

FOG DRIP

(A Summary of the January 6, 1956 Seminar)

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INTRODUCTION

Numerous reports of fog drip in considerable amounts from trees in clouded areas in the Hawaiian Islands are to be found. Most of these have been passed by word of mouth and have come from the ranching areas on Hawaii and Maui. The earliest and best accounts, however, have come from G. C. Munro, who became interested in this problem in 1927 while watching the drip from Norfolk Island pines on Lanai. At that time, a large tree which stood above the tin roofed house seemed to shed considerable water in foggy conditions. Mr. Munro went to considerable lengths to inform himself on this subject and wrote a number of articles about it. He also initiated a Norfolk Island tree planting program on the island in the hope of gathering more cloud water.

Reports are also available elsewhere of work done on this topic. The most frequently referred to work is by Dr. Marloth, working in South Africa (1). He found that several times as much water was available to a tree as a result of fog drip as by rainfall. This work has recently been renewed by the German Weather Service. Other work is listed in the attached bibliography.

More recently in Hawaii the subject has been brought forward by V. W. Thalman, of the Hawaiian Pineapple Company on Lanai, whose enthusiasm for more research on the subject stemmed from his observations of the fog drip while hunting on the mountain ridges.

A proposed experiment was discussed by him with M. D. Thorne and the author in 1952. This experiment depended largely on the accessibility of the mountain top. An access road was built early in 1955

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and the experiment initiated by the HAPCO Experimental Department in cooperation with PRI and the Territorial Board of Agriculture and Forestry.

Interest in the experiment also increased due to new PRI measurements of cloud water content and droplet size spectrum as part of the PRI cloud physics project, which indicated that considerable water might be obtained by either an expanded tree planting program on Lanai or possibly by constructing a barrier of wire or fibre that might catch this water. The measurements which follow, made by the Experiment Department of HAPCO, Lanai present some of the results of this investigation.

COMPARISON BETWEEN RAIN-FALL AND FOG DRIP UNDER SELECTED NORFOLK ISLAND PINES

The initial phase of the experiment was nothing more than measurements from six raingages placed randomly under a pine tree (Fig. 1) nearby the Lanai Hale raingage. These gages were moved at intervals to make certain that they were not fortuitously placed under water collecting points of the tree. The first six weeks of data collected at this location are shown in Table 1.

Table 1.-Raingage readings in the open and under a Norfolk Pine.

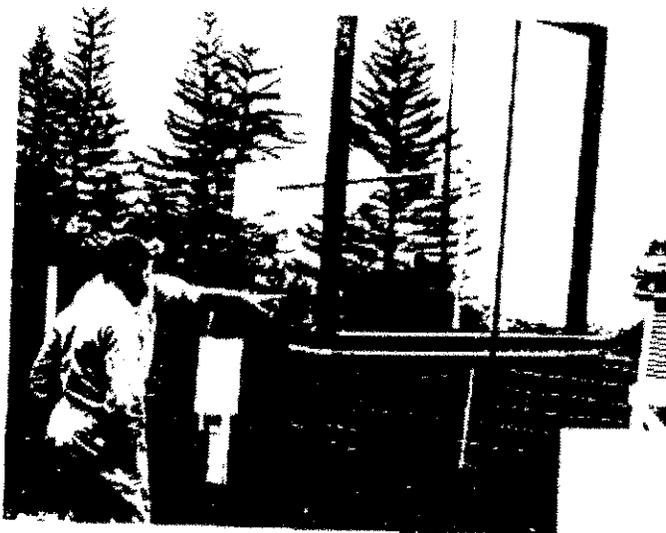
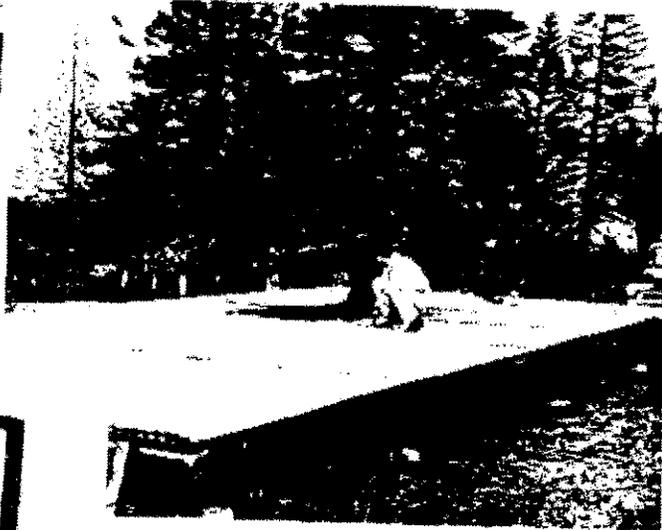
Date	Gage Readings in the open (Rain)		Gage Readings Under Norfolk Pine						Average Fog Drip #1-6
			#1	#2	#3	#4	#5	#6	
June 1-7, '55	0.18		1.08	0.63	0.08	0.50	0.62	0.13	0.51
7-14	0.06		0.10	0.13	0.12	0.17	0.08	0.06	0.11
14-21	0.10		0.63	1.00	0.71	0.63	0.88	0.64	0.75
21-28	0.17		0.92	2.29	1.00	1.23	2.00	1.22	1.44
28-30	0.07		0.36	1.44	0.54	0.60	0.52	0.61	0.68
30-July 5	0.22		1.10	4.47	2.48	1.09	1.25	1.89	2.05
Total	0.80								5.54

The average water falling under the tree during this interval was approximately seven times the amount of rainfall during that period. This was a period of very strong trades. Record sailing times were made in the Transpacific Yacht Race held during this interval.



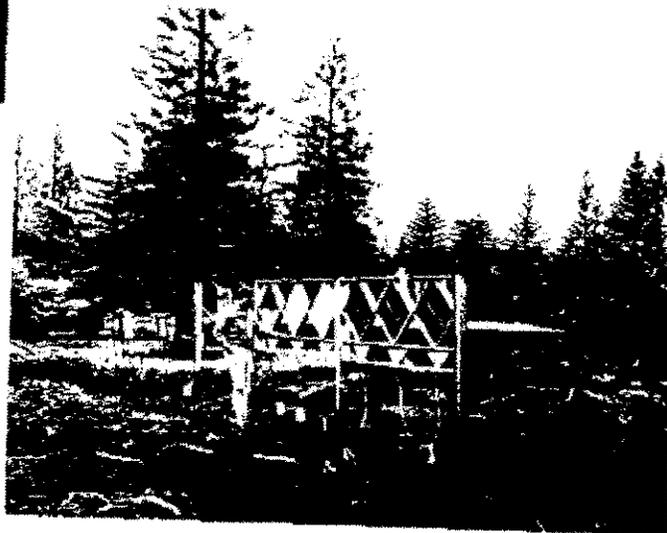
←  
 FIG. 1 Six raingages were placed under a Norfolk pine on the crest of Lanai Hale. These gages were moved each week according to a randomized plan so that they would not be fortuiously placed under a water collecting point of a tree.

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 FIG. 3 A water shed constructed under a 40 ft. Norfolk pine was used to measure the total drip from a single tree.



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 FIG. 4 Apparatus referred to in text as a "harp". It consisted of a frame with vertically stretched wires directed into the wind by a wind vane. Water collected on the wires was lead away through the pipe at the bottom and measured each day.

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 FIG. 5 Frames of different kinds of materials were tested for their water collecting properties. Results of these investigations are shown in Table 2.



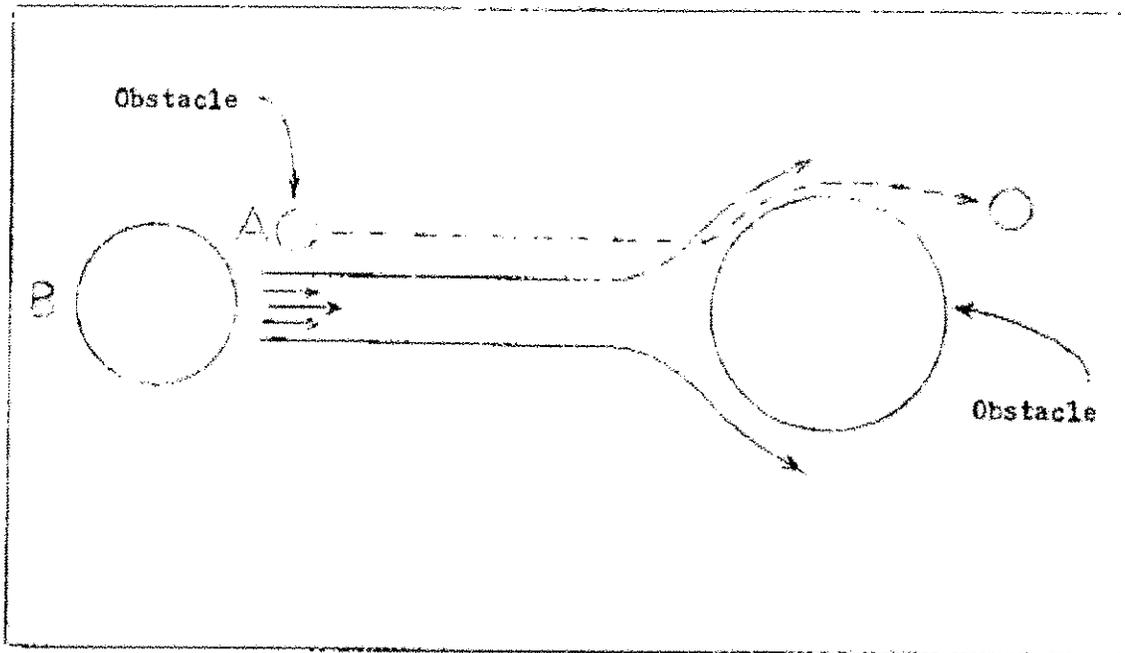


Figure 2. Diagrammatic representation of the collection of water droplets by impingement. Explanation in text.

WHAT IS TOTAL WATER  
POTENTIAL OF CLOUDS?

Cloud measurements made during "Project Shower" indicated that an amount up to 3 grams of water, in droplet form, per cubic meter of cloud, is found in Hawaiian clouds. Most of these measurements indicated less than one gram, however, and average conditions, all factors accounted for, probably are about 1/2 gram/m<sup>3</sup>.

Interpreting this in terms of our experiment, this means that with a wind speed of 11 miles per hour (5 meter/sec.) the following amounts of water in droplet form would flow through a hoop with a cross sectional area of one square meter oriented perpendicular to the wind:

	<u>Cloud water content</u>	=	<u>Water per day</u>	
at	.3 gm/m <sup>3</sup>	=	34 gals/day	in continuously cloudy conditions
	.5 gm/m <sup>3</sup>	=	58 gals/day	
	1.0 gm/m <sup>3</sup>	=	115 gals/day	

These figures must then be reduced by the percentage of cloudy weather (which must be estimated due to lack of record) and the efficiency with which the water can be captured. This latter figure depends on the cloud drop size spectrum, the size of the collecting obstacle, the speed of the wind and the overall obstruction to the wind which any collecting obstacle may offer.

Only a part of this information can be obtained from records or the literature. Because of practical limitations, our objective was only to obtain a first estimate of the amount of cloud water at this location and the proportion which might be collected with relatively easy methods.

THE PHYSICAL PROBLEM

The collection of water droplets by impingement has been worked out theoretically by Langmuir and Blodgett (2).

The problem is represented in simple form in Fig. 2. It is analogous to the behavior of a balloon drifting with the wind. If a billboard lies in its path, it will, in all probability, be

deflected by the wind flowing around it, never striking the obstacle. If a wire or long narrow obstacle lies in its path, the wind will not be deflected enough to deflect the balloon. In Fig. 2, the droplets marked "A" might be deflected while those marked "B" would not. The speed of the wind, hence, the momentum of the droplet, the relative sizes of the droplet and obstacle, and the shape of the obstacle are important.

The percentage collected is called the "collection efficiency". It is easy to see that if the droplets are smaller, the wind weaker, or obstacle larger, the collection efficiency is reduced. For the problem stated here based on our measurements of the size of the droplets, available collecting wire or surface, it was believed that half of the cloud water might be collected with good engineering.

The best collector, theoretically, is one which has the most finely divided collecting surface, which obstructs the path of each particle, and which does not offer a major obstruction to the wind.

#### THE LANAI EXPERIMENT

So far as the economic evaluation of fog drip is concerned, the following major items of information are required:

(1) Percentage of time favorable for fog drip (including variations in cloud water, wind speed). (2) Relative efficiency of various collecting surfaces (including trees, screening, fibre glass, etc.).

Beginning in early July 1955, an enlarged program of measurements was carried out. In addition to the raingages under the Norfolk pine, a water shed of corrugated steel was built under a comparable tree (Fig. 3) and measurements were begun of the total water drippings from the tree. Later a recording device was attached so that continuous records were obtained.

A "harp"-like instrument (Fig. 4) with spaced, vertical wires was mounted on a swivel and oriented perpendicular to the wind flow by means of a wind vane. Water collecting on the wires was allowed to flow into a bottle for daily measurement. Squares of various screens, fibre glass and filtering materials were mounted in frames for measurements of the collecting qualities of each (Fig. 5).

Regular meteorological instruments were installed at the experiment location to record wind at two levels above the ground, relative humidity, temperature, sunlight, evaporation, and rainfall. These measurements were later recorded continuously. Later in the experiment, a 30 foot tower was erected to test large areas of materials and to investigate the wind profile.

Several different types of materials were tested as fog drip collectors. As will be seen in Table 2, none of these materials seem to offer much promise of commercial application. Of those tested, considering the factors of durability, cost, and efficiency, the louvered aluminum shade screen worked out best.

Table 2. -Comparative moisture collection efficiency of different types of materials.

"Harp" Gallons/yd. <sup>2</sup> /day	Ratio of Collection to "Harp"	No. of Observations
	Fibre Glass	
	A = 1.04	43
Average	B = .394	8
"	C = .677	14
"	D = .637	21
"	E = .643	21
"	F = 1.135	30
.304	Air Conditioning Filter	
(Potential <sup>1/</sup> 4 gal/day)	Single = 1.060	44
	Double = .675	28
(Maximum day potential 15 gal/day)	Louvered Alum. Screen	
	Single = 1.18	16
	Double = 2.10	16
	Plastic Screen = 1.09	16

<sup>1/</sup> Potential: only a small percentage of the cloud droplets were obstructed by the wires on the "harp". This calculation is to show what should be caught if the paths of all droplets were obstructed.

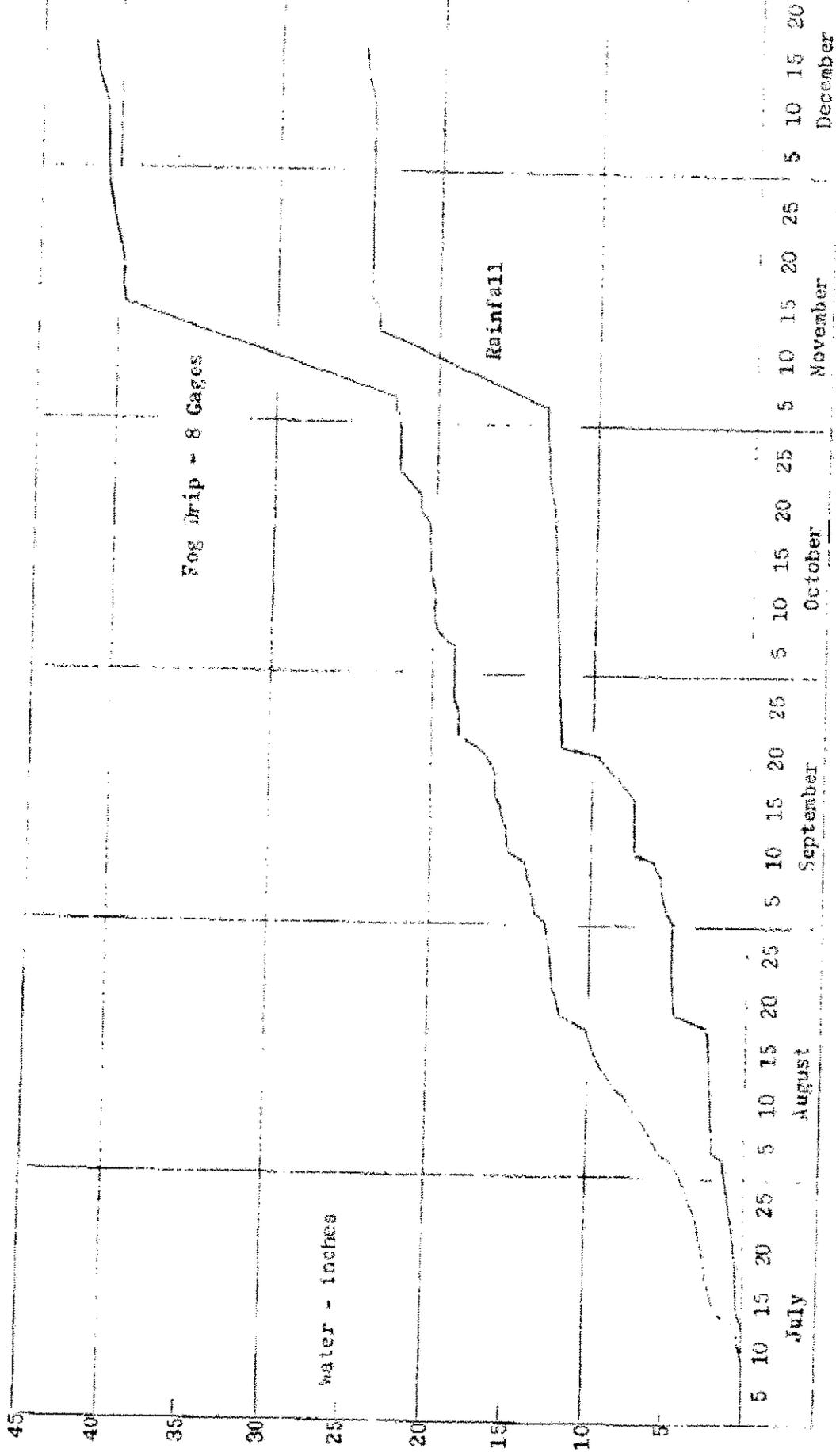


Figure 6. Accumulated rainfall and fog drip from July to December, 1955.

SEASONAL EFFECTS

Seasonal influences in Hawaii favor summer as the period in which the greatest fog drip occurs. On Lanai this cycle is in opposite phase to the rainfall which occurs primarily in winter.

Water from fog drip is a much more regular source during this summer period than water from rain. It is believed that this can be quite an important consideration in the ecology of certain regions. This is illustrated in Fig. 6 which shows the accumulation of water from each source from the time the experiment began. Altogether, an amount of water was obtained by the trees, in rain and fog drip conditions, roughly twice the rainfall for the period. An examination of the daily records showed that in moderate to heavy rainfall, the trees actually shed water so that less water was caught in the gages under the tree. In view of this, it can be stated that for this area the water obtained from fog drip very probably exceeds the rainfall considerably.

SUMMARY AND CONCLUSION

It appears from the initial data obtained that appreciable amounts of water are collected in forests by fog drip. It seems certain that forrestation should be continued and enlarged in Hawaiian water shed areas which are frequently clouded.

The type of tree used will have an important bearing on the efficiency of the forests' removal of water from the air. The qualities of tree which should be sought are: (1) overall large dimensions, especially height; (2) fineness of leaf structure, needles preferred; (3) the ability to withstand wind and not be shaped by it; (4) wind obstruction; and (5) opaqueness. Although different trees have not been tested, the Norfolk Island Pine seems to be well suited to this task.

Up to this date, economical methods have not been found to remove water from the clouds by artificial barriers. Although the materials tested are roughly of equal efficiency to the Norfolk pine needles in removing the water, any method thus far considered for collecting water by this means is prohibitively expensive.

ACKNOWLEDGMENT

A large part of this work was done by Mr. Jack L. Larsen of the experimental Department of the Lanai plantation of Hawaiian Pineapple Company. The large installation on the top of Lanai Hale and almost daily collection of data were done under his supervision.

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Vol. 4, No. 1

March, 1956

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