

# Evaluation of DOD Army Aviation Filters

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## ABSTRACT

This program was divided into two phases: 1) comparison of DOD and API approved coalescer/separators and 2) determination if any current DOD coalescer/separators could pass API/IP 1581 5<sup>th</sup> Edition using the DOD 80-gpm and 350-gpm housings.

In Phase I, seven evaluations were performed according to an approved design of experiment to compare the water removal efficiencies for the current DOD system and an equivalent references American Petroleum Institute/ Institute of Petroleum (API/IP) system. DOD evaluations were performed with and without water bottoms. These evaluations demonstrated that an equivalent API system out performs the current DOD system.

In Phase II, ten evaluations were performed with products provided by three different manufacturers. Two manufacturers were able to pass API/IP 1581 5<sup>th</sup> Edition by improving the separator's water shedding performance.

## INTRODUCTION

The question has arisen if the current DOD filtration system is adequately protecting hardware in the field. Some operators in the field have begun procuring API/IP housings and coalescer/separators that defeats the military standardization. An additional problem is these same outfits are using different length elements, thereby compounding the logistics problem.

The U.S. Army Tank-automotive and Armaments Research, Development and Engineering Center (TARDEC) requested a test program be designed to compare the water removal efficiencies between the current DOD and an equivalent API/IP system to determine if there were substantial differences in water removal efficiencies.

DOD aviation filtration systems were procured according to MIL-F-52667F and MIL-F-52308J, and coalescers were procured according to MIL-PRF-52308J. MIL-F-52308J references American Petroleum Institute/Institute of Petroleum (API/IP) 1581 4<sup>th</sup> Edition as the test protocol for evaluating candidate coalescers. Since revision J is a MIL-PRF, previous procurements of the element were to 52308 when it was MIL-F-5308. API/IP 1581 4<sup>th</sup> Edition was canceled in favor of API/IP 1581 5<sup>th</sup> Edition due to issues involving the additive chemistry recommended in the 4<sup>th</sup> Edition. Since API/IP 1581 5<sup>th</sup> Edition is a relatively new specification, no DOD coalescers have been qualified to this standard.

## OBJECTIVES

The objectives of this program were:

- Determine the quantity of water before failure in the DOD system with and without water bottoms,
- Compare the above results with an equivalent API/IP system.
- Determine if any manufacturer can produce prototypes to meet performance of API/IP 1581 5<sup>th</sup> Edition using the 80- and 350- DOD housings per MIL-PRF-52308J.

The test conditions for the first two objectives were:

JP-8 (Category M) test fuel,

50-gpm (de-rated flow rate) and 80-gpm (rated flow rate),

Elements were challenged with 19 mg/L red iron oxide for 30 minutes,

Water injection challenge started at 0.1%,

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Subsequent water challenges were 0.5% with 0.5% increases until failure or 4%,

Water challenge at each concentration lasted for 30 minutes.

The test fuel was evaluated for drag reducer additive before testing and none was found. The following analysis was performed for all tests:

- Microseparometer,
- Conductivity,
- Fuel system icing inhibitor (FSII),
- Solids (after element challenged with red iron oxide),
- Water by Aquaglo, ASTM D 3240.

All API/IP 1581 5<sup>th</sup> Edition evaluations were performed with category M fuel (JP-8).

#### DOD and API System Descriptions

The DOD 50-gpm housing was supplied by TARDEC and contains 4 coalescers and separators, Figures 1 and 2. Each coalescer/separator is rated for 20-gpm, hence the capacity of the vessel should be 80-gpm based on the number of coalescers/separators.



**Figure 1. Coalescers/Separators Mounted in a DOD housing**



**Figure 2. DOD Coalescer/Separators**

The separators mount over the coalescers and are not sealed at the bottom. The original vertical design of this

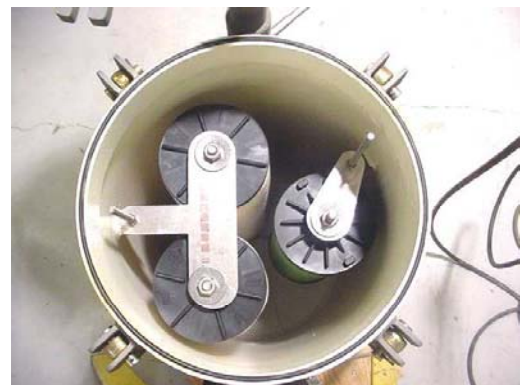
system depended upon water bottoms to seal the separator.

An API/IP filtration system was fabricated to meet the performance criteria (80-gpm) of the DOD system, Figures 3 and 4.



**Figure 3. API Housing**

As shown in Figure 4, there are two 15.24-cm (6") coalescers and one 15.24-cm (6") separator in the API/IP system as compared to four each in the DOD system.



**Figure 4. API/IP Coalescers and Separator**

#### **DOD EVALUATIONS**

##### **Design of Experiment**

A design of experiment was agreed upon to evaluate the current DOD system for the 80-gpm DOD filtration system and compare these results with a similar API/IP filtration system. To reduce the variability of the design of experiment, coalescer elements were purchased from the current Government approved vendor. The coalescers were from the same lot and produced 12/05/02. The separator used for all DOD evaluations was furnished by TARDEC. All evaluations were performed in the appropriate full-scale housing. The fuel flow is inside out for the coalescers.

The forensics of a new element is shown in Figure 5.

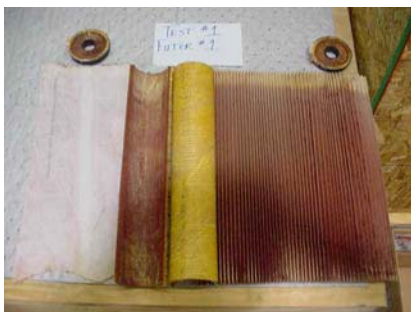


**Figure 5. New DOD Coalescer**

Test #1 - DOD without Water Bottoms Evaluation – 50 gpm

Test #1 was performed at 50-gpm, without water bottoms. The aquaglo water tester malfunctioned during this test, therefore Karl Fischer titration was used to determine water content. At 0.1% water contamination, the system averaged approximately 5 ppm water downstream. Visible water droplets were seen at the top of the housing with 0.5% water contamination indicating failure. The average Karl Fischer water content was approximately 17 ppm.

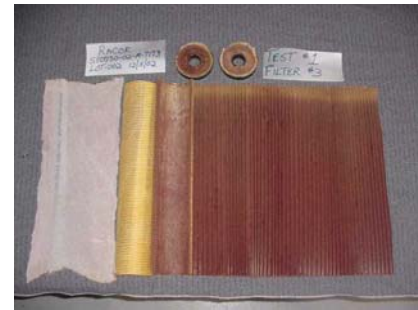
The forensics for the coalescers used in Tests #1-5 are similar to the results shown in Figures 6 - 9.



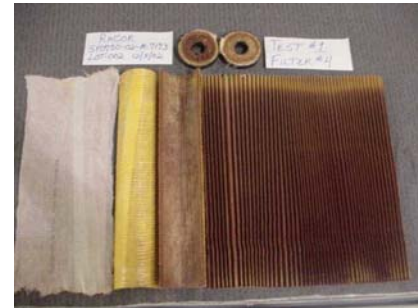
**Figure 6. Coalescer #1**



**Figure 7. Coalescer #2**



**Figure 8. Coalescer #3**



**Figure 9. Coalescer #4**

The forensics does not indicate any structural failures. The red iron oxide was evenly dispersed on the particulate section of the filter and on the internal side of the coalescer. There was minimal discoloration of the cotton sock.

Test #2 - DOD with Water Bottoms Evaluation – 50 gpm

Test #2 was performed at 50-gpm and with water bottoms. During the particulate loading portion of the test method, it was obvious at least one coalescer had a failure as red iron oxide was visible in the housing. The water contamination test was started just to determine if there was any indication it would improve the performance of the system. With a water contamination level of 0.1%, with the water bottom below the separator, the water content was >12 ppm. Once it rose above the bottom of the separator, the effluent water content was 2 ppm. With 0.5% water contamination, the effluent water content averaged approximately 3 ppm. The test was terminated at this point due to the structural failure.

The forensics did show one coalescer did fail at the end cap. The red stains on the outside of the yellow coalescing material and the cotton sock confirmed the failure.

Test # 3 and #4- DOD with and without Water Bottoms Evaluation – 80 gpm

Test #3 and #4 were performed with the same filtration system as they both immediately failed at a water contamination level of 0.1%. Test #3 was performed without water bottoms and had aquaglo readings greater than 150 ppm. The water bottoms were increased to reach the bottom of the separators but the results

remained the same, greater than 150 ppm. No structural failures were found in the test articles.

#### Test # 5 - DOD with and without Water Bottoms Evaluation – 50 gpm

Due to the element failure in Test #2, Test #5 was a repeat of those test conditions. Since the initial portion of the test is “without” water bottoms, effluent water levels were determined at 0.1%. Without water bottoms it failed again at 0.1% water with an aquaglo water level of >120 ppm.

The sump water level was increased to the bottom of the separator and the test was continued. The system failed at 1.0% with effluent water levels >120 ppm.

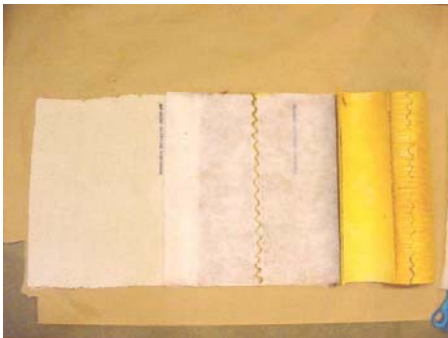
No forensics was performed on these coalescers.

#### Test # 6 - API System – 50 gpm

As described in 3.2, the API/IP system contains two six-inch diameter coalescers and a six-inch separator. The elements for this test were threaded base, i.e.; they screw directly into the housing base. The construction of the API/IP elements are similar to that of the DOD elements; thereby eliminating any design variables.

This test was terminated after 4% water contamination as it had exceeded the API/IP 1581 5<sup>th</sup> Edition performance criteria of 3%. The effluent water concentration was 2 ppm. Even at 4.0% water contamination, the differential pressure was only 3 psid compared to approximately 14 psid for the DOD system at an equivalent water contamination level in Test #1.

The forensics for the API/IP coalescers is provided in Figures 10-11.



**Figure 10. Test #6 – Sock and Coalescing Media**



**Figure 11. Test #6. Particulate Removal Media**

No structural failures were found.

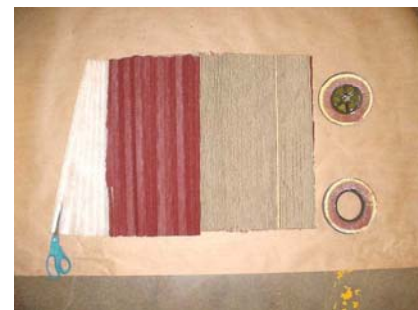
#### Test # 7 - API System – 80 gpm

The API/IP coalescers used for this test were open-ended. Therefore, the mounting utilized a rod, washers, and nut. This test was terminated at 1.0%. At 0.5% water contamination, the readings were <1, 2, and >24 ppm at 0, 15, and 30 minutes, respectively. The water contamination was increased to 1.0% with the initial effluent water concentration being >120 ppm. The differential pressure at termination was 4.5 psid as compared to an initial differential pressure of 6.3 psid (after red iron oxide loading) for the DOD system. One possible explanation for the poor performance of the API/IP system at 80-gpm is the use of open-ended coalescers that could allow for water leakage.

The forensics for test #7 is shown in Figures 12-13. Again, no structural failures were found.



**Figure 12. Test #7 – Sock and Coalescing Media**



**Figure 13. Test #7 – Particulate Removal Media**



## API/IP 1581 5<sup>TH</sup> EDITION TESTING

DOD aviation filtration coalescers have historically been procured according to MIL-F-52308J. The most current revision to MIL-F-52308J references American Petroleum Institute/ Institute of Petroleum (API/IP) 1581 4<sup>th</sup> Edition as the test protocol for evaluating candidate coalescers. API/IP 1581 4<sup>th</sup> Edition was canceled in favor of API/IP 1581 5<sup>th</sup> Edition due to issues involving the additive chemistry recommended in the 4<sup>th</sup> Edition.

Since API/IP 1581 5<sup>th</sup> Edition is a relatively new specification, no DOD coalescers have been qualified to this standard or to MIL-PRF-52308J.

### Scope of Work

The scope of work for this phase of the program was to validate that filter manufacturers can produce a DOD configuration element that can meet the performance specified in MIL-PRF-52308J (API/IP 1581 5<sup>th</sup> Edition). Five evaluations each were performed in an 80-gpm, Figures 14 and 350-gpm housing, Figure 15. The 80-gpm housing contains 4 coalescers/separators, whereas the 350-gpm housing contains 18 coalescers/separators.



Figure 14. DOD 80-gpm housing



Figure 15. DOD 350-gpm housing

### Solicitation of Elements

Initially, five manufacturers expressed interest in participating in this program. After contract negotiations and clarification of the test protocols, two manufacturers preferred not to participate. However, discussions with one of the manufacturers revealed that the U.S. Air Force was utilizing improved separators. Therefore, it

was recommended and approved to use the improved separators with the two best performing coalescers from the three participating manufacturers. The improved separator part number is NSN 4330-01-511-8316. The improved separator is 200 mesh with an increased length whereas; the DOD separators use a 100 mesh.

### Test Protocol

API/IP 1581 5<sup>th</sup> Edition protocol was used for all 10 evaluations, utilizing M category fuel. The API/IP 1581 5<sup>th</sup> Edition protocol consists of the following test segments:

30 minutes – media migration

30 minutes – water challenge, 100 ppm

45 minutes – solids challenge, 19 mg/L

90 minutes – water challenge, 100 ppm

15 minutes – water challenge, 3%

### Test Results

The overall test results for each evaluation at 80-gpm and 350-gpm is shown in Tables 1 and 2, respectively.

Table 1. 80-gpm Test Results

Test	Water Content at 100 ppm, pass/fail	Particulate Content, pass/fail	Water Content at 100 ppm, pass/fail	Water Content at 3%, pass/fail
A – Manufacturer A with DOD Separators	Pass	Pass	Pass	Fail
B – Manufacturer B with DOD Separators	Pass	Pass	Fail	Fail
C – Manufacturer C with DOD Separators	Pass	Pass	Pass	Fail
D – Manufacturer A with "Improved" Separators	Pass	Pass	Pass	Fail
E – Manufacturer C with "Improved" Separators	Pass	Pass	Pass	Pass

Table 2. 350-gpm Test Results

Test	Water Content at 100 ppm, pass/fail	Particulate Content, pass/fail	Water Content at 100 ppm, pass/fail	Water Content at 3%, pass/fail
A – Manufacturer A with DOD Separators	Pass	Pass	Pass	Fail
B – Manufacturer B with DOD Separators	Fail	Fail	Fail	N/A
C – Manufacturer C with Improved Separators	Pass	Pass	Pass	Pass
D – Manufacturer C with DOD Separator	Pass	Pass	Pass	Pass
E – Manufacturer A with "Improved" Separator	Pass	Pass	Pass	Pass

## Separators

It is noted that these evaluations utilized 4 different separators. In the 80-gpm evaluations, the standard DOD separator meeting drawing 13217E6316 was used for the first three evaluations. Evaluations D and E used a modified version of NSN 4330-01-511-8316. The screen was still 200-mesh, but the diameter and length was modified to conform to the 80-gpm configuration.

In the 350-gpm evaluations, the DOD bayonet separator drawing 13216E2773 has a larger diameter than the separator conforming to drawing 13217E6316. This increase in diameter reduces the velocity of the water droplets impacting the separator and reduces the velocity of the fuel exiting the bottom of the separator. The two "improved" separator evaluations utilized NSN 4330-01-511-8316.

## Conclusions

Based on the data generated during this study (both Phase I and II), the following conclusions can be made:

- Coalescer/separators meeting MIL-PRF-52308J look feasible when using the "improved" separator.
- The API/IP system appears to be able to remove higher water concentrations than the standard DOD system. There maybe some size and weight tradeoffs that require further studies.

## Recommendations

Based on this research, the following recommendations are suggested:

- Start converting DOD filtration systems to API/IP equivalent systems.
- Standardizing the element lengths to reduce inventory and logistical burden.
- Leverage the military requirements with industry to potentially reduce cost, improve performance and availability of product.

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