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FOURTH PROGRESS REPORT

on

DEVELOPMENT OF A RADIOACTIVE-DUST COLLECTOR

to

CHEMICAL AND RADIOLOGICAL LABORATORIES
ARMY CHEMICAL CENTER

MARYLAND

February 15, 1954

by

R. D. Ellsworth, W. A. Spraker, and J. E. Yocom

R. B. Engdahl, Chief

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Battelle Memorial Institute

505 KING AVENUE COLUMBUS 1, OHIO

March 5, 1954

Commanding Officer
Chemical Corps
Chemical and Radiological Laboratories
Army Chemical Center
Maryland

Attention Mr. J. P. Mitchell, Chief
Radiological Division

Dear Sir:

Development of a Radioactive-Dust Collector
Chemical Corps Contract No. DA18-108-CML-5095

Enclosed is a copy of the fourth bimonthly Progress Report for this project covering the work done from December 15, 1953, to February 15, 1954. The most significant contribution of this report is the description of two filter-feeding mechanisms which are an improvement over those reported in the Third Progress Report. It is our recommendation that the rotary-disc type of feeder mechanism be designed in detail and fabricated as soon as possible, as it seems to incorporate all of the advantages of the other mechanisms and yet is simple and compact.

We would appreciate having your comments in regard to the feeder mechanism recommended so that we can proceed with the actual construction. If you have any questions, please let us know. Also, if a conference for the purpose of discussing the project, especially the filter-feeding mechanism, appears desirable at this time, it can be arranged either here at Battelle, or, if more convenient, at the Army Chemical Center.

Yours very truly,

Richard B. Engdahl, Chief
Fuels and Air Pollution Division

RBE:jvc

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1168-2

TABLE OF CONTENTS

	Page
INTRODUCTION	22
SUMMARY	23
LABORATORY INVESTIGATION TO DETERMINE OPTIMUM SAMPLING ARRANGEMENT AND FILTER CHARACTERISTICS	23
Test Apparatus	24
Evaluation of Sampling Cones	25
Millipore Filter Characteristics	25
AUTOMATIC FILTER-FEEDING MECHANISM	26
Rotary-Disc Feeder Mechanism	26
Tape-Type Feeder Mechanism	29
Discussion	29
Conclusions	30
ISOKINETIC CONTROL APPARATUS	31
FUTURE WORK	34

LIST OF FIGURES

		Following page
FIGURE 13.	AEROSOL DUST FEEDER	24
FIGURE 14.	DETAILS OF MAGAZINE AND FILTER CONSTRUCTION	27
FIGURE 15.	SKETCH OF PROPOSED SAMPLING NOZZLE AND ROTARY FILTER FEEDER	27
FIGURE 16.	DETAILS OF ROTARY-DISC FILTER-FEEDING MECHANISM	27
FIGURE 17.	SKETCH OF TAPE-TYPE FILTER-FEEDING MECHANISM	29
FIGURE 18.	REVISED HOT-WIRE LOCATION	33
FIGURE 19.	CALIBRATION OF HOT WIRE LOCATED BEHIND FILTER	33

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R. B. Engdahl, Chief

February 15, 1954

This report summarizes the progress which has been made during the period from December 15, 1953, to February 15, 1954.

Two designs for a filter-feeding mechanism are presented with the recommendation that one be approved so that it can be detailed and fabricated.

The laboratory investigation is discussed and a new dust-feeding device described briefly.

The isokinetic-control apparatus is discussed and certain design modifications described.

1168-4

SUMMARY

The operational difficulties encountered when using the sonic dust generator described in earlier reports made it necessary to design a more positive type of dust-feeding mechanism for some of the test work. A brief description of this dust feeder is included in this report. Also, the results of some preliminary tests to determine the amount of wall loss which occurs in the horizontal cone are discussed.

Two designs for a filter-feeding mechanism are presented and discussed. Because of its simplicity and compactness, it is concluded that the rotary-disc type of mechanism is the most suitable and should be detailed and built.

In the discussion of the isokinetic control, it is pointed out that the effect of the wall boundary layers inside the small sampling and metering nozzles were so great that the controlling circuit was too sensitive when using hot wires in the inlet opening. A hot wire was placed just downstream of the filter and calibrated. The results, which were consistent and reproducible, are included in this report. Future plans for this isokinetic-sampling control are outlined.

LABORATORY INVESTIGATION TO DETERMINE OPTIMUM SAMPLING ARRANGEMENT AND FILTER CHARACTERISTICS

Laboratory work is being done to determine (1) the effect of low velocities in a horizontal cone on the amount of wall loss, (2) the amount of deposition on the wall of the elbow if a vertical cone is used, and (3) the effect of a more sudden enlargement than the proposed seven-degree cone

on the velocity profile across the filter and the resulting dust-collection pattern. In addition to this, the characteristics of the millipore filter as it becomes loaded with dust is to be determined, and the entire problem of making both a radioactive and size-particle count studied.

Test Apparatus

The sonic dust generator described in the Second Progress Report and discussed in the Third Progress Report has been operated fairly satisfactorily. One of the major difficulties, however, has been the determination of the dust concentration of the aerosol being sampled. Because of this, a more positive type of dust-feeding mechanism has been designed and will be used for the test work at present. The sonic generator has not been discarded, however, and will be used as time and need warrant.

Figure 13 shows the type of dust-feeding device which is to be used for the tests to determine the wall loss resulting from either low velocities in the horizontal cone, or the use of an elbow with the vertical cone, as well as the effect of a much greater enlargement from the sampling nozzle to filter diameter. The test dust will be scattered uniformly in the groove around the top of the turntable. The table will be rotated by the small motor at a speed of about one revolution per hour. The aspirating effect of the small tube inserted in the throat of the venturi section will draw the dust into the air stream. As the air expands downstream of the venturi throat, the dust should become uniformly dispersed. This type of feeder will permit the use of moist air if it is felt that high-humidity conditions should be investigated.

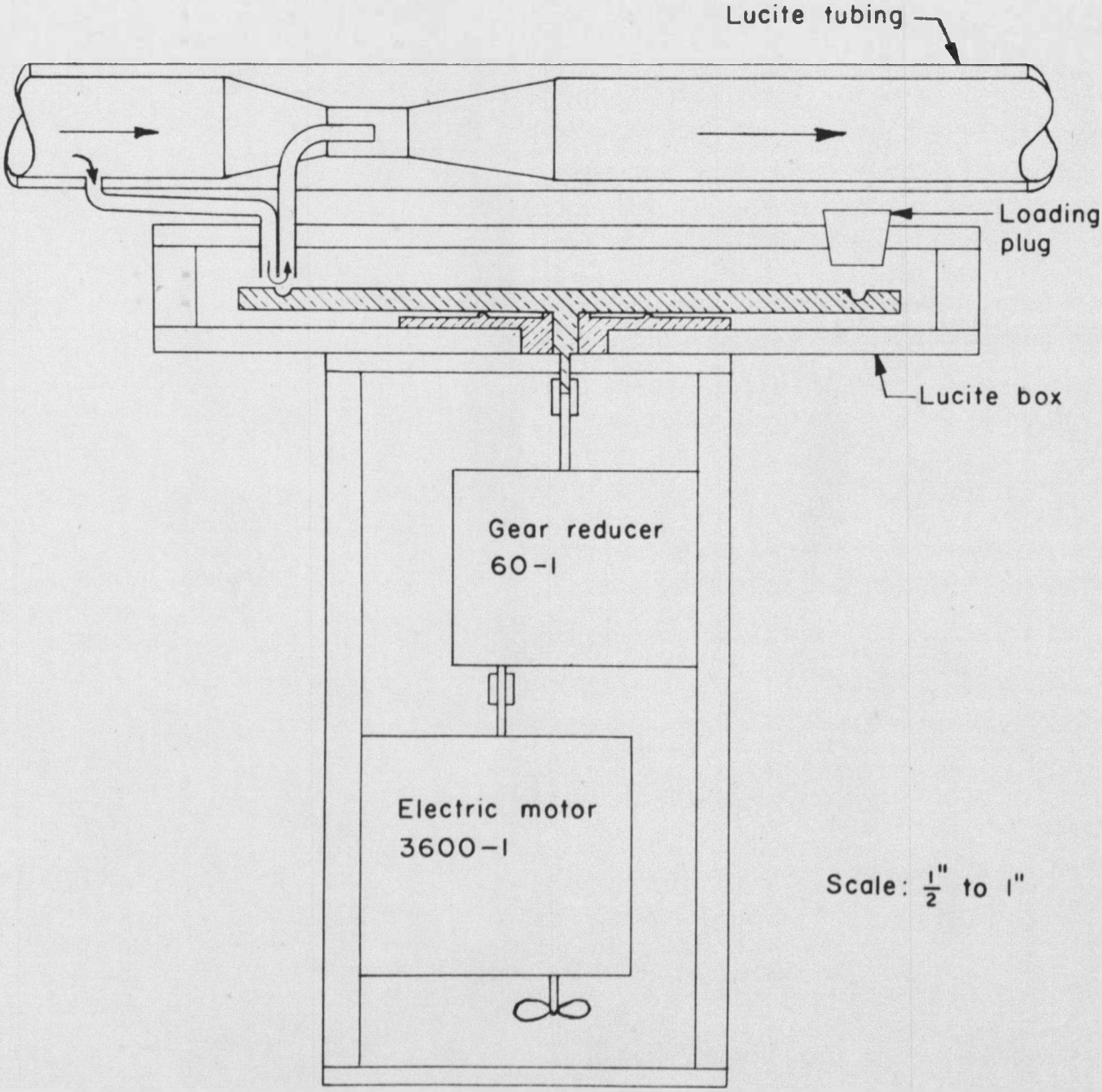

FIGURE 13. AEROSOL DUST FEEDER

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1168-7

Evaluation of Sampling Cones

The initial testing of the seven-degree horizontal sampling cone shows that there is a definite settling out of the particles on the lower half of the cone. The collection of the particles on the filter is selective when using this arrangement, in that the lower section becomes loaded more rapidly. This indicates that the settling velocity of the particles has a pronounced effect inside the cone and that a vertical and much shorter cone is necessary. More tests of this type will be made and the evaluation of this arrangement should be complete before the end of February.

Because the vertical cone arrangement would simplify the nozzle-orienting device considerably, it will be studied as soon as possible to see what, if any, particle deposition there is on the walls of the sampling elbow. Both this and the effect of a more rapid enlargement should be fully evaluated before the end of the next report period.

Millipore Filter Characteristics

Although we do know the approximate specifications for the exhauster, which will be required for this unit, the millipore filter will be studied further to see the effect of dust loading on pressure drop and particle deposition on the filter. Arrangements are being made to have some indium sulfate prepared so that it can be mixed with the dust and then exposed to a neutron source after it has been collected on the filter. Since only the indium-salt particles will become radioactive, a check can be made of the ratio of "hot" to "cold" particles. In addition, work is in

1168-8

progress to study methods of preparing autoradiographs of "hot" particles by use of liquid stripping emulsions.

AUTOMATIC FILTER-FEEDING MECHANISM

Two alternate designs for a filter-feeding mechanism were presented in the Third Progress Report dated December 15, 1953. Both of these designs were discussed with N. S. Capasso, project officer, during his visit to Battelle on January 14, 1954. At that time, it was agreed that although the pickup-type mechanism fulfilled all of the requirements, it would have to be simplified to be practical. It was also agreed that the minimum number of filters which the automatic-feeding device should handle would be 24, so as to provide for twelve hours of continuous sampling at thirty-minute periods. The purge operation, which would clean out the sampling nozzle after a period of nonsampling, was considered to be essential and was added to the list of requirements.

In the light of the above discussion, two mechanisms have been designed which we feel incorporate all of the requirements set forth. Both have been designed to function in either a horizontal or vertical position. Both are relatively simple and appear to be foolproof in their operation. Although there are many other equivalent mechanisms that will accomplish the same result, it is believed that the two discussed below are most suitable because of their simplicity and compactness.

Rotary-Disc Feeder Mechanism

This type of feeder mechanism consists of a rotating disk which alternately moves a filter and a spacer from the unexposed-filter magazine

1168

to the exposed-filter magazine, stopping with the filter in position for sampling for a predetermined period. The filter and backing are held in a filter holder especially designed to protect the filter and prevent the dislodging of any collected dust.

Figure 14 shows the details of the magazine. The hinged door not only simplifies the loading operation but also permits the selection of any particular filter without disturbing the others in the magazine. This might be important if a quick analysis of a certain sample was desired. The sliding lid, 1, has a tab, 2, which slips into a slot on the base plate and automatically opens the bottom of the magazine as it is pushed into position. A compressed spring, 3, provides the power necessary to push the unexposed filters out of the magazine as well as keep the stack of exposed filters and spacers compact as they are forced against the piston, 4.

Figure 15 is a sketch of the proposed sampler and rotary feeder as used with a vertical cone. It should be noted that this same mechanism can be used for a horizontal cone. (The factors to be considered in the selection of the type of sampling nozzle which should be used are discussed elsewhere in this report.) The unexposed-filter magazine, 5, is shown in position on the right with the lid, 7, open. The exposed-filter magazine, 6, is shown on the left with its lid, 8, in the open position. The motion of the rotary disc is counter-clockwise, as indicated.

Figure 16 shows the essential details of the rotary-disc mechanism. The magazine base is held in position by the magazine carriers, 12, on the top plate, 13, of the driving mechanism. The purging port, 10, is smaller in diameter than either the filter or spacer and hence passes underneath. The motion of the mechanism is stopped when the carrying port

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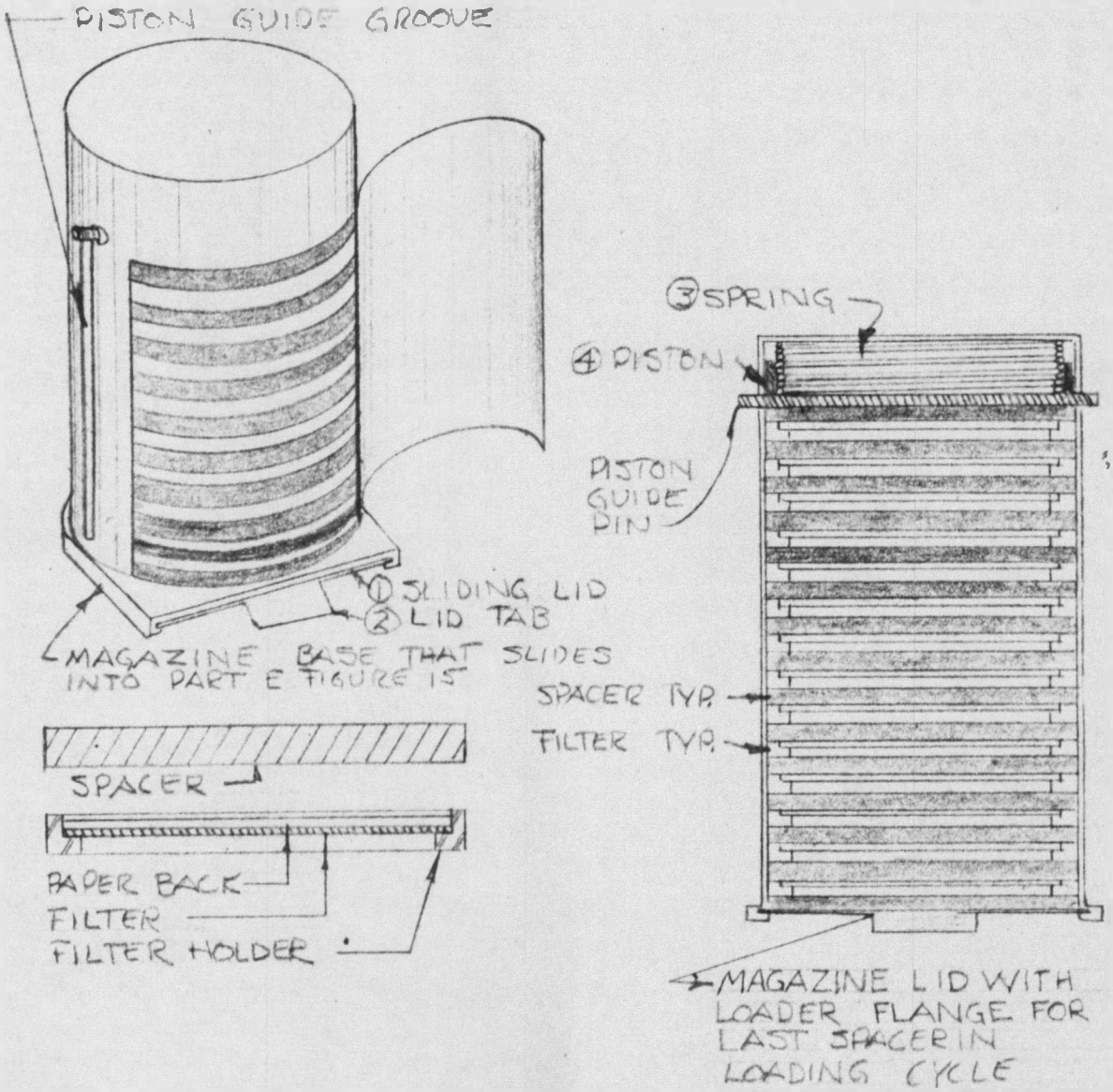

FIGURE 14 DETAILS OF MAGAZINE AND FILTER CONSTRUCTION

NOTE - AT THE END OF EACH SAMPLING CYCLE A SPACER IS ALWAY AT THE BOTTOM OF THE EXPOSED STACK AND IS LEFT IN THE MACHINE. BY DOING THIS THE MAGAZINES CAN BE ONE DISC SPACE ABOVE THE ROTATING DISC

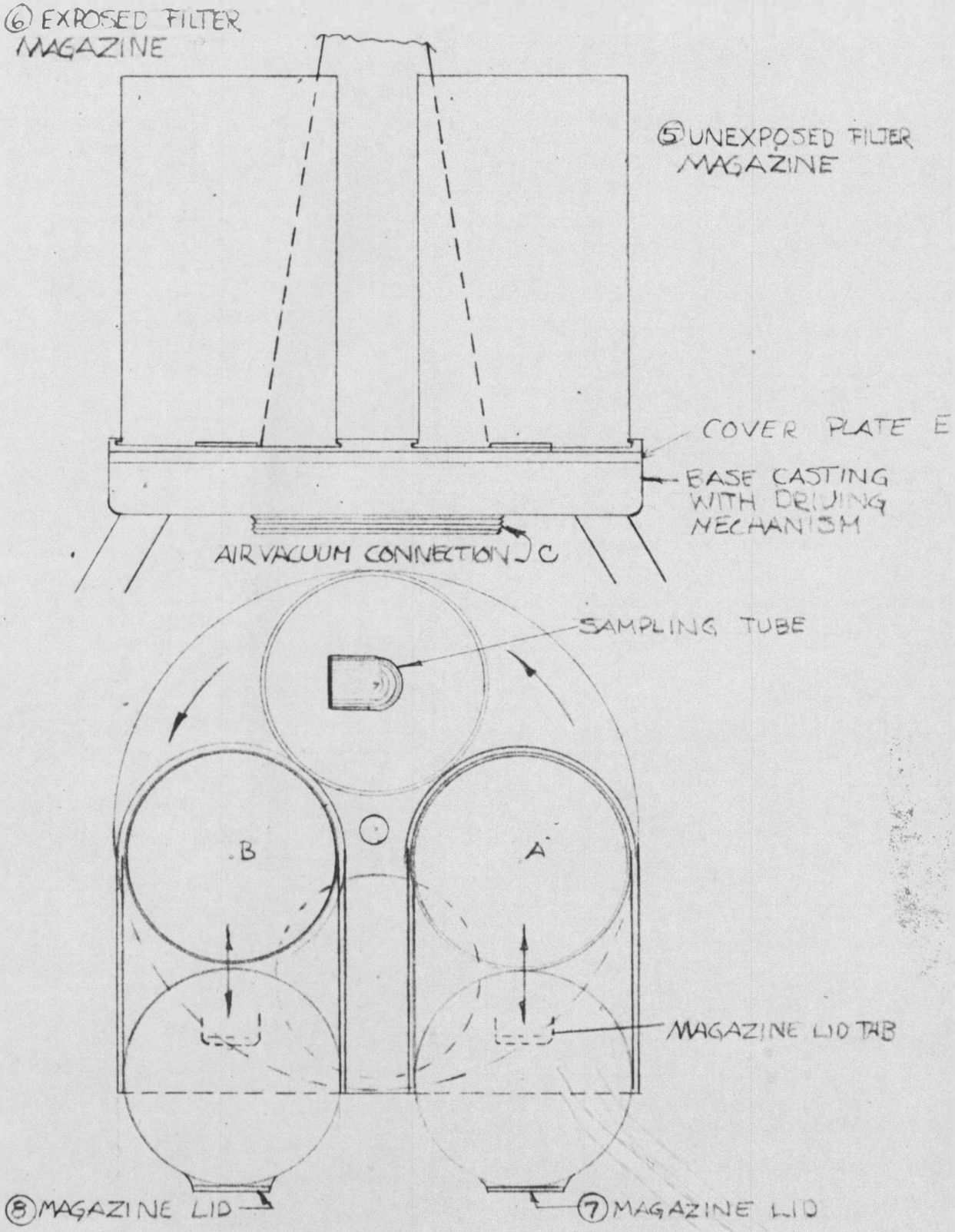

FIGURE 15 SKETCH OF PROPOSED SAMPLING NOZZLE AND ROTARY FILTER FEEDER

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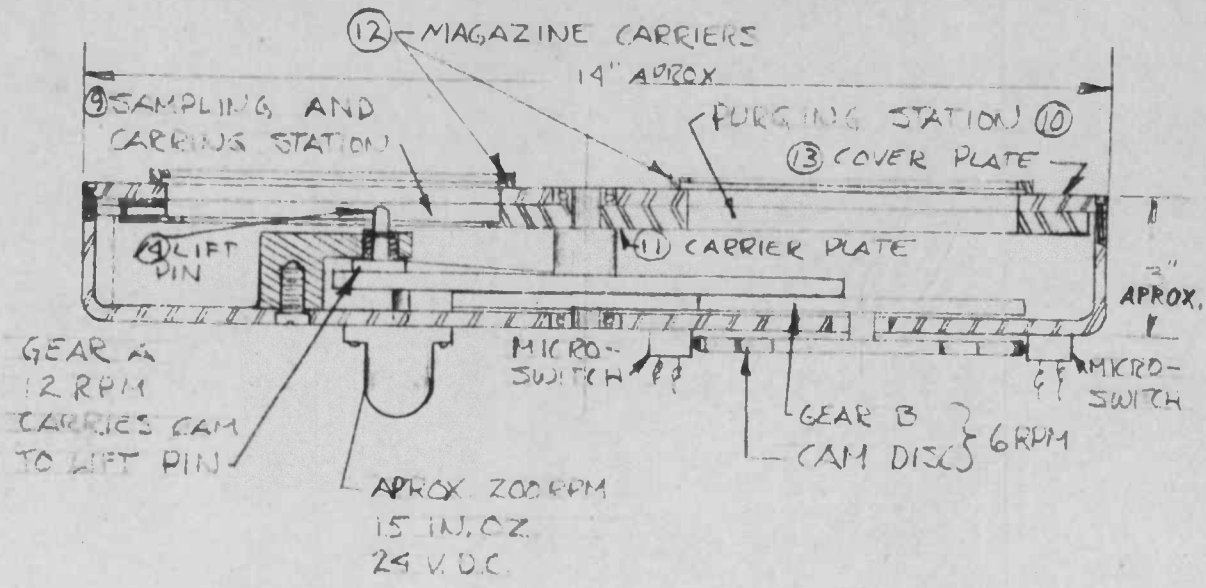


DETAILS OF BASE PLATE (PART-D) DRIVING MECHANISM

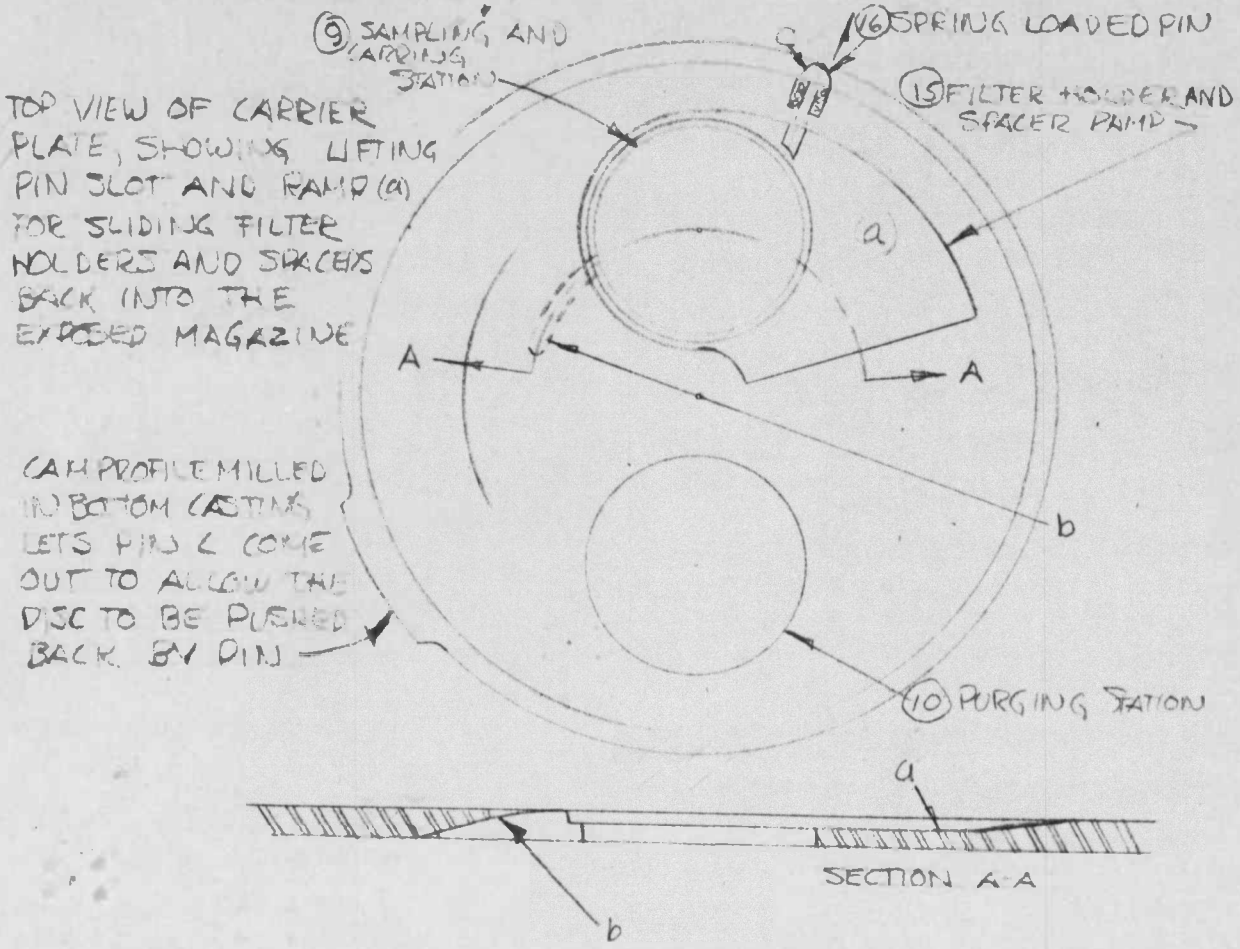


FIGURE 16. DETAILS OF ROTARY-DISC FILTER-FEEDING MECHANISM

reaches a point midway between the two magazines, and the purging port is directly under the sampling nozzle.

When the signal from the control timer energizes the system, the blower operates at full capacity for a brief period to purge the sampling nozzle. The carrier plate, 11, then rotates the carrying port, 9, under the unexposed-filter magazine and a filter, in its holder, is dropped into position and held by the spring-loaded pin, 16. It is then moved to the sampling position where the rotary motion stops for the predetermined sampling period. When the sampling period is over, the carrier plate again rotates, carrying the exposed filter to a position directly beneath the exposed-filter magazine. The filter is then stopped by the lift pin, 14, and forced up into the magazine by the tapered surface, 15, of the carrier plate as it continues to rotate past this point. The carrying port then moves around and picks up a spacer and moves it over to the exposed-filter magazine where it is forced up by the same action. The plate stops rotating when the carrying port is midway between the two magazines.

At the end of each sampling cycle, a spacer is always at the bottom of the exposed stack and is left in the machine. By doing this, the magazines can be one disc space above the rotating disc. The complete cycle for purging, loading, and depositing requires two revolutions of the carrier plate. This cycle could be accomplished in a ten-second period without distorting or jarring the filters. Although the original design shows a capacity of 24 filters, the number could be increased without difficulty. As shown in Figure 16, the feeding mechanism would be driven by a small 24-volt d-c motor, with the operation being controlled by micro switches actuated by a rotating cam.

1168-14

Tape-Type Feeder Mechanism

The tape type of feeder mechanism retains the individual filters with their backing on a conveying medium such as paper so that they can be wrapped on a drum. This tape is then advanced one space at a time, the filters being spaced between open ports which allow for a purging operation. After the filter is exposed for a predetermined period, that section of the tape is cut off and stored in a compartmented magazine, which indexes either up or down. The most important feature of this mechanism is its large storage capacity for both unexposed and exposed filters.

Figure 17 shows a sketch of the tape type of feeder mechanism. The filters and backings are secured in the recess shown on the conveying tape. Every other opening in the tape is left so that there will be no filter exposed during periods of nonsampling, and so that the nozzle may be purged before taking a new sample. The feed roller indexes the tape so that the openings are directly beneath the sampling cone. The tape moving between two guide strips, both of which would be under compression by a spring, would provide the necessary air seal. As soon as a sample had been taken, the exposed filter would be moved into the magazine and detached from the tape by means of the cutting mechanism shown. The exposed-filter magazine would index to another position so that each sample would be in a separate compartment.

Discussion

Although the rotary-disc feeder has not been designed in detail as yet, it features and parts are familiar enough so that we believe it could be built in approximately eight weeks. The tape-type feeder would

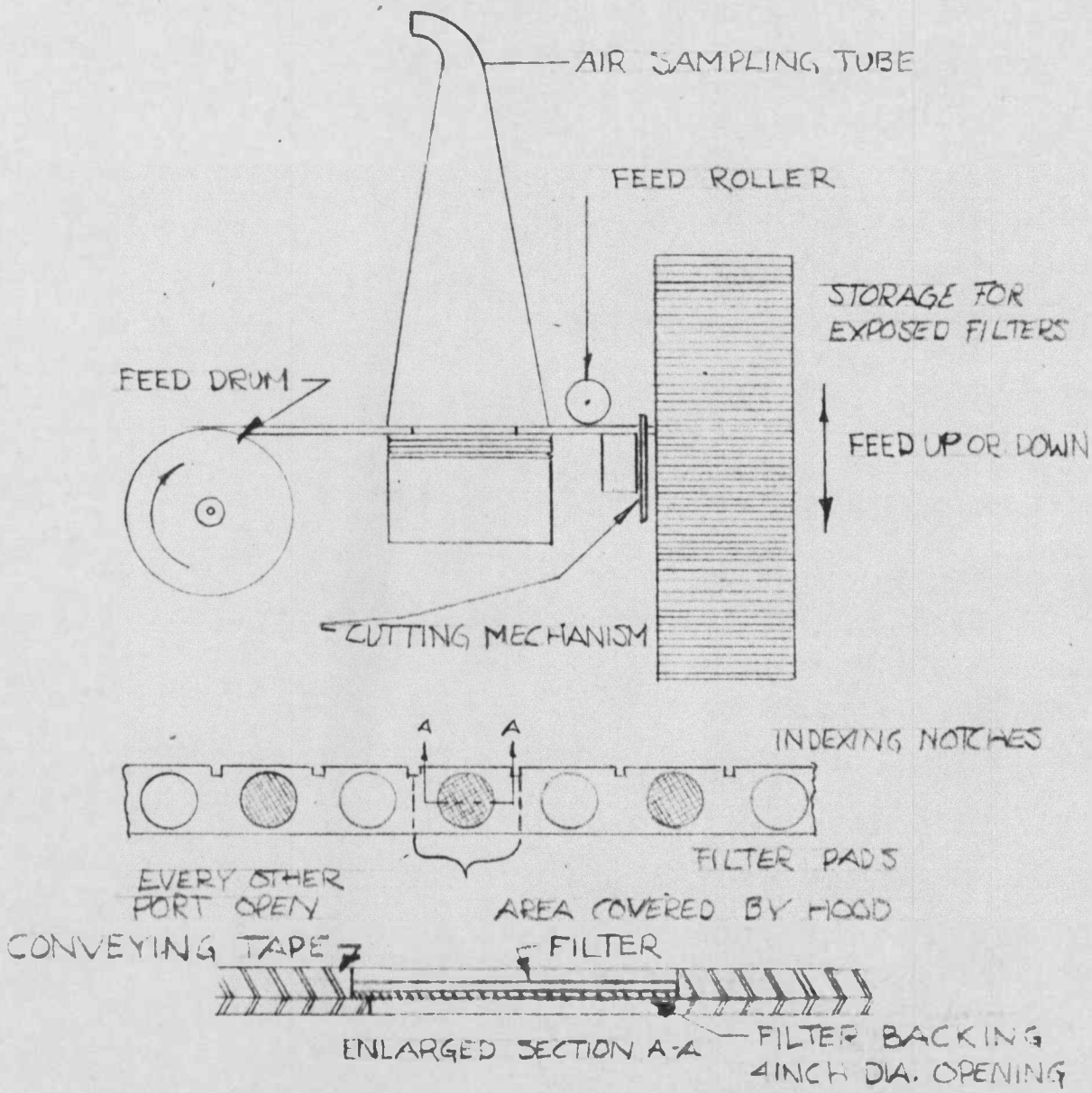


FIGURE 17 SKETCH OF TAPE-TYPE FILTER-FEEDING MECHANISM

probably require a somewhat greater expenditure of time for development because of the problem of finding a suitable conveying material. However, after being developed, the tape type of feeder might be less expensive to manufacture than the rotary type.

The rotary-disc mechanism utilizes the filters in a form which is presently available. It would only be necessary to mount the individual filters with their backing in the holding rings and stack them in the magazine between spacers. In contrast, the tape type will probably require that the manufacturer of the filter make the mounting on the conveying tape. Also, because the section of the tape which has the purge hole cannot be cut off readily by itself, the exposed-filter magazine will have to be very deep to accomodate two filter diameters plus the necessary space between openings to allow for indexing.

Conclusions

Although there are many other mechanisms which will accomplish the same results, we believe that the compactness, simplicity, and availability of the rotary-disc feeder makes this mechanism the most suitable for this dust sampler. As stated before, the features of this mechanism are familiar to our design engineers, hence, there should be no delay in the development of a working model.

We recommend at this time that the rotary-disc mechanism described in this report be designed in detail and that a working model of the filter-feeding device be built as soon as possible. This work should be completed and necessary modifications, if needed, made within a period of three months. For the present, it would be best to design the filter magazines to hold 24 filters. This could be increased at a later date if necessary.

ISOKINETIC CONTROL APPARATUS

Further testing of the control apparatus outlined in the last report has brought certain inconsistencies to light. It will be recalled that the apparatus consisted of two hot wires located in the sampling nozzles with control being obtained by balancing a Wheatstone bridge containing the two hot wires. It was found that variations in the inlet-flow conditions to the nozzles caused variations in the bridge readings without corresponding variations in flow as registered by the flowmeter. It appears that this condition is caused by changes in the wall boundary layer inside the sampling nozzle. The nozzle will therefore be quite senstitive to variations in wind direction and to objects in the near vicinity.

With the above in mind, it was decided to move the hot wire to a location where variations in inlet conditions would have little effect on it. The most obvious such location is behind the filter. At this point there is no danger of contamination of the hot wire by incoming particles and the flow distribution behind a filter should be quite uniform.

At this point a question arises as to the effect of the density variation across the filter on the hot-wire reading. Mc Adams* states that for single cylinders of diameters comparable to the hot wire with air flowing normal to the wire, the heat-transfer coefficient may be determined as follows:

*"Heat Transmission" Second Edition, McGraw Hill, 1942, p 220.

$$\frac{hD}{K} = K_1 + K_2\left(\frac{\rho VD}{\mu}\right)^a$$

where:

h = Heat-transfer coefficient (Btu/sec/ft^2/F)

D = Wire diameter (ft)

K = Thermal conductivity of fluid (Btu/sec/ft^2/ft/F)

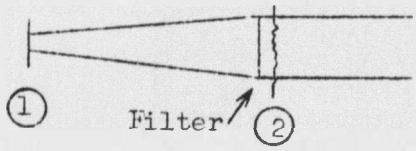
K_1, K_2, a = Numerical constants

ρ = Fluid density (lb/ft^3)

V = Fluid velocity (ft/sec)

μ = Fluid viscosity (lb/sec ft)

If we now consider two hot wires, one located in the sampling nozzle with essentially ambient pressure and density, and the other located behind the filter in a region of reduced pressure and density, we can then determine the relationship between the heat-transfer coefficients at the two locations.



$$\frac{h_1D}{K} = K_1 + K_2\left(\frac{\rho_1V_1D}{\mu}\right)^a$$

$$\frac{h_2D}{K} = K_1 + K_2\left(\frac{\rho_2V_2D}{\mu}\right)^a ,$$

but, from continuity:

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

$$\text{or } V_2 = \frac{\rho_1 A_1 V_1}{\rho_2 A_2} ,$$

therefore,

$$\frac{h_2D}{K} = K_1 + K_2\left(\frac{\rho_1 A_1 V_1 D}{A_2\mu}\right)^a .$$

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It is therefore seen that the heat-transfer coefficient and, therefore, the hot-wire reading at Location 2 varies from that at Location 1 only as a function of the differences in area between the two locations. The product of density and velocity at any location is constant if the effects of compressibility are ignored.

Figure 18 shows the test rig as rebuilt to include a single hot wire behind the filter. The bridge circuit was modified to include a 1/2-ohm resistance in place of the other hot wire and the resultant circuit was calibrated. Figure 19 shows the calibration of the hot wire when located downstream from the filter. Some scatter will be noted in these data. This is due for the most part to temperature changes in the resistors used in the bridge circuit. These resistors have now been insulated in an effort to obtain a more constant temperature.

It will be noted that the hot wire used is approximately 3-3/4 inches long and spans the width of the duct behind the filter. It may be possible to shorten this while maintaining comparable accuracy and durability.

The velocity measured behind the filter is 2.1 per cent of the ambient-air velocity due to differences in area and static pressure between the sampling nozzle and behind the filter.

It is planned to measure the ambient-air velocity with a non-directional probe similar to the one developed by the Hastings Instrument Co. The output from this probe will be combined with the output from the hot-wire bridge circuit to operate either a valve actuator or a fan-motor speed control. A compensating circuit will be provided to take into account the difference in velocity between the hot-wire location and the sampling nozzle.

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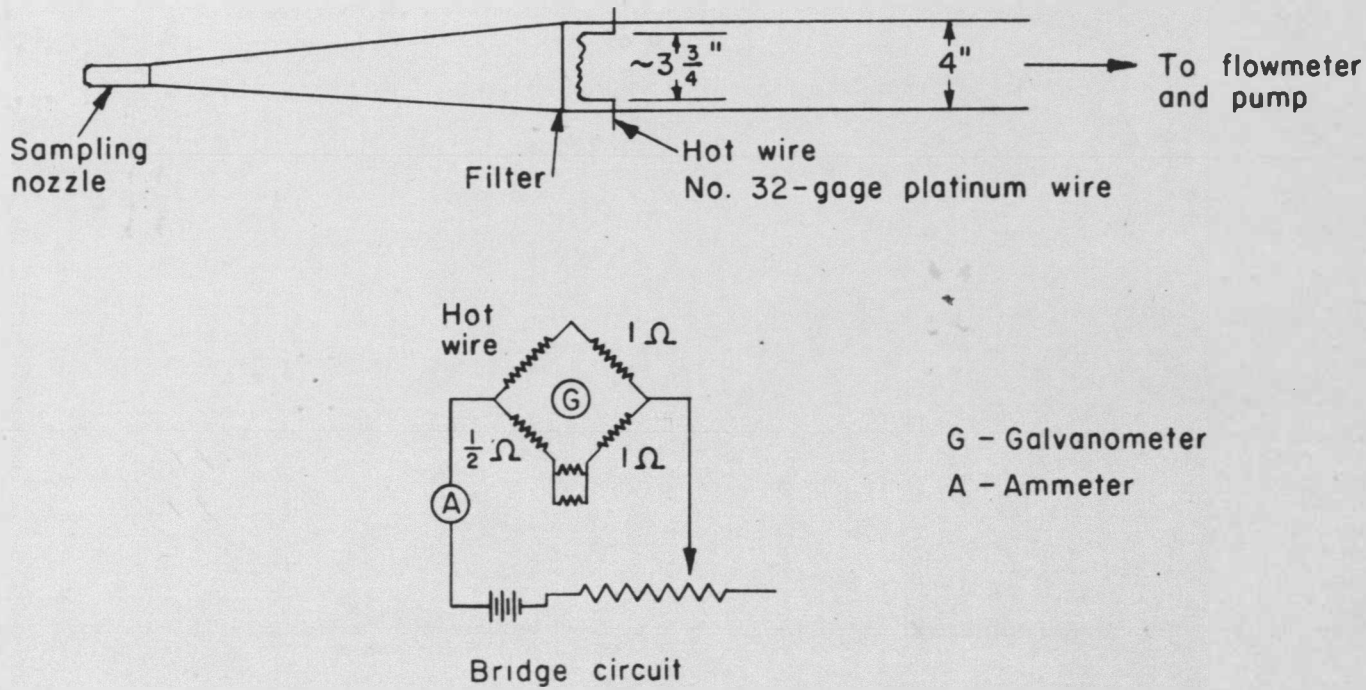

FIGURE 18. REVISED HOT WIRE LOCATION

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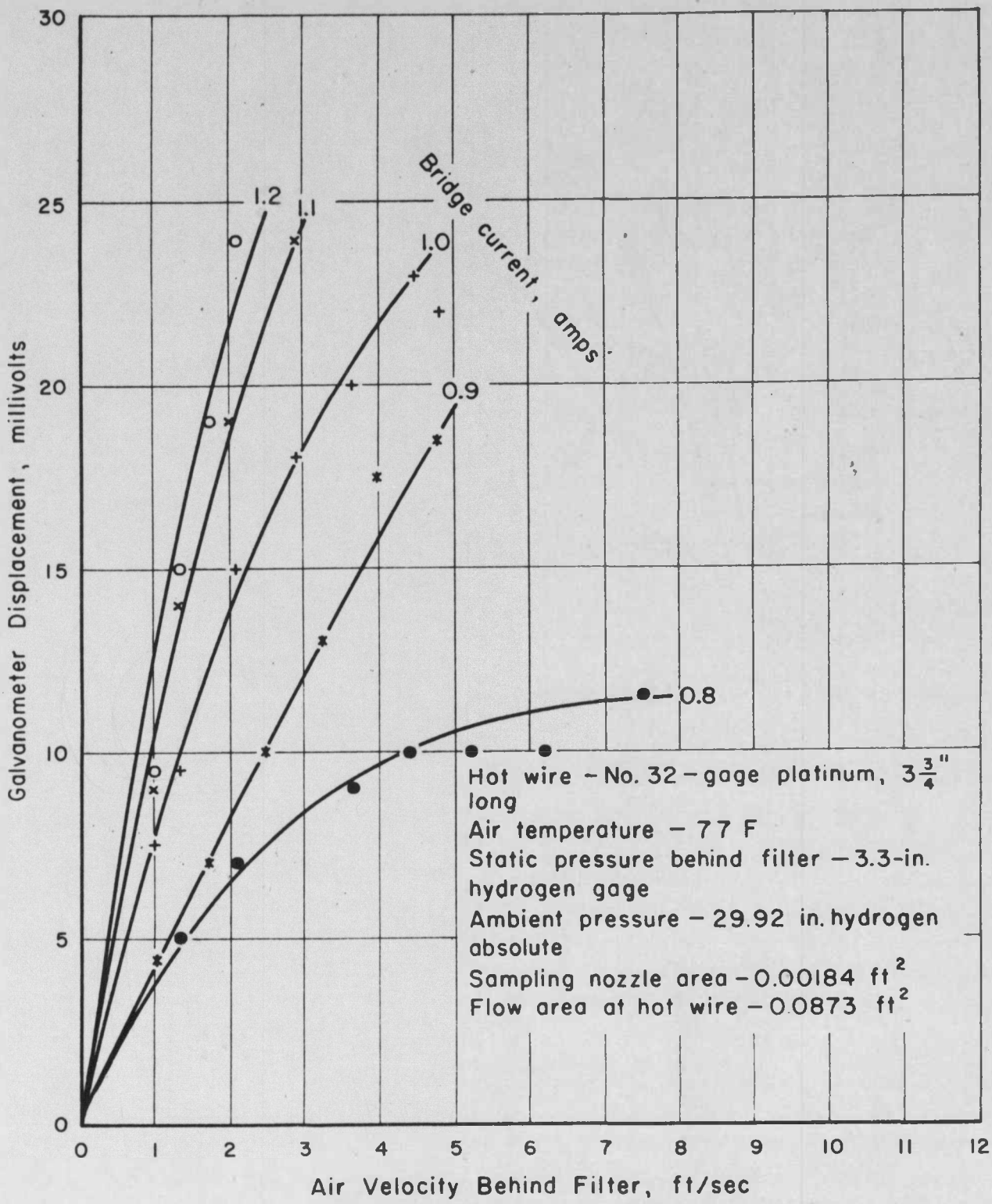

FIGURE 19. CALIBRATION OF HOT WIRE LOCATED BEHIND FILTER

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FUTURE WORK

If the rotary-disc type of filter-feeding mechanism described in this Fourth Progress Report is acceptable to the personnel responsible for this project at the Army Chemical Center, the detailed design and fabrication of a working unit will be started. Barring any unforseen difficulties, the filter-feeding mechanism should be completed by the first of May. The other components, such as the exhauster, control timer, flow recorder, flow controller, and orienting device, are being developed separately from the feeder mechanism and should also be ready by the first of May so that the entire unit can be assembled and tested by the first of June.

During the next report period (February 15 to April 15) the evaluation of the various sampling nozzles should be complete and the optimum design developed so that the nozzle can be fabricated. The exhauster should be obtained and the necessary equipment to maintain isokinetic sampling and record the air flow designed and, if possible, built or acquired before the middle of April.

More consideration will be given to the counting technique during the next two months and every effort will be made to have some tests run with the indium sulfate mixed with the dust so that the ability to measure the ratio of hot to cold particles can be checked.

Information on the effect on the collection of various sized particles when sampling nonisokinetically will be obtained as time permits.

RDE:WAS:JEY/jvc
March 1, 1954

1168-2