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Design, Development and Evaluation of The Performance of on Electrical Bee Smoker for Bee Keeping Industry

Charithangi MP [1]*,Rambanda M[2], Atapaththu DMK[4] , Samarakoon SAMC[5] and Perera DPL[3]

Department of Agricultural Engineering and Soil Science, Faculty of Agriculture, Rajarata University of Sri Lanka, Anuradhapura, Sri Lanka [1,2,3]

Bee Development Unit, Department of Agriculture, Bindunuwewa, Bandarawela, Sri Lanka[4]

Department of plant Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka, Anuradhapura, Sri Lanka[5]

ABSTRACT

Bee keepers use a harmless smoke to calm the bees before opening the hives in order to reduce the activity level of honey bees to reduce the chance of bee keepers being stung by bees. This study was conducted to introduce an efficient and convenient electrical bee smoker for bee keeping industry. Major components of the designed bee smoker are smoke generating unit, smoke blowing unit and power supply unit. Total weight of this kept at 1.1 kg while the cost of the machine was about LKR 2,000. Ability to control the smoke flow rate according to the requirement is the most salient feature of this. Performance of electrical bee smoker (T1) was compared with the manually operated bee smoker (T2). The results revealed that the electrical bee smoker is significantly superior in functional performances and purity of smokes. Results showed that the smoke emission rate with minimum of impurities in the smoke for a longer duration of time is significantly high in new smoker. Satisfaction level of bee keepers about functional performance was also taken using a pre tested questionnaire. Results were analyzed using Friedman method of non-parametric analysis. According to the data collected by the questionnaire a significant different ($p<0.05$) was observed between functional performance of T1 and T2. There was no any significant difference between T1 and T2 in behaviors of bees. 73 % of the bee farmers were satisfied with the overall performances of new smoker. According to the results of this study it can be concluded that the newly designed electrical bee smoker is much easier to use and economic for bee keepers.

KEYWORDS: *Bee Keeping, Bee Smoker, Electrical Smoker*

[1]* Corresponding author Charithangi MP: charithangi30@gmail.com

1 Introduction

Bees are the insects which were arrival in the course of organic evaluation on earth, about 70 million years ago. They are numerous with over 20,000 species grouped as super family Apoidea in the insect order Hymenoptera. Among many thousands of species of bees there is a group called honey bees that live as group of many individuals and store honey in their nests consisting of waxen combs (Akratanakul ,1999). Although the number of the honey bee species which are in the world is debatable among the taxonomists. But at least four species are recognized. *Apis cerana* is the most common domesticated honey bee species in Asia among them. Rearing of bees in a broader sense is called Apiculture. Apiculture has to do with the management and scientific background for the management of honey bees, usually for honey production or wax production or crop pollination (Anon,2006). In Sri Lankan condition, bee keeping and honey hunting has a long history. Meepani is valued by Sri Lanka's Ayurvedic medical system, where it is an essential ingredient in various medicines. The systematic beekeeping activities in Sri Lanka commenced in the year 1940 with the active support by the State Department of Agriculture (Punchihewa, 1994). The beekeeping practice is mainly with domesticated bee, *A.cerana* and 35% of honey comes from these hives, as much as 65% of honey comes from wild bees like *A. dorsata.* Only one-the meemassa (*Apis cerana*) is suitable for domestication, because it builds its hive in enclosed spaces, which makes it suitable for beekeeping. It could be estimated that 40 MT of honey is produced through bee keeping and there is no proper information on the number of bee colonies.

When consider the beekeeper's tools and equipment, every bee keeper needs a veil, a smoker and a hive tool. The smoker is an apparatus for making smoke and directing a stream of it upon the bees to quiet them. An experienced bee keeper always keeps it right at hand during manipulation. The use of a little smoke quiets the bees so that they may be handled more readily. The use of an excessive amount disorganizes them unduly. A puff of smoke at the entrance and a few more under the cover and they scurry across the frames and into the honey cells to save what they are occupied in that manner they take no notice of the bee keeper or his examination of the hive .After they have gorged themselves they are equally indifferent (Punchihewa,1994). The commonly used commercial bee smoker includes metal receptacle and fire pot.

2 Statement of the problem

The mostly used commercial smoker consists of a metal receptacle or fire pot and a manually operated bellow. Although, it is been used by majority of the bee keepers, it has several failures such as low firing time of smoker fuel, detrimental effects of bees due to impurities releasing , low smoke emission rate, inability of smoke controlling, punch the bellows with use both hands and low efficiency. Due to this, bee keepers have been failed to properly restrain the bees when working with them. Therefore, injuries to the bee keeper, damages to the colony and less amount of final product can be seen. Although, bee keeping is a profitable self -employment in Sri Lanka, most of the people do not like to engage it due to the dangerous experiences of bee keepers. As, this smoker is a manually operated one, it is very difficult to do other work when operating the smoker. Therefore, by introducing an efficient, electrically operated, economical smoker to the bee keeping industry, it can be popularized among people and the honey production of the country can be increased.

3 Objectives of the study

General objective of the study was introducing an efficient and affordable smoker to the bee keeping industry, in order to increase the honey production and popularize the bee keeping among people. Specific objectives of the study were design an electrically operated bee smoker and evaluate the performance of the new smoker compare to the existing smoker.

4 Review of literature

Bee keeping for honey production is an ancient art with honey farming an important part of early man's diet (Fernando, 1986). Rural employment, nutrition and income generation in developing countries are the potentials of bee keeping offers to agriculture. Honey provides a valuable food. Bees wax has many uses at home and in industry. Bees are important pollination agents and thus aid crop production. Bee keeping need not interfere with other rural farm activities. The whole family can be involved. The required inputs can be substantially produced locally (Wicramasinghe,R.H.,1982).When considering bee keeping industry in Sri Lanka, there are three species of honey bees and normally, they are called as Danduwelmessa ,

Bambara and Meemessa. In scientifically they can identify as *Apis florea*, *Apis dorsata* and *Apis cerena* respectively. Meemessa is the most popular bee species in Sri Lanka and the largest bee species is *Apis dorsata* (Fernando,1986). Climatic conditions and plant community are directly affected for bee keeping industry. They can complete their life cycle due to preferable climatic condition. They can find enough foods for feeding, if they have more plants which are rich in pollens and floral nectar. Since, Tea, Rubber and Coconut are the major plantation crops in Sri Lanka, those plantation lands can be used for the rearing bees and can earn the additional income (Hettiarachchi K,1994).

The purpose of the enhancing the national honey production, the Bee Development Unit (Bindunuwewa) in Sri Lanka was established in 1976 .The Main bee keeping unit is situated in Bindunuwewa at Bandarawela and subunits in Colombo, Ratnapura, Buttala and Mawathagama. Production of bee keeping appliance, production and processing bees honey, conducting training on bee keeping and equipment manufacture, maintenance of colonies for marketing, certification of bee keeping equipment produced by private sector manufactures, coordinating with private and government organizations, assisting research programs on bee development are the conducting activities during the year by Bee Development Unit (Department of Agriculture,(2006).Retrieved March 22,2015,from www.DOASL.lk).

When working with the colonies, need to slow, careful, deliberate movements to minimize the bee stings. Bees are more attracted to quick movements. Mashed bees can release an alarm pheromone. It can alert and incite other workers to defend the colony. The smoker helps to mask the alarm pheromone (Anon,2014). According to some scientists, they believe after the smoking action honey bees can store large quantities of honey in their stomach to feed off in case the smoke is from a fire that could damage the hive .They cannot move easily after they engorge with honey. After the smoking, reduce the activity level of honey bees and also reduce the stung of bee keepers by bees (VSU,2014). After the bee sting, local tenderness and swelling are the normal reactions. Bee keeper's body develops immunity to bee venom. So, swelling becomes less severe. A more severe allergic response to a bee sting is a systematic reaction. Symptoms of the systematic reaction are swelling of lips, tongue, eyelids, abdominal pain, nausea, vomiting, dizziness, tightness in the chest with difficulty breathing or swallowing, weakness or confusion, death (Anon,2014).

When considering the existing Bee Smoker, it is a simple device. Fuel chamber is loaded with combustible. The fire is going well, close the top, which cuts off air to the fire. Fire will smolder with few minutes and smoke will issue forth. Bellows forces air into the bottom of the fuel chamber at high velocity, blowing out any flame or glowing embers remaining (VSU,2014).

5 Methodology

All the designing, fabrication and testing works of newly design electrical bee smoker were carried out at the engineering workshop of Faculty of Agriculture, Rajarata University of Sri Lanka and evaluation was done at the Bee development Unit, Department of Agriculture, Bindunuwewa, Bandarawela. Electrical power was selected as the operating power source of the bee smoker due to high efficiency. A preliminary test was done to select optimum dimensions for the machine via a personal interview of bee keepers. Readily available, low cost and durable materials available in the local market were used to fabricate the machine in order to facilitate the repair and maintenance at village level workshops. Galvanized metal sheets, plastic pipe, wooden, foils and metal meshes were the row materials which used to fabricate this machine. Drawbacks of manual bee smoker, smoker fuel material, power supply source, safety and durability, easy maintenance, time saving and heat resistance were major factors considered at the designing process. Low firing time of smoker fuel, detrimental effects of bees due to impurities releasing, low smoke emission rate, inability of smoke controlling, punch the bellows with use both hands and low efficiency have been identified as the major constrains of the existing manual bee smoker.

Major components of the electrical bee smoker were Smoke generating unit, Smoke blowing unit and Power supply unit. Smoke generating unit comprises of two chambers as internal chamber and external chamber (Figure 5:1). Cuboid shape with the dimensions of 8 cm x 8cm x 22cm was designed using gauge 26 galvanized metals as an internal chamber and 12cm x 12cm x 25cm was designed using the same metal as an external chamber. Gauge 26 galvanized metal sheets were used due to its light weight, durability and heat resistance. Cuboid shape was used for the chambers as it facilitates the fabrication. In addition to that, this shape is important to fix the blower and other accessories (handle, battery case) to the external chamber. Circle with 8 cm diameter was cut in both chambers as smoke releasing hole. This circle was cut in 4 cm away from the top of the external chamber and 2.5 cm away from the top of the internal chamber. Rectangular shaped with the dimensions of 4 cm x 6 cm was cut as the burning hole in both chambers in order to control the air flow in to the burning chamber as the burning characteristics of coconut husks (fuel material) are mainly depend on the amount of air flow in the burning chamber. In addition to that, burning can initiate from this hole .It was made 4 cm away from bottom of the external chamber and 2.5 cm away

from bottom of the internal chamber. The veil was made to the external burning hole and it was opened and closed as required. The internal chamber was consisted a top plate and it could be opened to insert the fuel and the main absicht of the internal chamber is retention of smoker fuel. Metal wire mesh was fixed to the bottom part of the chamber. Maximum chamber capacity of fuel was 704 cm^3.External chamber also consists top and bottom plates and could be opened when it require. The fuel material can be inserted to the chamber through the top plate. Bottom plate works as an ash collector and ash could be collected to this bottom plate directly through the metal mesh .The filter was fixed between the external chamber and internal chamber to reduce impurities releasing through the outlet.

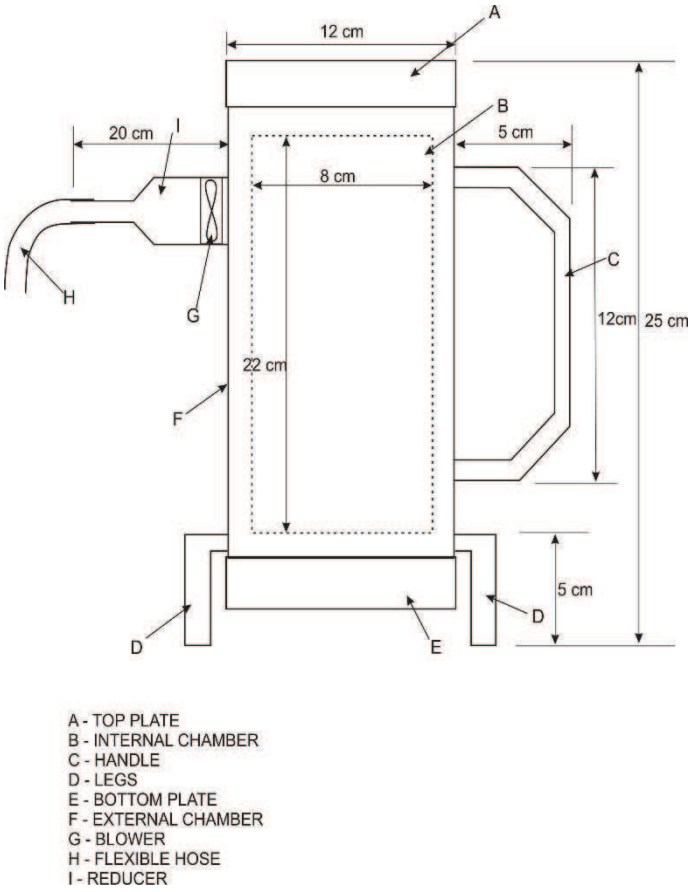

Figure 5. 1: Electrical bee smoker

Smoke blowing unit comprises of blower, plastic reducer and a flexible hose and purpose of this unit is for the taking out the smoke from the internal chamber via a blower and direct to the required place with a control through the plastic reducer. The flexible hose was fixed to the reducer and it could be remove or fix according to our requirement (Figure 5.2). Therefore the smoke can be directed to the right places where we need. Suction side of the blowing unit was fixed to the external chamber and delivery side is connected to this flexible hose.

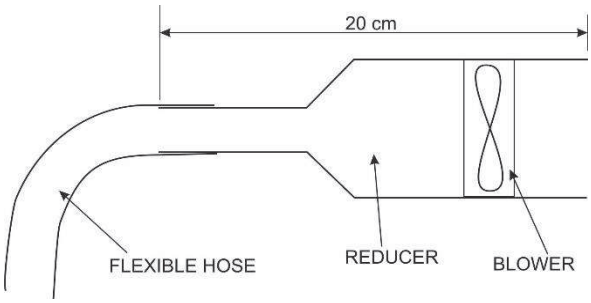

Figure 5.2: Smoke blowing unit

When considering the power supply unit, power was supplied by 12 V, DC rechargeable battery .The regulator was used to control the smoke emission rate from regulating the voltage and it can be changed in 1.3V -12V range. Power supply unit was let in the wooden case which is fixed to the external chamber. DC jack base was fixed to the wooden case and it was given place where for connect the AC-DC power adapter and the switch was consisted on the wooden case to on or off the blower.

In addition to the main components of the smoker, handle to carry the smoker, a battery case to put the rechargeable battery and four legs to place the machine on the floor without any harm, can be considered as the other fixed accessories. Handle and battery case were made of wooden as it is a good heat resistant material. Legs were made using 26 galvanized gauged metals and fixed the four rubber bushes.

External chamber, legs, wooden handle, foil which was pasted to outside of the internal chamber and inside of the external chamber and heat susceptible sealants are common safety practices which used in fabrication process.

5.1 Performance evaluation

Performances of both manual and electrical bee smokers were compared. Newly designed bee smoker and a manual operating bee smoker were tested for the following parameters with standard conditions.

- Smoke emission rate
- Test for the firing time of smoker fuel
- Test for the impurities in the smoke

Smoke emission rate (Q) of outlet was assumed as similar to the air flow rate of the blower of the newly designed bee smoker. Velocity of air flow (V) was measured using a flow meter. Smoke emission rate is the amount of smoke that can be emitted per unit time (m^3 /min). Equation 01, was used to calculate the smoke emission rate.

$$Q = AV \quad (1)$$

Q = Smoke emission rate

A = Cross sectional area of the flow meter

V = Velocity of air

Equation 02, was used to calculate the firing time of smoker fuel. Firing time of smoker fuel is the time difference between the beginning of smoke releasing ($T1$) and last moment of the smoke releasing ($T2$) per unit fuel weight (W).(Unit – Minutes / g)

$$T = (T2 - T1)/W \quad (2)$$

Equation 03, was used to calculate the impurities released from outlet (W_*). A filter paper, which was dip in castor oil was exposed to the smoke for a unit time to obtain the quantity of impurities. (Unit-g/hour)

$$W* = (W2 - W1)/T \quad (3)$$

$W*$ = Impurities released from outlet

$W1$ = Weight of the castor oil filter paper before exposition of smoke

$W2$ = Weight of the castor oil filter paper after exposition of smoke

T = Smoke exposition time

Although the machine parameters reflect the performances of a machine, the responses of users on the performances of a machine are also very important to take a decision on a machine. The satisfaction levels of bee keepers for functional performance of bee smokers and behavior of bees were compared using a pre tested questionnaire. Fifteen registered bee keepers under the Bee Development unit, Bindunuwewa, were randomly selected for this interview. As all of them are well experienced with the manual bee smoker, before the interview, all the farmers were given the newly designed bee smoker to use their day to day bee keeping activities in order to get experience on the new one. Data was analyzed by using Friedman method of Non-parametric analysis.

6 Results and discussion

The size of the machine was decided based on convenience of the bee keeper. Preliminary test was done to select correct dimensions of the machine via a personal interview of five bee keepers. Table shows value they given and average values of the chambers.

Table 6.1: Given values and averages

No of bee keepers	**Values they given**					
	External chamber			**Internal chamber**		
	Width(cm)	Length(cm)	Height(cm)	Width(cm)	Length(cm)	Height(cm)
1	12	12	30	8	8	28
2	8	8	10	5	5	10
3	15	15	30	12	12	25
4	15	15	30	8	8	25
5	10	10	25	7	7	22
Average value	12	12	25	8	8	22

6.1 Fabrication of the machine

Total time taken to fabricate was about four weeks. When assembling the machine, both internal and external chambers were fixed by nuts and bolts. The space between both chambers was 2cm apart from all the sides. The wooden handle and battery case were fixed to the external chamber using nuts and bolts. The smoke blowing unit and the smoke generating unit were connected using pop rivets, nuts and bolts. Almost all components of the machine were fixed using non – permanent fastening methods, because all parts could be detached and repaired easily at household level. Although, after every usage of machine it should be clean and release the ash and other impurities directly through the opened bottom plate of the external chamber. The battery should be charged properly before using machine and time taken for charging depend on according to the number of hives that we have to harvest. After the analysis of cost, the cost for material was Rs: 1400 /= and fabrication cost was Rs: 600 /= .So, grand total was Rs: 2000/=. The specifications of the machine was tabulating in following.

Table 6.2.Specification of machine

Component of the equipment	Dimensions
Total weight of the machine	1.1kg
Total height of the machine	27 cm
Total length of the machine	12cm
Total width of the machine	12cm
Total length of the smoke blowing unit	20cm
Maximum height that coconut husk can fill	11 cm

6.2 Operating the machine

When operating the machine, pieces of coconut husk should be filled into the internal chamber. Before insert the coconut husk, some amount of water should be added to it. After putting the husk, it should be compressed well in the internal chamber. Size adjustable burning hole should be opened in order to provide the air. Then, the switch of the blower should be switched on and the smoke flowing rate can be adjusted by controlling the voltage using the regulator. After using the smoker, the bottom plate of external chamber should be opened to remove the ash and other impurities.

Plate 6.2.1: Internal and external chambers of smoke generating unit

Plate 6.2.2:- Power supply unit and Smoke blowing unit

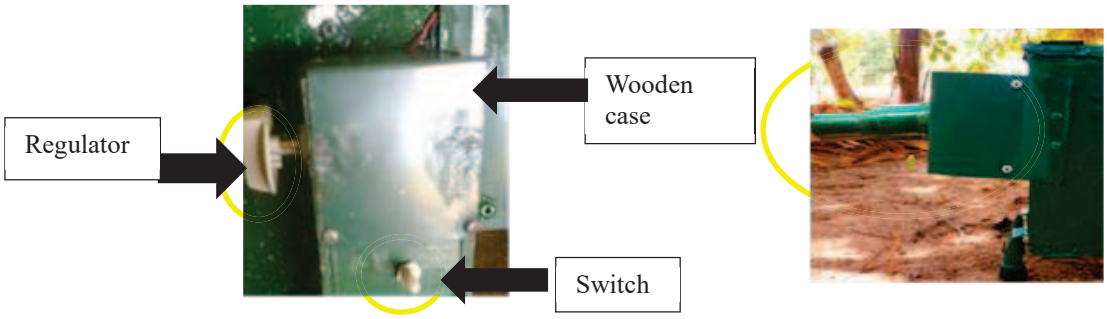

Plate 6.2.3.:- Complete electrical bee smoker

6.4 Performance evaluation

The performance of the electric smoker was compared with the existing manual smoker. The final results were tabulated in following table.

Table 6 3: Results of manual and electrical bee smokers

Performance	**Manual machine**	**Electrical machine**
Smoke emission rate (m^3/minutes)	$1.30x10^{-6}$-$3.73x10^{-5}$	1.03
Firing time for smoker fuel (Minutes) (for 35 g of smoker fuel)	17.67	34.33
Amount of impurities release from outlet (g/hour) (for 35g of smoker fuel)	38.586	7.752

6.4.1 Amount of impurities release from outlet

Table 6.4: Impurities experiment results of electrical and manual bee smokers

Description	**Trails of Electrical Bee Smoker**				**Trails of Manual Bee Smoker**			
	First	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**
Weight of the empty filter paper (g)	0.8626	0.8624	0.8626	0.8625	0.8621	0.8626	0.8626	0.8624
Weight of the polythene (g)	0.6979	0.6977	0.6977	0.6977	0.5694	0.5578	0.5685	0.5652
Weight of the filter paper with castor oil+ polythene (g)	3.3783	2.4810	3.2213	3.0268	2.9840	2.6954	3.0193	2.8995
Weight of the filter paper+ castor oil+ polythene+ impurities (g)	3.5883	2.7810	3.4865	3.2852	4.2840	3.9274	4.3460	4.1858
Weight of the impurities (g) within 2 minutes	0.2100	0.3000	0.2652	0.2584	1.3000	1.2320	1.3267	1.2862
Weight of the impurities per hour(g/hour)				7.752				38.586

Impurities in the smoke can bring detrimental effects for the bees. Manual machine was released high amount of impurities than electrical machine. In electrical machine, a filter has been fitted to the external chamber, so that impurities releasing can be minimized. So then, minimize the impurities released from outlet.

6.4.2. Firing time of smoker fuel

Table 6-5: Results that given by the both machines

Description	Trails of Electrical machine			Trails of Manual machine		
For 35 g of smoker fuel	First	Second	Third	First	Second	Third
Beginning of the smoke released (minutes)	1.57p.m	2.45p.m	4.00p.m	1.57p.m	2.45p.m	4.00p.m
Last moment of the smoke released(minutes)	2.33p.m	3.17p.m	4.35p.m	2.18p.m	3.02p.m	4.15p.m
Time difference	36	32	35	17	17	15
Average	34.33			17.67		

There was a small hole between the receptacle and bellow of manual bee smoker but it cannot close as requirement. Therefore oxygen supply cannot be controlled and firing time of smoker fuel was low. But electrical smoker was not opened to the external environment and oxygen content can be controlled inside the chambers. Therefore firing time of smoker fuel was higher than manual machine.

6.5 Satisfaction Level of Bee Keepers

Satisfaction Level of Bee Keepers was found using a questionnaire. Fifteen skilled bee keepers were selected randomly at bee development unit, Bindunuwewa. An evaluation criterion was divided into two basic indicators.

Functional performance of bee smoker

Functional performance of honey bees (Behaviors of bees)

Both qualitative data were analyzed by using Friedman method of non-parametric analysis. Based on satisfaction level of bee keepers for functional performance of smokers, they were highly satisfied for the electrical bee smoker than manual bee smoker. But, satisfaction level of bee keepers on bee behavior, no any significant different among smokers.

7 Conclusions and recommendations

7.1 Conclusions

According to the testing and evaluations, this electrical bee smoker was a successful machine. Because of, it had shown minimum detrimental effects to the bees, low smoker fuel requirement, easy handling and higher safety. Similarly, this machine can be used to plunder the bee hives even in difficult places such as Ant-hills and even hives of *Apis dorsata* (Danduwel messa), *Apis florea* (Bambara) as it has a flexible long tube to direct the smoke.

This machine can be used skillful and non -skillful bee keepers. So bee keeping can be started even in homes as an additional income without any fear or stings of bees. Machine has an ability to inspirit the people for bee keeping. Ultimately, national bee honey production can be enhanced.

7.2 Recommendations

The newly constructed bee smoker can introduce to bee keepers by conducting awareness programmes or extension services with engaging Bee Development Unit, Department of Agriculture. In addition to that, new relevant researches should be carried out to improve the performances of this machine. Further, enhancement of heat resistant ability of some components is important to improve this machine.

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