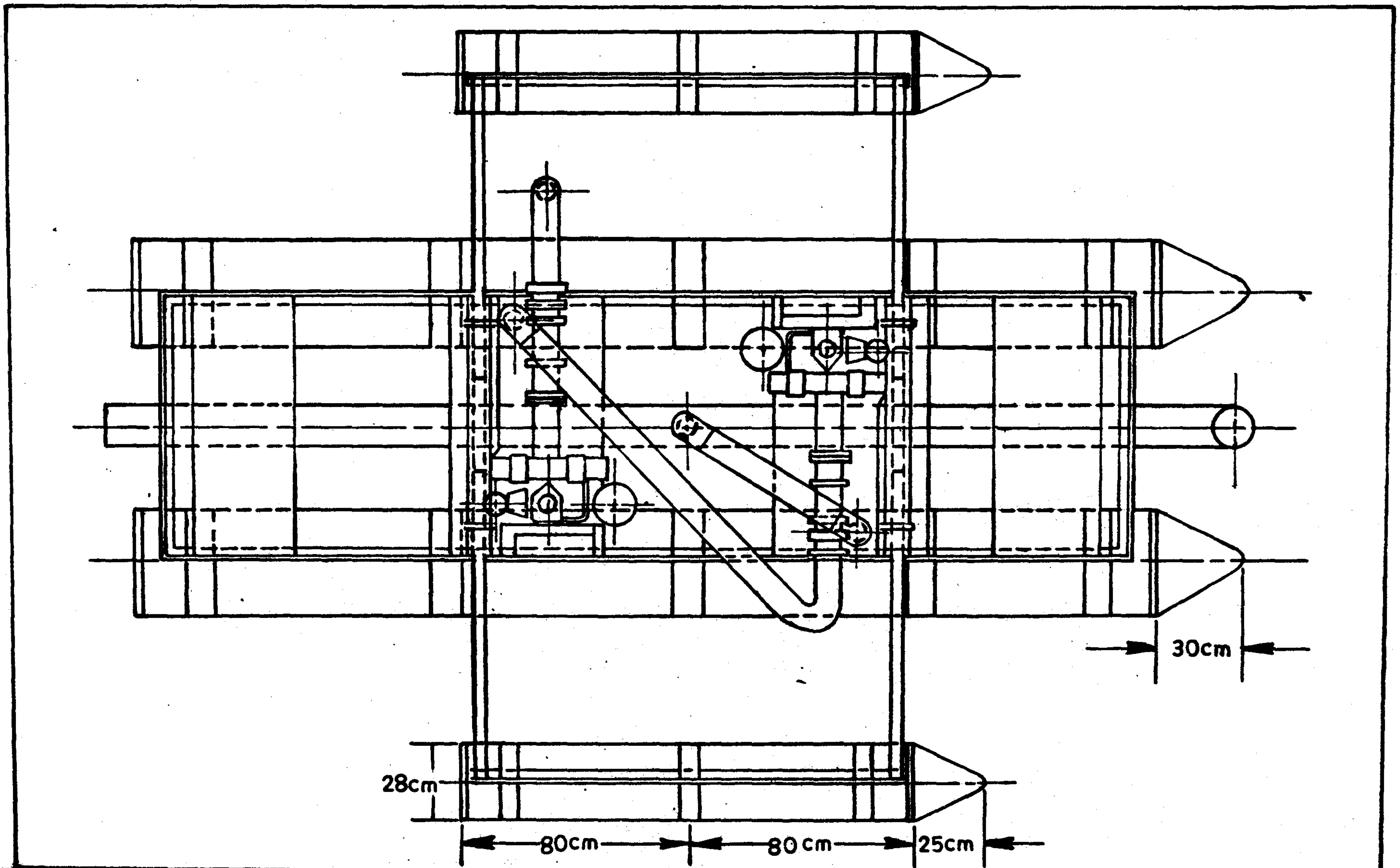


Fig. 23. Prototype Salvinia Harvesting Machine - elevation view (pipe connections not shown)


30cm
28cm
80cm
80 cm
25cm

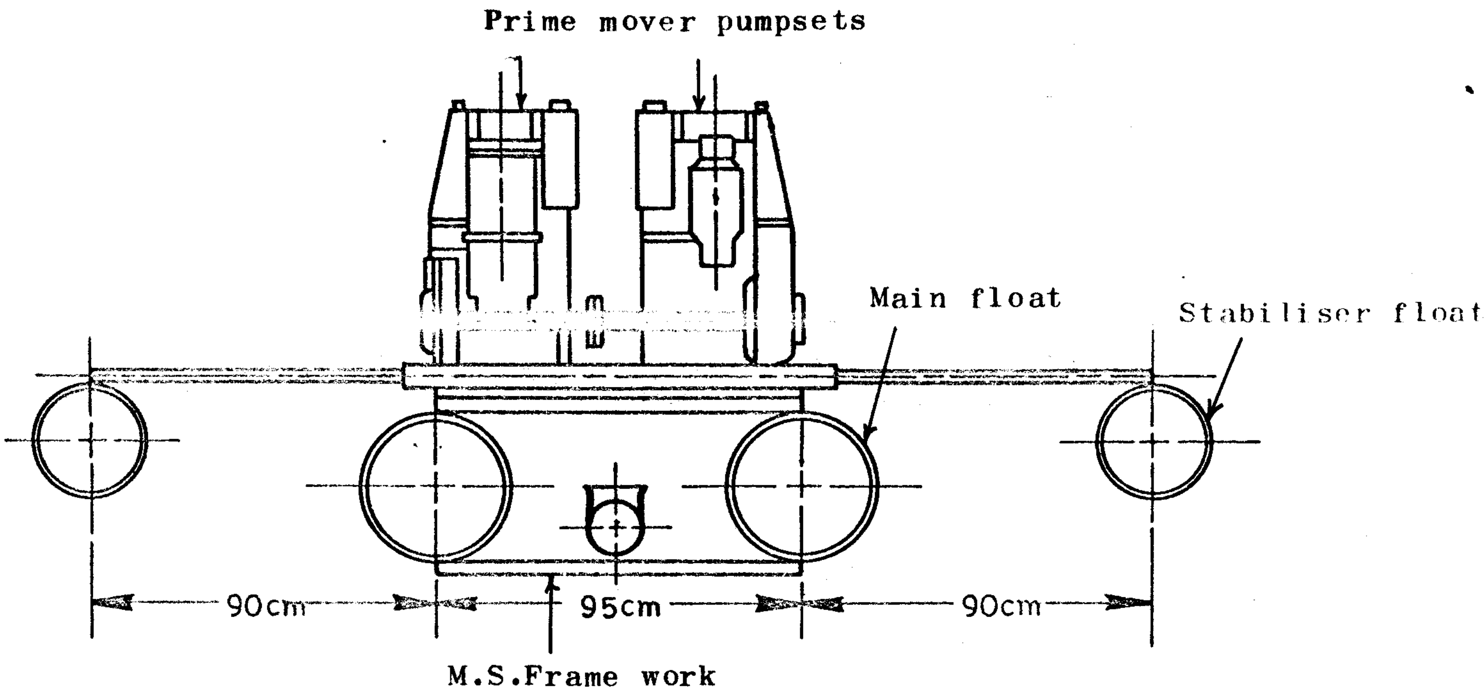


Fig. 25. Prototype Salvinia Harvesting Machine - side view
(pipe connections not shown)

APPENDIX-5

ASSUMPTIONS AND CALCULATIONS TO DETERMINE OPERATING COSTS OF THE SALVINIA HARVESTING MACHINE

I Assumptions.

a) Fixed cost

1. Life of machine	: 10 years
2. Salvage value	: Nil
3. Interest on investment	: 10 % of average of investment.
4. Insurance, repair, tax & storage costs	: 5 % of total cost of the machine
5. Cost of construction of field fermentation pond from locally available materials	: Nil

b) Variable cost

1. Average spread density	: 160 T/ht (measured)
2. Pumping capacity of Salvinia Harvesting Machine	: 16 T/hr (measured)
3. Cost of oil consumption	: 15 % of cost of fuel
4. Wages for skilled workers	: Rs. 20.00/- day
5. Wages for unskilled workers:	
a) men	: Rs.15.00/- day
b) women	: Rs.10.00/- day

6. Minimum number of skilled labourers to operate the machine	One
7. Minimum number of unskilled women labourer for gathering and feeding of the weed	Three
81 Diesel consumption for 2 pumpsets	3 lt/hr (measured)
9. The cost of Diesel/litre	Rs.3.40/-
10. Total working hrs. per day	8 hrs.
11. Operating hr. field efficiency	60 %
12. Overhead charges for items fabricated	20%

II. Calculations:

The economies of operations of the Salvinia Harvesting Machine was calculated as follows:

a) Fixed cost

1. Rough cost of machine

Table 24. Cost of components of prototype Salvinia Harvesting Machine.

Sl. No.	Items	Quantity	Total cost (Rs)	Source of information
1.	Pumpsets	2	10200	Open market price as on 3/81.
2.	Ejector system	1	600	Estimated fabrication cost.
3.	Floating platform	1	1200	-do-
4.	Accessory units like gathering arm and filtering unit	1	1000	-do-
5.	Overhead charges for fabrication work		560	
6.	Pipe and pipe fittings for extended portions of pumpset and ejector system including fitting and assembling charges.	1	1400	Open market price as on 3/81.
	Total		14960 Say 15,000/-	

2. Depreciation by St. line method : 1500.00/year

3. Interest on investment at 10% on average cost | 750.00

4. Insurance, maintenance and storage value at 5 % of annual fixed cost | 750.00

Total 3000.00

Hence fixed cost/hour = $\frac{3000.00}{x}$

Where x = No. of hrs. of use per year

Therefore cost for, say 500 hr. of annual use = $\frac{3000.00}{500}$ = Rs.6.00/hr

b) Variable cost per hour.

Harvesting rate = $\frac{16}{160}$ = 0.1 hectare/hr.

Cost of fuel/hr. = 3 x 3.40 = 10.20

Cost of oil (15 % cost of fuel) = 10.20 $\times \frac{15}{100}$ = 1.50

Cost of skilled labourer per hr. = $\frac{20}{8 \times 60\%}$ = 4.20

Cost of unskilled 3 women labourers per hour. = $\frac{10 \times 3}{4.8}$ = 6.20

Total variable cost = Rs.22.10

Therefore total operating cost/hr.

1. For, say 500 hrs. of annual use = Fixed cost, Rs.6.00 +
Variable cost, 22.10

Total Rs.28.10

2. Total cost for clearing one hectare of weed infested paddy field in 10 hrs. of operation = Rs.28.10 x 10 = 281

= Say Rs.280/ha.

MECHANICAL CONTROL OF THE FLOATING TYPE AQUATIC WEED, SALVINIA MOLESTA (African Payal)

BY

M. R. SANKARANARAYANAN

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement

for the degree

Master of Science in Agricultural Engineering

Faculty of Agriculture

Kerala Agricultural University

Department of Agricultural Engineering

COLLEGE OF HORTICULTURE

Vellanikkara - Trichur

1981

ABSTRACT

Salvinia molesta, locally known as 'African Payal' is a noxious floating type aquatic weed of common occurance, particularly in the State of Kerala in India. The infestation is the heaviest in the Kuttanadu region and in the Kole lands of Trichur District of the State, where alone more than 50,000 hectares of inland water surface is under the grip of this weed.

In the present project, the possibilities of mechanical control of the Salvinia weed were investigated. The study concentrated on the development and evaluation of a prototype Salvinia Harvesting Machine which utilised a novel design concept of fluidising the mass by means of a centrifugal-ejector pump combination. The machine consisted of two 5 H.P portable pumpsets as the prime mover and an ejector system mounted on a floating platform. The machine pump out the weed-water mixture into a floating filtering unit at zero lift from which the water was drained by gravity, the material was automatically loaded into a country boat. The results of tests conducted indicated that the 10 H.P machine was capable of pumping the Salvinia weed at an average rate of 16 T/hr at zero lift conditions. The proportion of the weed pumped was of the order of 15 % by weight of the secondary flow when pumping water alone. The special features of this equipment were that it could utilise conventional irrigation pumpsets as the prime mover and that it did not allow the weed materials to be

drawn into and clog the primary pump. The machine was also capable of being operated as a self propelled unit.

In this project, certain accessory units such as a gathering arm, a floating fence and an automatic filtering unit were also successfully developed and evaluated. In addition to loading the material into a country boat, a disposal technique of pumping the weed materials into a field fermentation pond, which avoided any immediate transportation costs for the harvested material, was also investigated.

It was found that the bulk density of Salvinia was of the order of 400 kg/m^3. It was also found that the spread density value of the weed, depending on the stage of growth and degree of packing, could vary from 8 T/ha to 32 T/ha. A representative value for the spread density, under the still water condition at Kuttanadu, was found to be of the order of 16 T/ht. This meant that the prototype Salvinia Harvesting Machine would be capable of clearing the weed from a hectare in 10 working hours. The estimated cost of such an operation amounted to Rs.280/- per hectare which compared favourably with the reported costs of Rs.900/- to Rs.2700/- per hectare for manual collection and disposal of the weed. It is considered that the present work is a significant contribution to solving the problem of African Payal infestation in Kerala State.