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Nondestructive Test of Filter/Separator Elements

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NONDESTRUCTIVE TEST OF FILTER/ SEPARATOR ELEMENTS

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Final Report on Phase Two for Period

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FOREWORD

This is Report No. IITRI-C6196-7 (Final Report on Phase II) of IITRI Project C6196 entitled "Nondestructive Test of Filter/Separator Elements." Work was conducted under Contract No. DAAK02-69-C-0688 Project No. 69 PAN 9249702001010 for the U. S. Army Mobility Equipment Research and Development Center, Fort Belvoir, Virginia. Mr. Joseph Shea was the contract monitor. The program was directed by Mr. Edward G. Fochtman. Mr. Victor R. Ivanuski conducted much of the experimental work and Mr. Clarence Lamber prepared the apparatus design.

Our appreciation is expressed to Mr. Pat Wallace of the Keene Corporation and Mr. Cliff May of Banner Engineering Corp. for their cooperation during the plant tests.

Data on this project are recorded in IITRI Logbooks C19639 and C19640.

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ABSTRACT

NONDESTRUCTIVE TEST OF FILTER/SEPARATOR ELEMENTS

The nondestructive test procedure to evaluate the structural integrity of filter/separator elements has been further developed, a prototype tested designed and built and evaluated in two plants. The tester appears to function without difficulty. Only about one element in every thousand tested was found defective when tested in this apparatus. The defective nature of these elements was confirmed by tests at MERDC. More extensive use of the apparatus and correlation of results are required to establish performance on a statistically sound basis.

NONDESTRUCTIVE TEST OF FILTER/SEPARATOR ELEMENTS

1. INTRODUCTION

The objective of this program is to develop a nondestructive test procedure and prototype equipment to determine the structural integrity of filter/separator elements. Phase I of the program involved a feasibility study to determine technical feasibility of using a tracer gas system based upon ammonia and sodium fluoroscein. This phase of the program was successfully completed in December 1969. The report of the work on Phase I was reviewed and authorization to proceed was received in November 1971. The following is a report of Phase II of the program which has been concerned with further definitions of the nondestructive test procedure, the construction of a prototype testing apparatus, and the evaluation of the procedure and apparatus in the plant of a filter/separator manufacturer.

In this report we have discussed the further research conducted to define test parameters, design considerations for the NDT apparatus, the apparatus developed as a result of these considerations and the results of plant tests.

2. TEST PARAMETERS

The major test parameters involved in the procedure are the techniques used for impregnating or dyeing the sock with a Carbitol/sodium fluorescein solution and the amount of ammonia passed through the filter/separator element.

2.1 Preparation of Impregnated Sock

During Phase I of this program, the Carbitol/sodium fluorescein indicator was used to impregnate a sock of the type currently used on the outside of the filter/separator elements. A solution of 0.02-0.04% sodium fluorescein in carbitol was used to impregnate the sock which retains about 20 g of carbitol/dye solution.

The sock was stretched over the element to give good contact between the element and the indicator. This procedure was somewhat cumbersome and time consuming and, in addition, had the possibility of contaminating the surface of the filter/separator with a Carbitol solvent.

Another problem involved the procedure for impregnating the sock with the solvent and dye. In many cases, some unknown factor would cause a permanent change in sodium fluorescein which would then fluoresce under ultraviolet light. The proper conditions for impregnating these indicator socks have been difficult to define.

Consideration was given to a spraying the outside of a commercially available filter/separator element rather than place a dyed indicator sock over the element. This would have the advantage of placing the indicator in intimate contact with the element to indicate flaws with a higher degree of accuracy. It would also eliminate the problem of having to pull the indicator sock over each element. The disadvantages would be that (1) the solvent, Carbitol, is a rather powerful solvent and does attack some plastic-type materials; (2) the solvent is a humectant and may affect properties of the fuel even though it is present in extremely low concentrations; (3) the solvent might change the coalescence properties of the filter/separator element and result in more fine droplets. To evaluate this concept several elements were sprayed with the solvent-dye solution and tested for coalescence. Results of these tests were somewhat inconclusive, possibly due to a greater sensitivity of the surface when wetted with a Carbitol solvent which tends to adsorb moisture during handling. Since other techniques for using these socks in the testing procedure appeared to be progressing satisfactorily, it was decided to abandon this approach, and no further efforts were made to develop a technique involving direct spray of the solvent/dye on the surface of the elements.

Preparation of the dyed-indicator sock by spraying and by completely wetting were investigated, and it was found that completely wetting the sock in the dyed solution, wringing out by hand and allowing to dry in a room with a temperature of about 70°F and a relative humidity of about 40% was the most satisfactory technique. This technique has been used on the indicator socks used in the plant tests, described later in this report.

2.2 Ammonia Injection

During this phase we further investigated the amount of ammonia needed to give good indication of very small holes in the element. Results confirmed previous tests in that 5-7 cc of ammonia released as a pulse in an air stream flowing at 1 cu ft/min gave the most rapid and sensitive test.

3. NONDESTRUCTIVE TESTER DESIGN CONSIDERATIONS

As a result of the work conducted on the first phase of the program and the initial efforts of the second phase of the program, it was possible to develop a number of criteria for the tester design. These are discussed below.

3.1 Indicator Sock Configuration

It appeared necessary to utilize one sock for the testing of a fairly large number of elements. Placing the sock directly on the element was a time-consuming and cumbersome operation and it was decided to investigate the possibility of stretching the sock over an expanded metal canister which would fit fairly close to the outside of the filter/separator element. Canisters were fabricated and tested using the laboratory model of the NDT apparatus. It was found that satisfactory indication of flaws could be obtained when the sock was 1/8-in. away from the surface of the filter/separator element. On the basis of this, it was decided that canisters would be used to hold the sock away from the surface of the filter/separator element. This concept has proved to be satisfactory.

3.2 Air Humidification

It was decided to make the test apparatus completely independent except for electrical power supply. To do this, a small pumping system with a method to humidify the test air was fabricated.

3.3 Recovery of Dyed Indicator Sock

If the dyed indicator sock is exposed to the ammonia tracing gas, it fluoresces under UV light. This fluorescence gradually fades and the sock can be used over again. It was decided that the test apparatus should provide time for this sock to recover between each test use. In order to do this several socks, or several test stations, should be provided since the recovery time was 20-30 sec and the test time was less than 5 sec.

3.4 Ultraviolet Light Illumination

Direct impingement of UV rays upon the eyes causes burns and must be avoided; however, ordinary glass removes a large fraction of the harmful UV rays. It is desirable to illuminate the element with as intense UV radiation as possible. This was accomplished by using a baffle arrangement which prevents direct viewing of the UV lamps and the addition of a glass plate in the viewing area.

3.5 General

It was decided that the tester should be semi-automatic in operation with solenoid rather than manual valves. The prototype should be adequate for the testing of several hundred filters per day; however, it was not necessary that it include all aspects of a final design. It was expected that the prototype would be used for plant tests to further evaluate the concept of 100% nondestructive testing. However, a later model which would incorporate all automatic features would be developed for long-term testing providing results of the prototype evaluation were satisfactory.

4. DESCRIPTION OF NONDESTRUCTIVE TEST APPARATUS

4.1 Original Design

On the basis of the above, several design concepts were considered and one believed suitable to test between 500-1000 elements per 8-hr day was selected. This apparatus was constructed, later modified, and used for the plant test. It is described in the following paragraphs and working drawings are attached to this report.

This apparatus, in partially assembled form, is shown in Figures 1, 2, and 3, and discussed below. The system has a series of six canisters which contain test elements in a trough-like shield. Elements are rotated to a viewing area where the surface is illuminated by ultraviolet light, air with the tracer gas is passed through the element, and the element is rotated by hand to inspect the entire surface. After inspection, this element holder is not used or exposed to tracer gas during the inspection of the next five elements. This allows sufficient time for the dyed sock indicator to recover.

The tester can be used with the sock indicator or with an element which has been sprayed with the solvent/dye.

A separate module containing an air pump, humidifying chamber, and wet and dry bulb thermometers provides air for the system.

The following numbered comments refer to Figures 1, 2, and 3.

1. Viewing port. An additional adaptor and glass plate were attached to this hood.

2. Four ultraviolet lamps were mounted inside the hood.

3. Bearing block. The element is rotated by the hand crank when in the viewing position. Air and tracer gas enter the element through the bearing block and the hollow shaft.

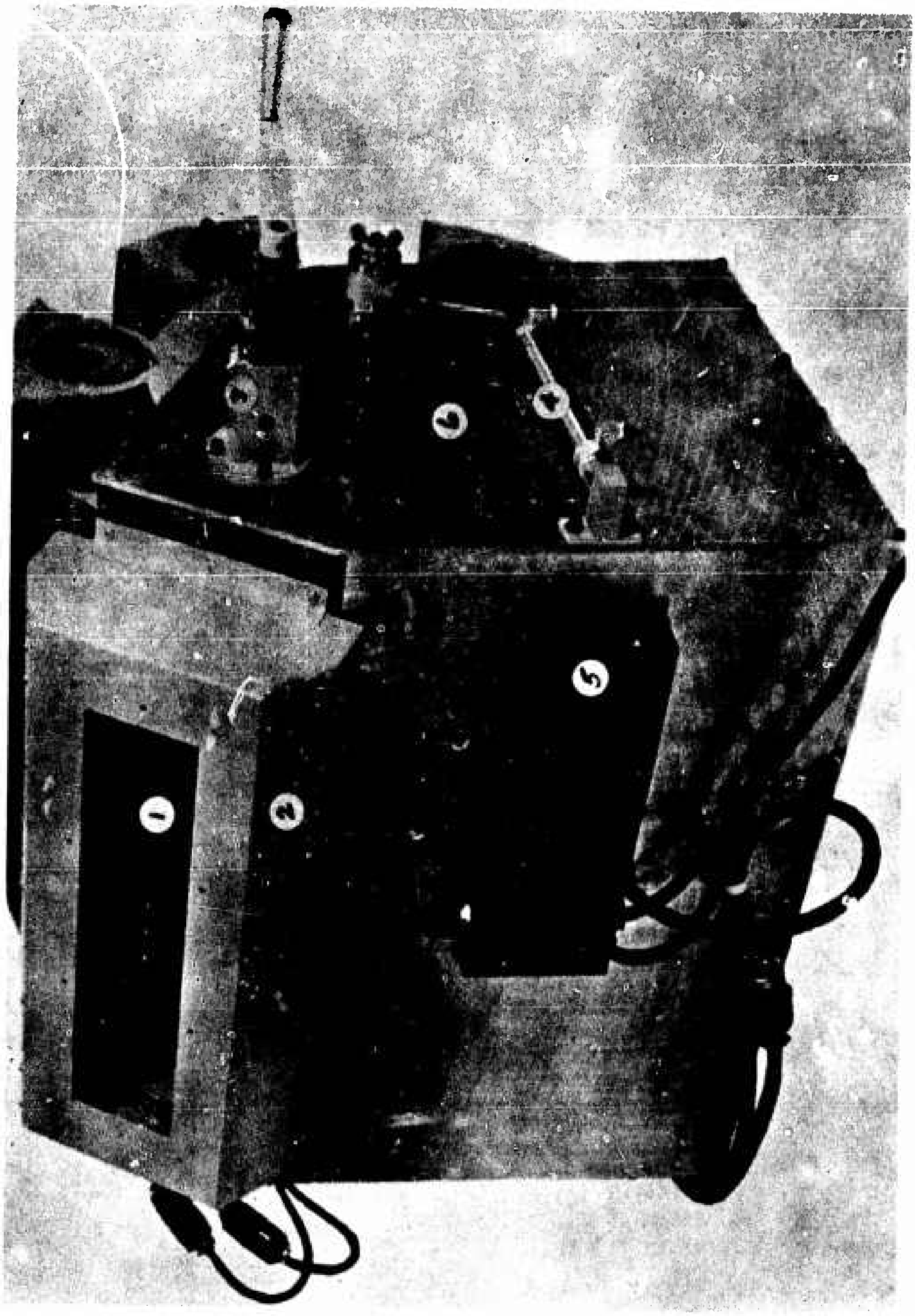

Figure 1

PARTIALLY ASSEMBLED NONDESTRUCTIVE F/S ELEMENT TESTER

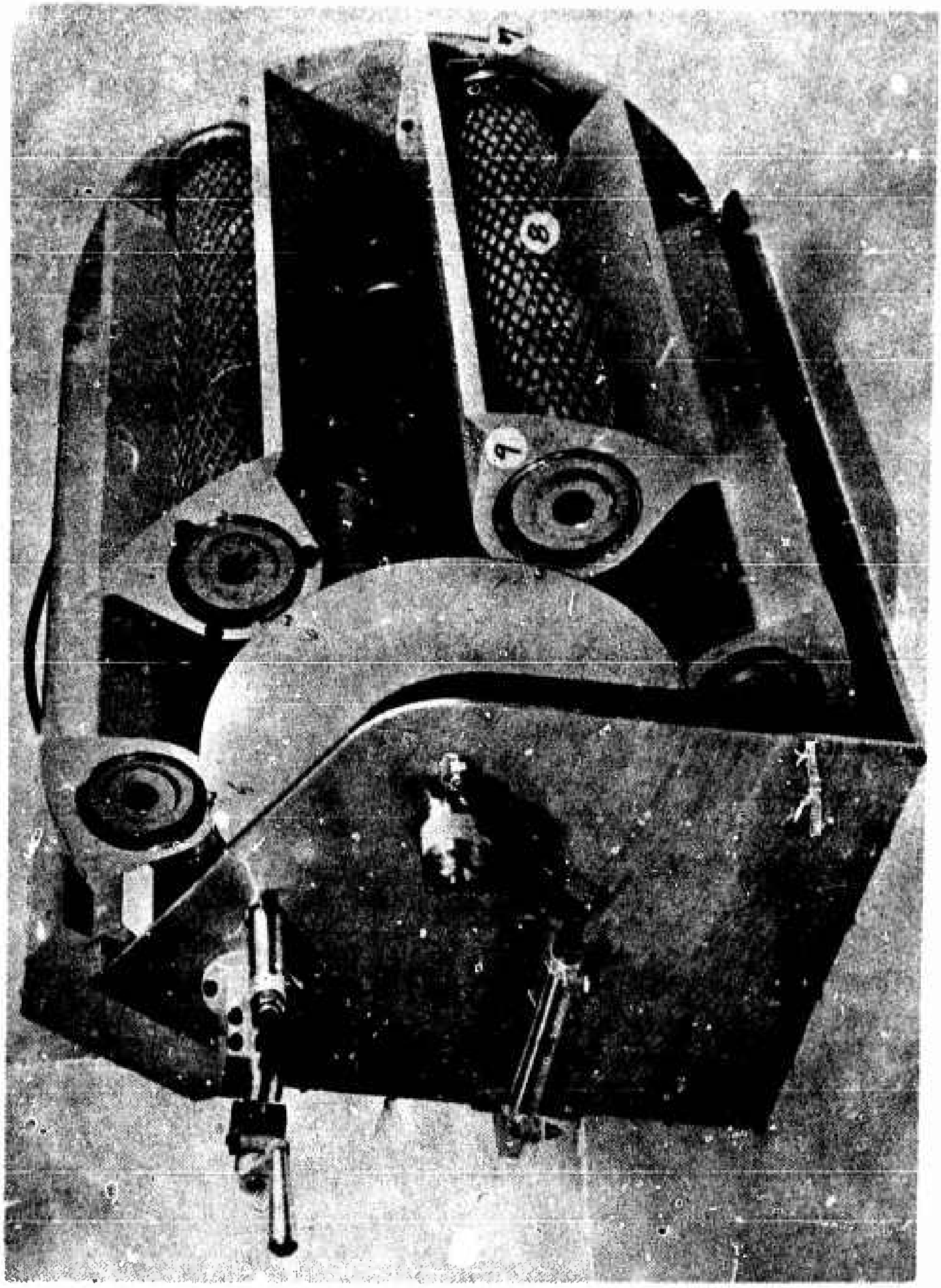

Figure 2

NONDESTRUCTIVE F/S ELEMENT TESTER
SHOWING CANISTER ARRANGEMENT

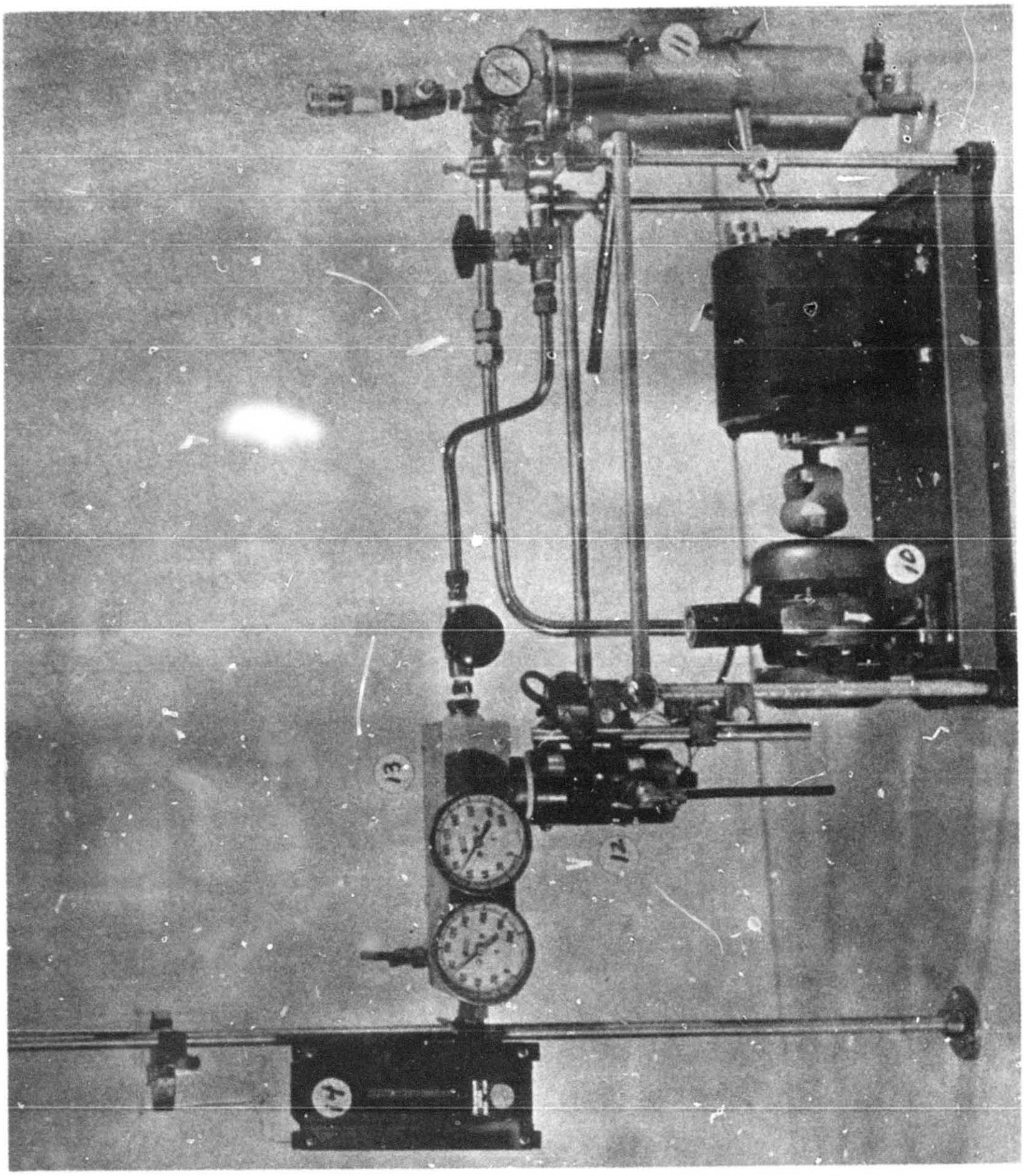

Figure 3

AIR SUPPLY AND HUMIDIFICATION SYSTEM

4. An air cylinder is used to rotate the assembly in the initial design. This was later replaced by a gear motor drive.

5. A control panel with manual switches was used to activate the tracer gas flow, activate the air cylinder and insert the hollow shaft into the element, and to rotate the assembly.

6. Solenoid valves to control tracer gas flow were mounted in this area.

7. A bearing is used to support the canister assembly at the left end of the viewing area. This end of the element was sealed with a flat gasket in the initial design. This was modified to provide an "o" ring seal.

8. A stainless steel expanded metal shield supported the dyed sock. The entire assembly (bearing and canister) can be removed for easy replacement of the sock.

9. The right end of the canister is not supported and it was necessary to provide cam followers as guides.

10. A 2-cfm, 30-psi air compressor can be used to supply test air.

11. An air filter was provided.

12. A heated water reservoir was provided to humidify the air.

13. Wet and dry bulb thermometers are used to measure relative humidity.

14. A rotameter, 0-2 cfm, is used to measure air flow to the element.

4.2 Modifications

Several modifications were required to insure smooth and satisfactory operation of the apparatus. These are discussed below.

The original carousel drive assembly involved the positioning of the element in the viewing area by an air cylinder (designated No. 4 above). This technique was found to be unsatisfactory since a considerable air pressure was required to move the carousel and once it started moving, it was difficult to apply a friction brake and a detention mechanism to stop the element exactly where required in the viewing area. This system was replaced by an electric motor and a belt drive. The motor was stopped by a switch on an indicator wheel about six inches in diameter attached to the drive end of the carousel shaft. While this worked reasonably satisfactorily, the indexing of the elements in the viewing position was not always accurate and the indexing switch was later moved to the left end of the canister support. This technique has proved satisfactory.

The air supplied to the element enters through a ¼-in. diameter hole in the crank mechanism on the right hand side of the tester. During plant tests it became apparent that the air from this relatively small hole tended to give a stronger indication of defects at the left end of the viewing area. The air inlet was modified by making a venturi-type nozzle of approximately 25° angle and with a cone-shaped insert the center of the nozzle. This spread out the air flow and insured a more uniform flow throughout the length of the element. This is particularly important when testing elements with very low pressure drops.

As a result of the initial plant test, it was decided that it would be more satisfactory to seal the left end of the element on the O-ring rather than on the flat surface of the end cap. Difficulty was experienced in obtaining a seal on the flat surface of the end cap, since the end caps were not always at 90° to the center line of the element. Specifications permit a 3° deviation from 90° and perhaps a soft rubber gasket would accommodate this much misalignment. In addition, this manufacturer utilized socks which were tied by a draw string and extended over the ends of the element. Occasionally the string was caught in the seal and caused a leak. The flat rubber gasket is required, however, to provide adequate friction to rotate the canister when it is in the viewing position. In our tests, we used a number of soft rubber pads to provide this friction, rather than a soft rubber circular gasket since the pads would permit the indication of a leak around the O-ring at this end of the element whereas a solid rubber gasket might seal on the flat surface of the end-cap and not indicate a defective O-ring seal.

The canister which holds the indicator sock was designed to fit fairly close to the outside of the filter/separator element. Some elements tested had a flash or bead of adhesive near the end-cap which exceeded the dimensions of the standard filter/separator element. These elements were too large for the canister. While this represents a deviation from the military specifications for this element, it was desired to test about 500 of these elements to evaluate their reject rate. As a result, canisters with an inside diameter of 3.80-in. were fabricated and installed in the unit. These larger canisters worked satisfactorily and have remained in the unit. The nondestructive test apparatus as used in the plant tests is shown in Figure 4.

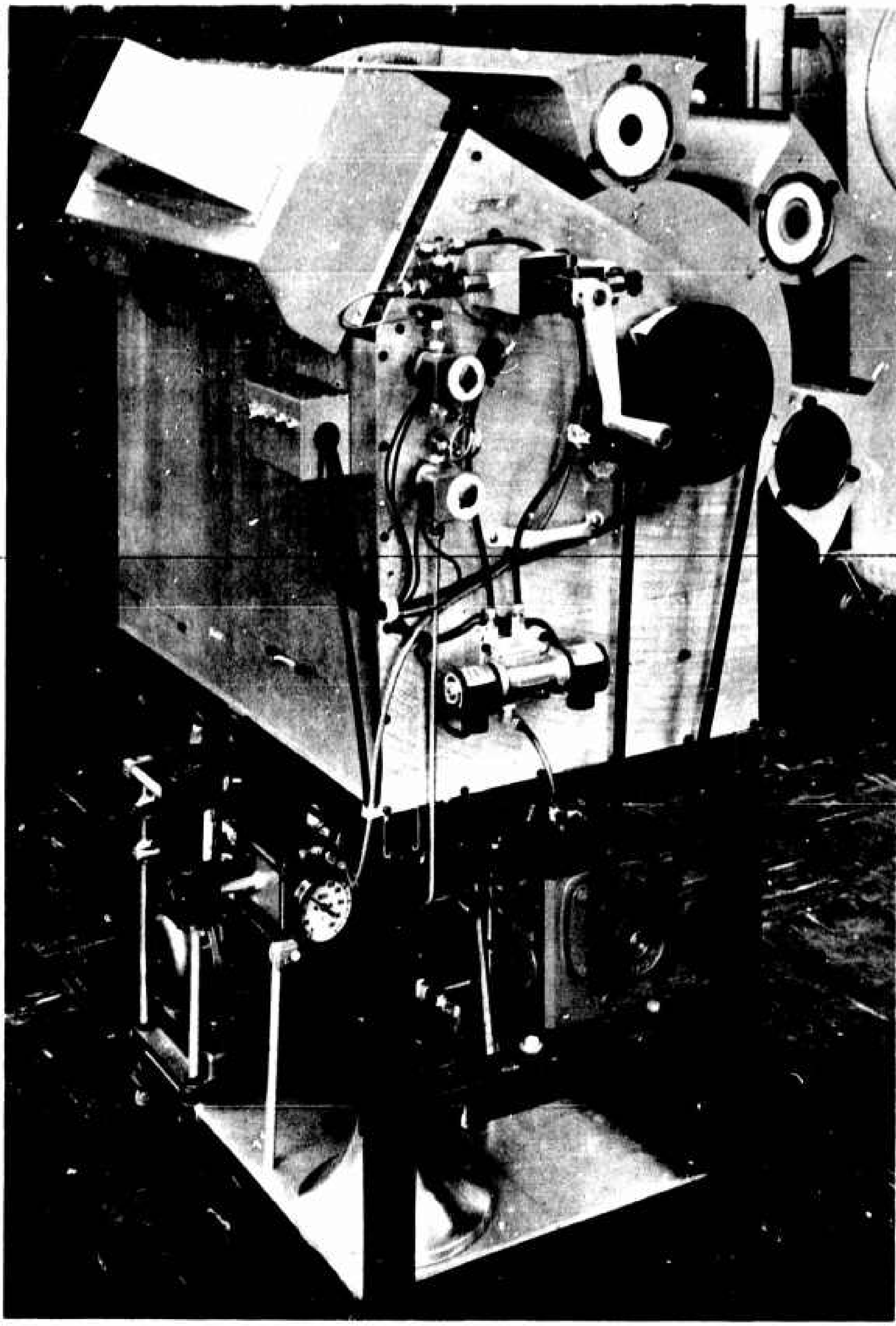

Figure 4

ASSEMBLED NONDESTRUCTIVE TEST APPARATUS

5. RESULTS OF PLANT TESTS

The nondestructive test apparatus was set up in the laboratory to accommodate the filter/separators from several different manufacturers. The apparatus was operated continuously for periods from 4-8 hr to check out procedures and techniques. After a number of the above modifications had been made the equipment was taken to two different manufacturers' plants and operated near the packaging station as these manufacturers produced DOD filter/separator elements.

5.1 Tests at the Keene Corporation

In December 1972 the prototype nondestructive test apparatus was taken to the Keene Corp. plant in Cookeville, Tennessee. The unit was installed and operating within a period of three hours. Initial tests indicated that many of the elements failed at the left end of the viewing area; however, when the element was rotated, there was no indication of failure. About 200 elements were tested in this manner, and 20% of them indicated a failure at the left side of the viewing area. Since this high rejection rate was competely unexpected, it seemed to indicate the nondestructive test apparatus was giving erroneous results and the apparatus was removed from the end of the production line. Review of the test procedures and close examination of rejected elements indicated that the end caps on many of the elements were at an angle that exceeded the $90 \pm 3°$ from the centerline in the specifications. Since the apparatus sealed on the flat end of the end cap with a hard rubber gasket at the left end of the viewing area, and a soft rubber gasket at the right end of the viewing area, these elements indicated leaks at the left end of the viewing area. The apparatus was modified to provide seal at the O-ring rather than on the flat end of the element and reinstalled on the production line within 24 hr. Further tests were conducted without difficulty.

It should be noted that the test apparatus was located just prior to the final inspection and packaging of the DOD element. During the previous few days, there had been a number of rejects produced by this line and it had been shut down until the difficulty could be located and corrected. The elements being inspected by the nondestructive test were not elements which had been approved for shipment and during subsequent operations elements with end caps which were not at 90° to the centerline of the element were rejected by the final inspector on the line.

Approximately 3000 standard DOD elements were evaluated with the nondestructive test equipment at this plant. Two elements were found to be defective. The defective areas were about ½-in. in diameter and were marked and returned to MERDC for testing. Poor coalescence was found in both marked areas and further investigation resulted in the finding that there was poor binding between the end caps and the element bodies.

As a result of our testing, it was apparent that very few defective elements would be found during normal production and the plant personnel were kind enough to suggest various defects which they could build into the elements for check-out of the test apparatus. Several defective elements were deliberately fabricated and tested. The results of these tests are given in Table 1.

In all cases, it was possible to detect the defect in a maximum period of 20 sec; most of the defects were detected in about 2 sec.

5.2 Tests at Banner Engineering Company

In January 1973 the nondestructive test unit was installed at the end of the DOD element production line at Banner Engineering Company. During a period of approximately 10 days, 3000 elements were tested and two defective elements were found. These elements were supplied to MERDC for evaluation and found to fail the coalescence test.

Table 1

DETECTION OF DELIBERATELY BUILT-IN ELEMENT DEFECTS (Keene Corporation)

Media defects	Test results
Pleated proper slit, 8 in.	Detectable, 10-20 sec
Pleated paper slit, 2 to 4-in. cuts	Detectable, 10-20 sec
Coalescing layer, 3/4-in. hole	Detectable, 2 sec
Coalescing layer, ½x½-in. hole	Detectable, 2 sec
Hole drilled in element, 1/8-in. diam.	Detectable, 2 sec
Hole in plug in element, 0.030-in.	Detectable, 2 sec
End cap defects	**Test results**
½x½-in. hole in paper and coalescing media but covered by tape	Detectable, <2 sec
50% of end cap not sealed	Detectable, <2 sec
3/8-in. strip not sealed	Detectable, 10-20 sec
3/4-in. strip not sealed	Detectable, <2 sec
1-in. strip not sealed	Detectable, 10-20 sec

The elements produced by Banner Engineering Company are somewhat different in construction from the elements produced by the Keene Corporation and plant personnel again agreed to deliberately produce a number of defective elements for evaluation of the test apparatus. Results of tests of these elements are given in Table 2.

5.3 Acceptance by Plant Personnel

In both cases, plant personnel were very receptive to the concept of nondestructive testing of filter/separator elements as they were produced. All the plant personnel from the line operators to management and laboratory staff were highly interested in the concept and viewed the nondestructive equipment as a means of further increasing the quality of their product. Complete cooperation was received during the two test periods and it is apparent that the use of this apparatus will be welcomed by plant personnel.

Table 2

DETECTION OF DELIBERATELY BUILT-IN ELEMENT DEFECTS
(Banner Engineering Corporation)

Media defects	Test results	
Filter paper, 2 pleats by 6-in. long	Detectable	8-15 sec
Filter paper, 4 pleats by 6-in. long	Detectable	8-15 sec
Coalescing media, ¼-in. hole	Detectable	1-2 sec
Coalescing media, ¼-in. hole + 1/16 drill	Detectable	<1 sec
All media, plastic insert 0.030-in. hole	Detectable	<1 sec
Coalescing media, 1-in. by 4-in. ½ media removed	Detectable	2-3 sec
End caps	**Test results**	
Gouge in coalescing media, 3/8 by 1/4-in. then capped	Detectable	2-3 sec
Filter paper 8 pleats by ½-in. down, then capped	Detectable	8-15 sec
Channel-hot plastic quenched ¼-in. strip	Detectable	2-4 sec
Channel-hot plastic not heated ½-in. strip	Detectable	3-5 sec

6. CONCLUSIONS AND RECOMMENDATIONS

As a result of the work conducted on Phase II of this program it can be concluded that:

- The prototype apparatus which has been developed is satisfactory for the evaluation of the procedures and operation at the end of a production line producing up to 1000 elements per 8-hr shift.

- It may be desirable to redesign the unit for one-man instead of two-man operation inasmuch as the labor cost represents a major fraction of the cost associated with testing.

- The unit succeeded in detecting defects in elements with no visual flaws. These elements failed the coalescence test.

- All the elements which failed the non-destructive test also failed the coalescence test.

As a result of the studies, the following recommendations can be made.

- Further evaluation of the nondestructive test equipment would be desirable to statistically determine rejection rates. A program to test at least 20,000 elements is recommended.

- A statistically significant number of elements passed by the inspector and by the nondestructive test apparatus should be destructively tested to determine capability of the nondestructive test apparatus.