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FOLIAGE PLANTS FOR IMPROVING INDOOR AIR QUALITY

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BACKGROUND

Indoor air pollution and "sick building syndrome", byproducts of the 1970 energy crisis, have become household words. Two of the key ingredients which have contributed to today's potentially serious indoor air pollution problems are tightly constructed buildings with dramatically reduced ventilation rates and the radical change in the nature of building materials and household furnishings. Add to this, new household products such as cleaning and polishing solutions, insecticides, glues, personal hygiene and health care products along with numerous electronic devices and radon gas and you have the ingredients for serious health problems.

For more than 15 years, the National Aeronautics and Space Administration (NASA) has been aware of the potential indoor air pollution problems associated with completely closed structures in outer space (1). Other agencies and researchers have also confirmed the presence of large numbers of trace organics inside modern buildings (2-28). In anticipation of long term manned space flight during the next 10 to 20 years, NASA is evaluating the beneficial effects of having plants in future manned space operations. Both the psychological and physiological affects of plants on man when confined for long periods of time in a closed system are of interest to NASA. The photosynthetic process that allows plant to live and grown requires a continuous exchange of gaseous substances between plant leaves and the surrounding atmosphere. The most common gaseous substances exchanged are carbon dioxide, oxygen and water vapor. The plant leaves normally give off water vapors and oxygen and take in carbon dioxide. However, it appears that plant leaves can also take in other gaseous substances from the surrounding atmosphere through tiny openings (stomates) on their leaves. Recent NASA studies have concentrated on determining the ability of plant leaves and plant roots to remove trace levels of toxic chemicals from closed experimental chambers. These same studies are also looking at the possibility that certain plants might give off trace levels of metabolites that could have undesirable effects on man in a completely closed system.

Studies to determine the ability of several types of plants to treat and recycle wastewater and remove trace levels of toxic chemicals from air inside closed chambers have been conducted by NASA for over 10 years (29-33). These studies at the Stennis Space Center (SSC) in south Mississippi have generated a great deal of public interest over the past several years because of the potential for this simple technology in treating domestic wastewater, industrial waste, controlling industrial air pollution and water reuse in addition to the promise of supplying an inexpensive means of indoor air pollution control. As a result of this public interest, in February 1988, NASA signed a jointly funded, two-year agreement with the Associated Landscape Contractors of American (ALCA) to evaluate the ability of certain foliage plants to remove indoor air pollutants such as formaldehyde, benzene, TCE and carbon monoxide from indoor environments. Previous NASA studies have demonstrated the ability of several varieties of houseplants to remove formaldehyde, benzene and carbon monoxide from sealed experimental chambers, Figures 1, 2, and 3 and Table 1. More recent studies under the NASA/ALCA joint agreement have produced additional data as shown in Table 2.

FIGURE 1

Formaldehyde Reduction in Closed Chamber With and Without Plants

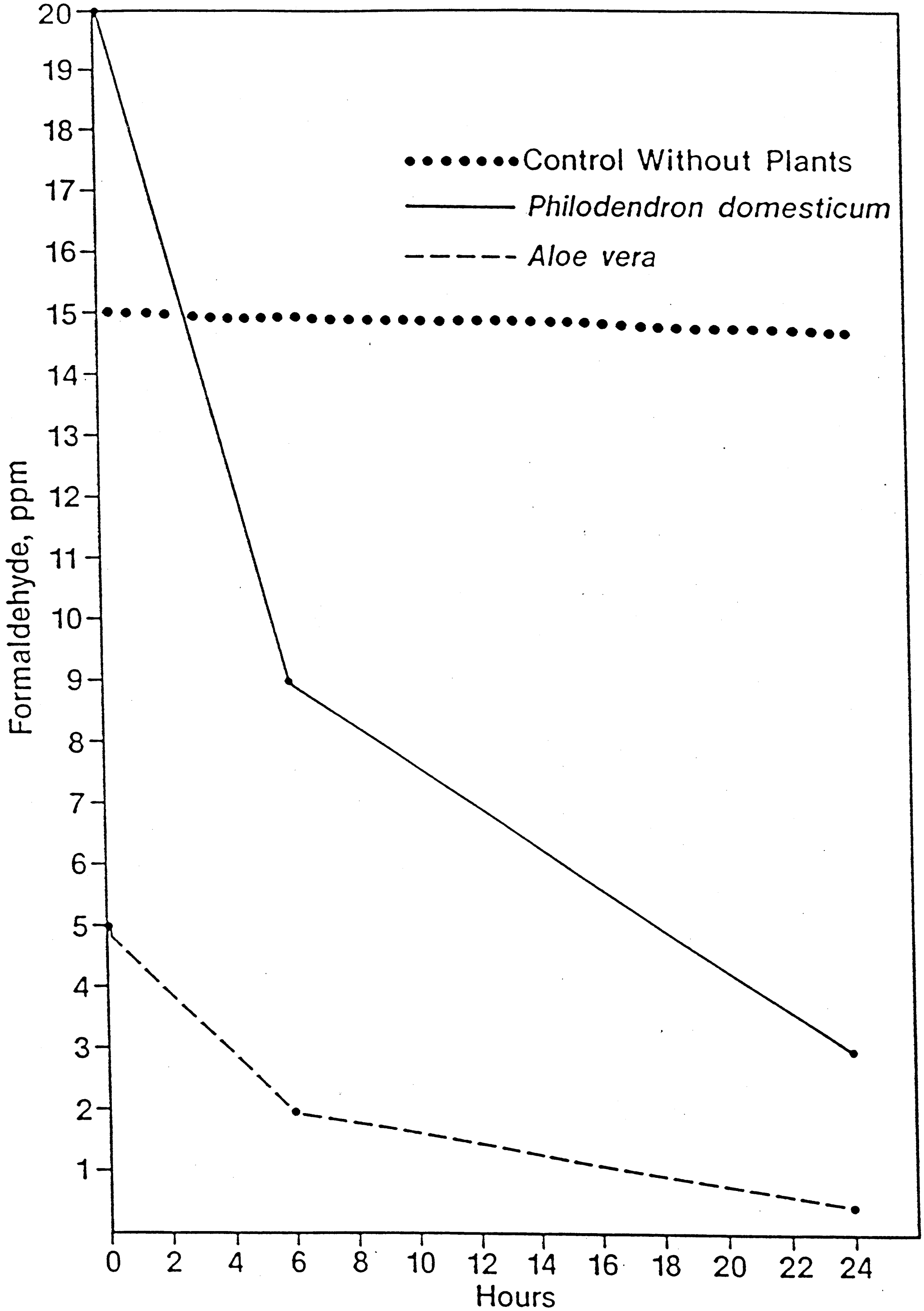


FIGURE 2

Benzene Reduction in Closed Chamber With and Without Plants

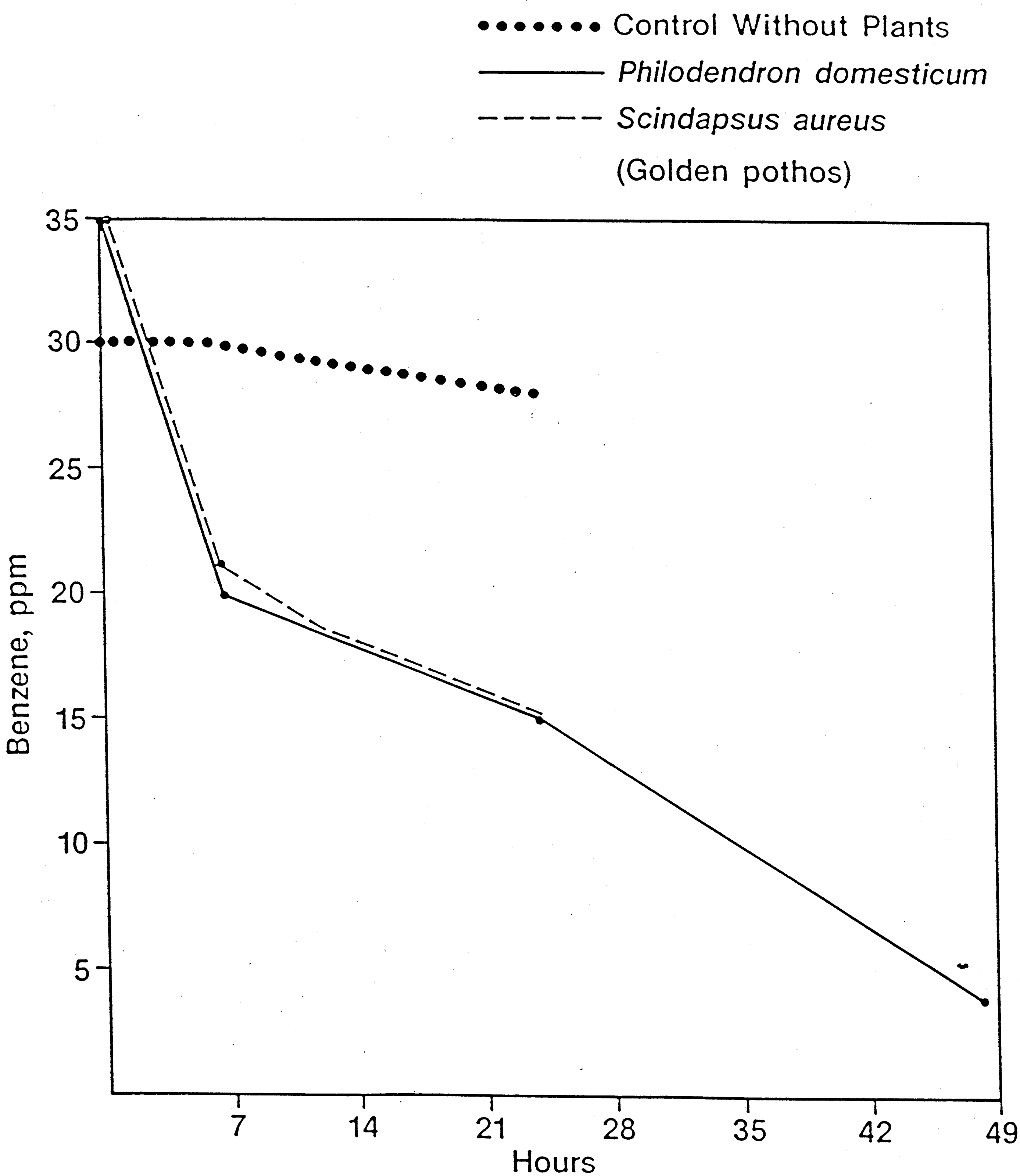
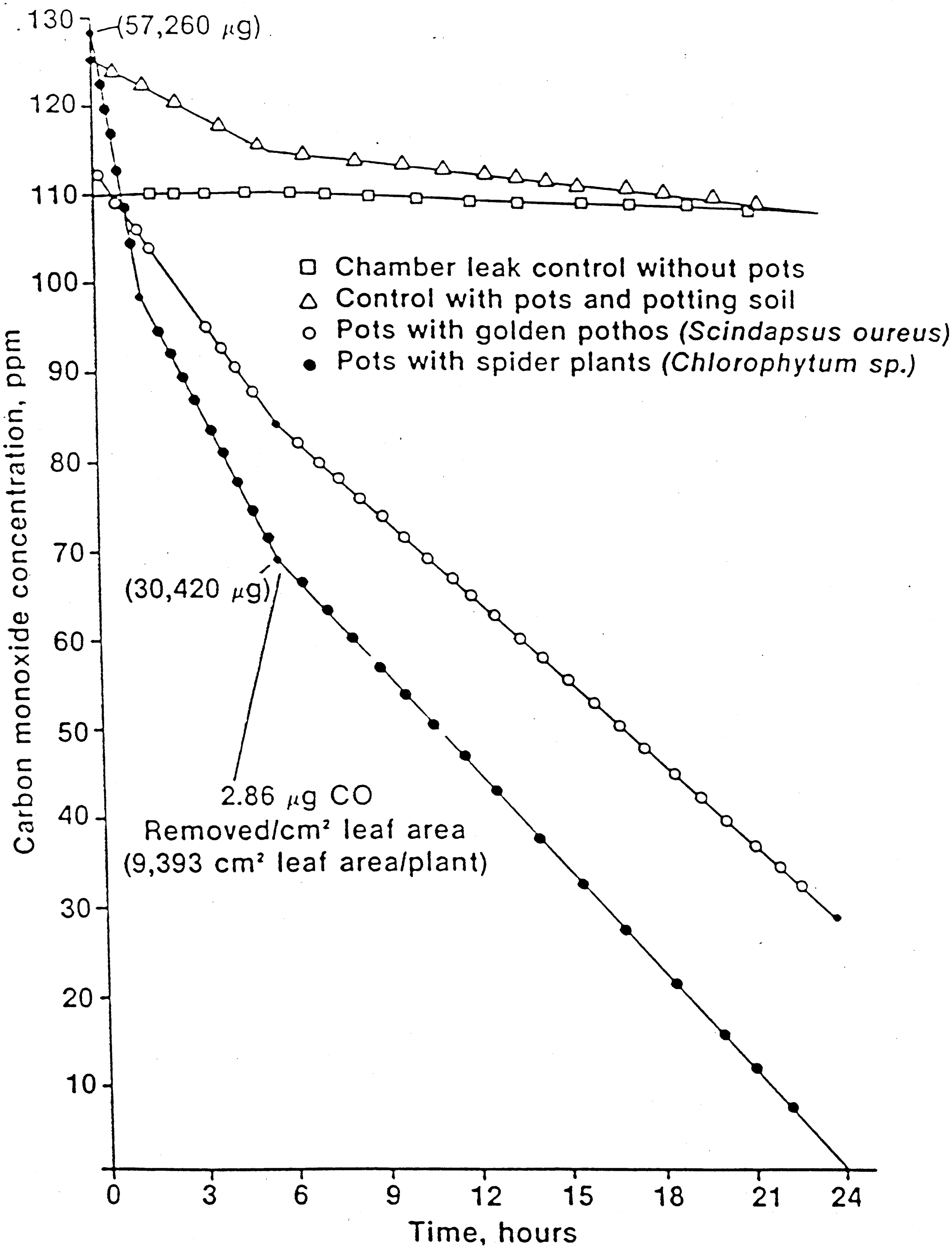


FIGURE 3



The use of spider plants and golden pothos for removing carbon monoxide from a closed chamber

TABLE 1

FORMALDEHYDE REMOVAL DURING A 24 HOUR EXPOSURE PERIOD

Plants*	Total Formaldehyde in Chamber (µg) Initial	After 6 hr	After 24 hr	Ave. Leaf Surface (cm^2)	µg Formaldehyde Removal Per cm^2 of Leaf Area 6 hr	24 hr
Philodendron oxycardium (heart leaf philodendron)	11,921	5,256	3,455	1,696	3.93	4.99
Philodendron domesticum (elephant ear)	11,575	4,665	1,555	2,323	2.97	4.31
low concentrations	1,209	570	432	1,361	.47	.57
Philodendron selloum (lacy tree philodendron)	11,403	4,665	2,747	2,373	2.84	3.65
Chlorophytum elatum (green spider plant)	12,975	7,319	2,709	2,471	2.29	4.15
Scindapsus aureus (golden pothos)	10,741	4,325	1,854	2,723	2.35	3.26
Aglonema modestum (Chinese evergreen)	11,248	8,238	6,866	1,894	1.59	2.31
Aloe vera	2,592	1,037	259	713	2.18	3.27
Brassaia arboricola (mini-schefflera)	8,333	----	4,904	1,743	----	1.96
Spathiphyllum 'clevelandii' (peace lily)	10,298	6,655	5,387	3,476	1.05	1.41
Peperomia obtusifolia (peperomia)	10,140	6,971	5,387	3,264	0.96	1.46
Dracaena fragrans 'massangeana' (corn plant)	10,003	7,878	5,974	2,934	0.72	1.37
Sansevieria trifasciata (mother-in-law tongue)	9,330	5,636	2,954	4,881	0.76	1.31
Tradescantia sillamontana (oyster plant)	10,298	7,341	5,704	6,843	0.43	0.67

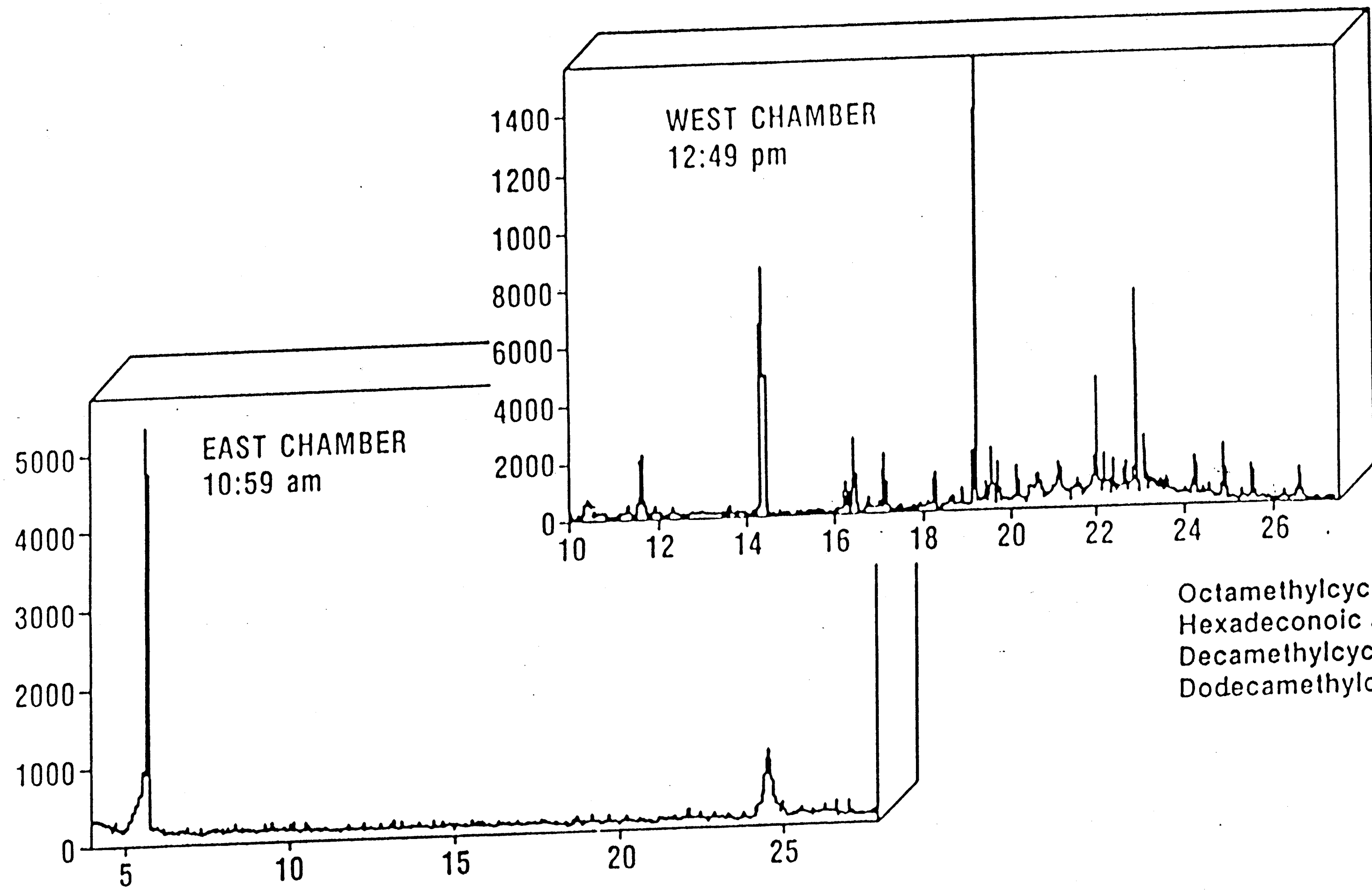
*Average of three or more different experiments

TABLE 2
BENZENE REMOVAL DURING A 24 HOUR EXPOSURE PERIOD

Plants*	Total Benzene in Chamber (μg)			Ave. Leaf Surface (cm^2)	μg Benzene Removal Per cm^2 of Leaf Surface Area	
	Initial	6 hr	24 hr		6 hr	24 hr
Gerbera jamesonii (Gerbera daisy)	65,000	46,000	21,000	4620.2 (5008.0)**	3.79	8.79
Chrysanthemum morifolium (Mums)	57,667	49,333	27,333	1296.9 (4225.2)**	1.97	7.18
Spathiphyllum mauna loa (Peach lily)	27,667	17,667	11,000	7804.1	1.28	2.14
Dracaena deremenisis "Warneckei" (Warneckei)	27,333	21,333	12,667	7239.7	0.83	2.03
Dracaena marginata (Marginata)	24,000	19,667	12,000	7578.2	0.57	1.58
Chamaedorea seifritzii (Bamboo palm)	18,500	14,000	9,000	10,322.9	0.44	0.92
Dracaena deremensis "Janet Craig" (Janet Craig)	23,333	18,667	12,333	15,270.0	0.31	0.72
Dracaena fragans "Massangeana" (Corn plant)	14,667	13,333	11,333	8,674.0	0.15	0.38

*Average of three different experiments except Bamboo palm which was an average for two experiments.
**Total surface area including flowers.

COMPARISON OF CHEMICAL PRESENCE WITH AND WITHOUT PLANTS



HYPERTAT CHAMBER—EMPTY

Commonly found chemicals:

1,1,1-Trichloroethane
Hexanol
Ethylbenzene
1,2-Dimethylbenzene
1,4-Dimethylbenzene
Octamethylcyclotetrasiloxane
Hexadeconoic acid, (2-pentadecyl-1,3-dio)
Decamethylcyclopentasiloxane
Dodecamethylcyclohexasiloxane

HYPERTAT CHAMBER—WITH PLANTS
(*Philodendron domesticum*)

Commonly found chemicals:

1,1-Dibromo-2-chloro-2-fluorocyclopropane

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FIGURE 5

INDOOR AIR PURIFICATION SYSTEM COMBINING HOUSEPLANTS AND ACTIVATED CARBON

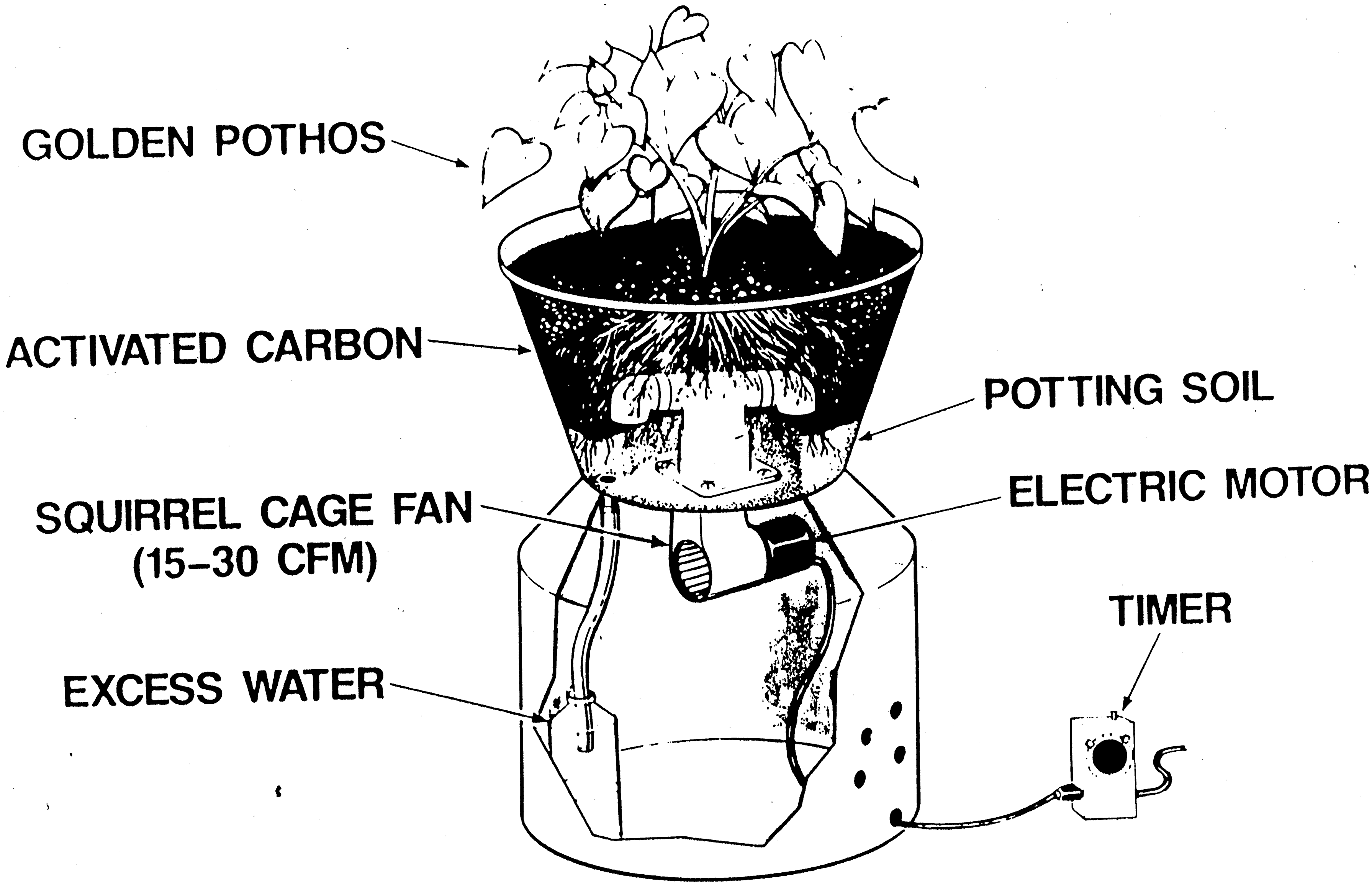
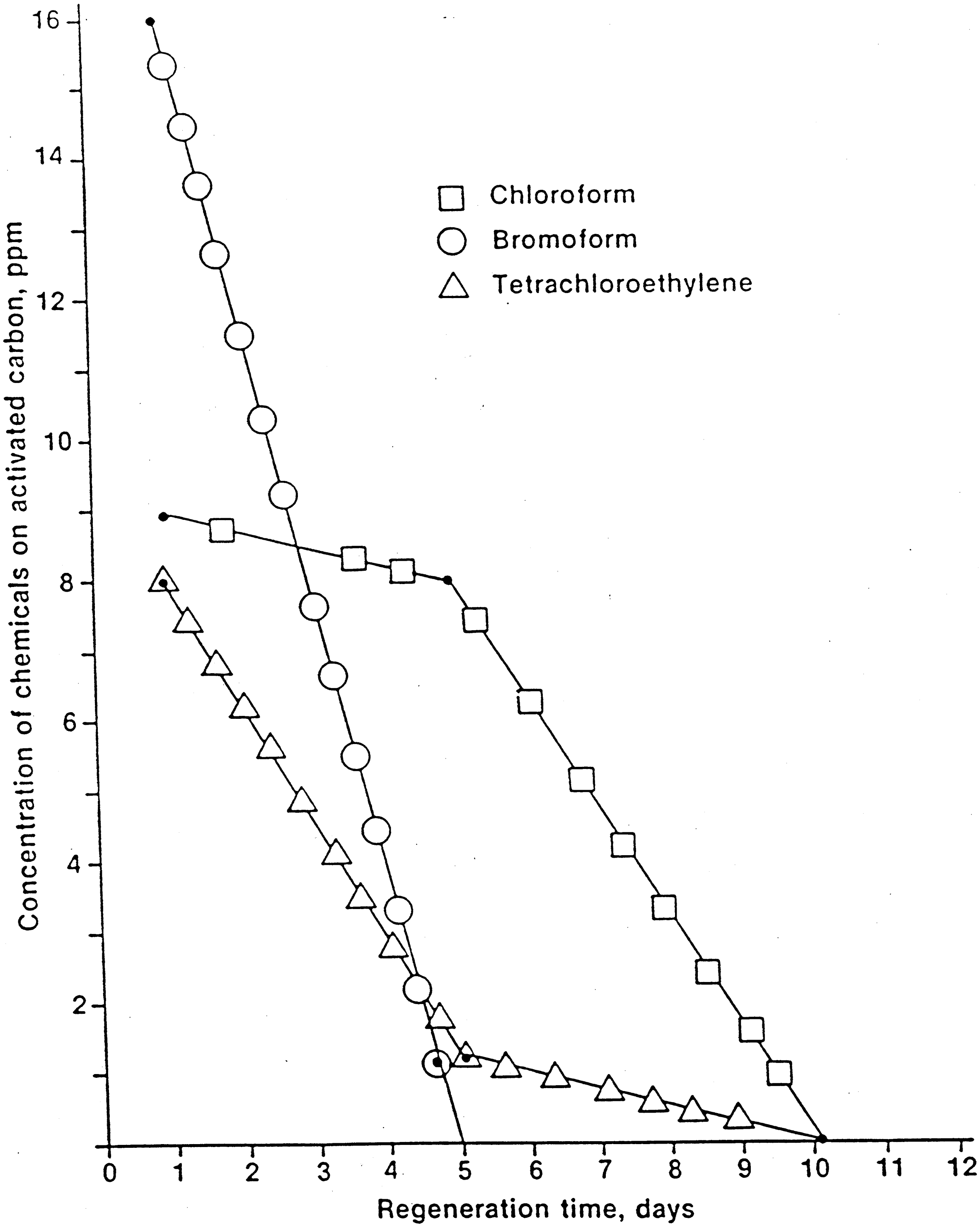


FIGURE 7



A bioregenerating activated carbon/plant system for removing toxic chemicals from indoor air and contaminated water. The detection limit is <1 ppm.

MATERIALS AND METHODS

All plant screening studies to date have been conducted in a clear, cubical chamber, Figure 4, measuring 73.7 cm (2.4 ft) on each side and constructed of 12.7 cm (.5 in) thick Plexiglas[R]. Chemical analyses were performed using a Sensidyne/Gastec sampler and/or a Hewlett Packard Model 5890 gas chromatograph equipped with a Hewlett Packard Model 5970B mass selective detector and using an HP 50 m ultra-performance cross-linked 5% phenyl methyl silicone capillary column.

A super-insulated (R-40) modular structure has recently been acquired by NASA at the Stennis Space Center to study indoor air pollution problems associated with energy-efficient buildings and closed facilities for future space applications. This new structure is separated into two rooms of approximately 350 ft^2 each. The first experiments with this facility were to determine the indoor air pollution inside this tightly sealed structure. One side of the building was used as a control while plants were placed in the other side. This would allow for a more realistic evaluation of foliage plants for reducing indoor air pollution. Results of the initial studies are shown in Figure 5. As can be seen, dramatic reduction in the air pollution in the side containing plants is demonstrated while the side without plants maintains a large number of air pollutants.

As data is being collected on the ability of foliage plant leaves to reduce indoor air pollution levels, another exciting study using some of the same plants combined with activated carbon filters is also being conducted. The carbon/plant filter studies are designed to assess the capacity of plant roots and their associated microorganisms to biodegrade toxic, organic chemicals absorbed on activated carbon, therefore, producing a bioregenerated carbon/plant filter. This system should be capable of removing high levels of cigarette smoke and toxic chemicals from the air inside homes and commercial buildings at a rapid rate when high capacity blower motors are used in the filters. The potential of these activated carbon/plant filters to also remove radon from inside buildings is encouraging. An artist's concept of an activated carbon/plant filter is shown in Figure 6. Data demonstrating the ability of plant roots and microorganisms to biodegrade toxic chemicals absorbed on activated carbon/plant filters is shown in Figure 7.

SUMMARY

NASA's research with foliage houseplants during the past 10 years has produced a new concept in indoor air quality improvement. This new and exciting technology is quite simple. Both plant leaves and roots are utilized in removing trace levels of toxic vapors from inside tightly sealed buildings. Low levels of chemicals such as carbon monoxide and formaldehyde can be removed from indoor environments by plant leaves alone, while higher concentrations of numerous toxic chemicals can be removed by filtering indoor air through the plant roots surrounded by activated carbon. The activated carbon absorbs large quantities of the toxic chemicals and retains them until the plant roots and associated microorganisms degrade and assimilate these chemicals.

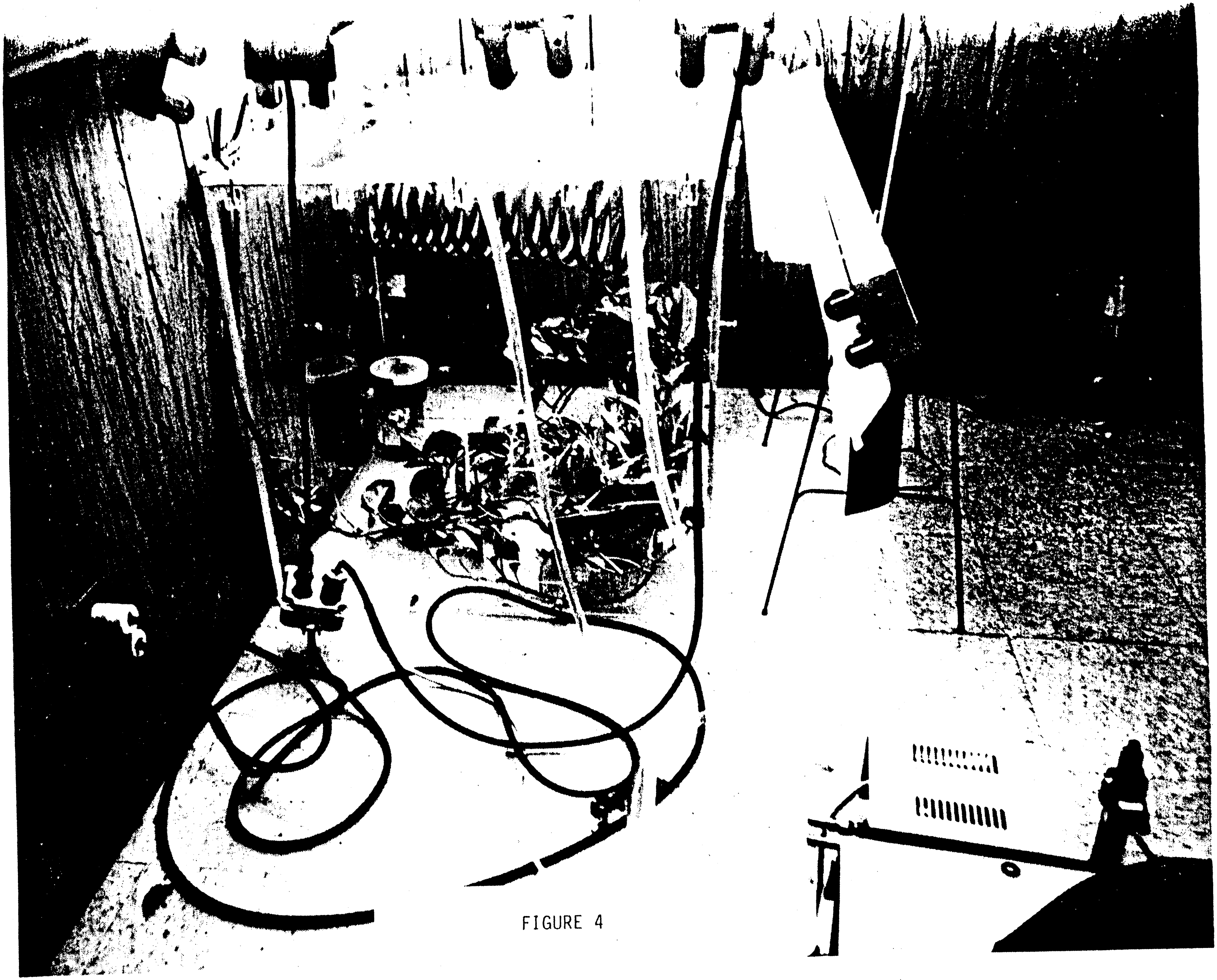


FIGURE 4

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