AEROSPACE RECOMMENDED PRACTICE

ARP219	REV. A
Issued 1961-10 Stabilized 2013-12 Superseding ARP219	

Procedure and Method for Conducting Test of Hydraulic Components in Contamination Controlled System

RATIONALE

This document has been determined to contain basic and stable technology which is not dynamic in nature.

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1. PURPOSE:

1.1 The purpose of this bulletin is to set forth recommendations of the SAE Committee A-6, Aerospace Fluid Power Systems and Equipment, relative to the procedures and methods to be used in conducting contamination controlled tests on aircraft and missile hydraulic systems and pumps. This is for the purpose of outlining a standardized procedure such that comparative results can be obtained.

2. SCOPE:

2.1 This procedure will be generally applicable to three classes of hydraulic components as listed below:

Class A - Motors, Pumps, Actuators, Accumulators, Reservoirs, and Non-metering Valves

Class B - Servo Valves and Metering Valves

Class C - Special short Life Duration Components

2.2 These recommendations are written to cover the following six main categories:

1. Test Circuit (Paragraph 3).
2. Test Procedure (Paragraph 4).
3. Calibration (Paragraph 5).
4. Contamination Test (Paragraph 6).
5. Type and Amount of Contaminant (Paragraph 7).
6. Method of Measuring Contaminant (Paragraph 8).

3. TEST CIRCUIT:

3.1 Class A Units - Pumps, Motors, Actuators, Accumulators, Reservoirs and Non-Metering Valves: The test circuit shall be set up as shown in Figure 1 for pumps. Figure 1A shall be used when Hydraulic Motors or other circuit components are under test. In this circuit, the reservoir shall be so constructed that the bottom of the reservoir shall be smooth without corners and the reservoir outlet or pump inlet connection shall be the lowest point on the reservoir.

3.2 Class B Units - Servo Valves and Metering Valves: The test circuit for servo valves and metering valves, Class B units, shall be set up as shown in Figure 3. The same precautions shall be taken in this circuit as outlined in Paragraph 3.1 to minimize contamination traps.

3.3 Class C Units - Short Life Components: Special short life duration components will use circuits shown in Figures 1, 1A, and 3, whichever is applicable.

3.4 For the purpose of introducing contaminant to the system during operation, a small contaminant chamber, consisting of a standard flared tube T connection of the AN-824-16 type, shall be in a line parallel to the main inlet line. This chamber shall be connected to the by-pass circuit with normal military fitting connections and shut-off valves such that the chamber can be connected in and out of the circuit through the use of the shutoff valves. To introduce contaminant the following sequence of valving should be observed:

1. Open Valve 2
2. Close Valve 1
3. Close Valve 3
4. Remove cap and place contaminant in chamber and replace cap.
5. Open Valve 3
6. Open Valve 1
7. Close Valve 2

3.5 This auxiliary parallel system containing the contaminant to be used in this test shall be in the inlet line of the unit under test. That is, if it is a pump that is undergoing test in the contamination controlled circuit, the position of this auxiliary circuit shall be in the pump inlet line as shown. In the event that some other circuit component is undergoing contaminated circuit tests, this auxiliary circuit to introduce the contaminant shall be immediately up-stream of the test unit. That is, if a servo valve is undergoing circuit test, the contaminant shall be introduced through this auxiliary circuit immediately up-stream of the servo valve.

3.6 The line connecting the outlet of a contaminant chamber to the unit inlet shall come into the main system at an angle of not more than 45° to insure minimum disturbance of the contaminant.

3.7 In the test circuit, sharp corners, "dead" circuit areas, or sections shall be minimized. All parts of the circuit shall be thoroughly cleaned prior to the circuit installation. The heat exchanger shall be of a coiled tube type in a water cooled jacket to minimize places for contamination entrapment. This is to minimize the collection of contaminant during tests in this piece of equipment. As shown in Figure 1, the sampling valves shall be located at a place where there is a bend in the circuit such that the normal circuit flow would be essentially straight into the sampling valves.

3.8 The total volume of fluid in the entire circuit, including that in the reservoir, shall be a maximum of 10 gallons. Of this amount, the reservoir capacity shall be between 1 to 4 gallons.

3.9 Circuit filtration may be used to obtain initial circuit cleanliness, as outlined in paragraph 4.1.2. However, prior to the start of tests introducing contaminant to the test circuit, all system filters shall be removed. This shall also include the removal of the filter housings, as well as the elements from the circuit to preclude the possibility of the housings trapping some circuit contaminant during operation.

3.10 Adequate precautions shall be used to determine that, if pressurization is used on the reservoir, that essentially no additional contaminant is added to the reservoir through this pressurization.

4. TEST PROCEDURE:

4.1 Class A Units - Pumps, Motors, Actuators, Accumulators, Reservoirs and Non-metering Valves: The system shall be operated with the pump running at rated speed and temperature with the outlet pressure cycled from 1/4 flow pressure to full flow at 80% rated pressure, at a cycle rate of 10 cycles per minute. The inlet pressure shall be at rated pressure. In these tests, and all subsequent tests, unless otherwise stated, these conditions shall be used.

4.1.1 The pump shall be operated as outlined above for a period of 30 minutes. During the last 5 minutes of operation, 100 ml samples of circuit fluid shall be taken from the pump inlet and system return line sampling valves.

4.1.2 The total contaminant in these two samples shall be measured according to proposed Aerospace Recommended Practice 598, in which the total number of particles are determined through a particle count method. The maximum number of particles counted in the system, prior to the contamination test, shall be as outlined in Table 1.

TABLE 1

ACCEPTABLE CONTAMINATION LEVELS PER 100 ML OF FLUID WHEN MEASURED IN ACCORDANCE WITH PROPOSED ARP 598	
Size Range (Microns)	As Measured In Hydraulic System, Class A, B, or C
5 - 15	20,000
15 - 25	9,000
25 - 50	2,500
50 - 100	150
Over 100 (Including Fibers)	30

4.1.3 If the system does not meet this initial cleanliness level, additional filtration and/or other means of cleaning shall be used until this cleanliness level is met.

4.1.4 This procedure covers a 50 hour test in a contamination controlled system; contamination placed in the system every 5 hours of operation. This will be a total of 10 tests of 5 hours duration. After the first 30 minutes of operation of each 5 hour test, the contaminant shall be placed in the system, as described below, and during the last 30 minutes of each 5 hour test, fluid samples shall be obtained from the unit inlet and outlet sampling valves as outlined below. Unless otherwise outlined in this procedure, the pump or other item under test shall be operated at rated conditions. This is in relation to temperature, speed, and/or flow and other conditions.

4.2 Class B Units - Servo Valves and Metering Valves: This system shall be operated in a 3 gallon total circuit capacity, as shown in Figure 3. The system shall be operated with the valve cycling at rated flow and temperature, at a cycle rate of 1 cycle per second.

4.2.1 The system shall be operated as outlined above for a period of 10 minutes. During the last 2 minutes of operation 100 ML samples of circuit fluid shall be taken from the valve inlet and system return sampling valve.

4.2.2 The total contaminant in these two samples shall be measured according to proposed Aerospace Recommended Practice 598, in which the total number of particles are determined through a particle count method. The maximum number of particles counted in the system, prior to the contamination test, shall be as outlined in Table 1 (Para. 4.1.2).

4.2.3 If the system does not meet this initial cleanliness level, additional filtration and/or other means of cleaning shall be used until this cleanliness level is met.

4.2.4 This procedure covers a 12-1/2 hour test in a contamination controlled system. Contamination is placed in the system every 1/2 hour of operation. This will be a total of 25 tests of 1/2 hour duration each. After the first 5 minutes of operation of each 1/2 hour test, the contaminant shall be placed in the system as described below. During the last 5 minutes of each 1/2 hour test fluid samples shall be obtained from the unit inlet and outlet sampling valves as outlined below. Unless otherwise outlined in this procedure, the item under test shall be operated at rated conditions. This is in relation to temperature, pressure, and/or flow, and other conditions.

4.3 Class C Units - Short Life Components: For short life components test procedures under classification A or B may be used with the exception that the time periods, of whichever procedure is used, may be varied. That is, in the case of a short life pump, instead of running 10 five hour tests, this might be accelerated such as running 10 one hour tests. In each unit segment of time the same amount of contaminant designated for classifications A or B shall be used.

5. CALIBRATION:

5.1 Class A Units - Pumps, Motors, Actuators, Accumulators, Reservoirs and Non-metering Valves: Prior to and after completion of the 50 hour contamination test, performance of the unit under test shall be measured at rated conditions. In the case of a pump, the delivery and case drain leakage shall be measured at three rated conditions: 1. Minimum outlet Pressure; 2. At 80% of rated pressure; and 3. At zero flow pressure.

5.2 Class B Units - Servo Valves and Metering Valves: Both before and after completion of the 12-1/2 hour contamination test, the hysteresis of the valve shall be measured together with other characteristics in clean oil at the rated conditions.

5.3 Class C Units - Short Life Components: Components in this classification shall be calibrated according to their standard conditions both prior to and after the completion of the respective contamination tests. This calibration shall be in clean oil.

6. CONTAMINATION TEST:

6.1 Class A Units - Pumps, Motors, Actuators, Accumulators, Reservoirs and Non-Metering Valves (Five Hour Test - 50 Hours Total): The unit shall be operated in this test under rated conditions, which will be defined in the detailed specification. The unit shall be operated for the first 30 minutes of this test with full system flow at 80% of rated system pressure. At the end of this first 30 minute run introduce the initial charge of contaminant to the circuit following the procedure as outlined in paragraph 3.4. The following five paragraphs describe the system operation in which a pump is the unit under test:

6.1.1 The system pump shall then be cycled continuously for 9 minutes at full flow (80% discharge pressure) and 1 minute at rated pressure at 0 flow. Under these conditions the pump shall be operated for the remainder of the 5 hour period.

6.1.2 After the completion of 1 hour of test during the 5 hour period (30 minutes after the contaminant has been introduced into the system), valve No. 2 shall be opened and valves Nos. 1 and 3 shall be closed.

6.1.3 With a rubber syringe sufficient fluid shall be withdrawn from the contamination chamber to permit pouring the slurry containing the contaminant into the chamber. The chamber shall then be recapped in preparation for the next 5 hour contaminant test.

6.1.4 Without shutting the unit or test circuit down, an identical amount of contaminant shall then be placed in the contaminant chamber by removing the AN820-16 cap.

6.1.5 During the last 30 minutes of each 5 hour operation, with the pump at full flow operation as outlined above, 100 ML samples of fluid shall be taken from the unit inlet and outlet system return line sampling valves. When the sampling valves are open, fluid shall be bled through these valves for a period of 10 seconds prior to actually obtaining the 100 ML sample. This is to permit a more representative sample of fluid for contaminant measurement. The total contamination in each of these 100 ML samples shall then be determined either as outlined in paragraph 4.1.2, or by a gravimetric weight method. A total of ten (10) 5 hour running periods, together with introduction of contamination and contamination sampling, shall be made unless otherwise outlined in the detailed specification.

6.2 Class B Units - Servo Valves and Metering Valves - (1/2 Hour Test - 12-1/2 Hours Total): The valve shall be operated in this test under rated conditions, which shall be defined in the detailed specification. This test program will consist of 25 one half hour tests, for a total of 12-1/2 hours of operation.

During the first 5 minutes of each 1/2 hour test, the following hysteresis tests shall be conducted three times:

Dead Band - Close the load valve and apply a 60 cps input current dither of 6% of rated ma peak amplitude for 3 seconds. Immediately after applying the dither, plot, on an X-Y automatic plotter, the differential pressure between the ports versus the input current (current on the horizontal axis). Vary the input current from +100% rated ma to Zero to -100% rated ma, and back to +100% rated ma at a maximum rated of 50% rated ma per minute. The maximum horizontal distance between the curves of the hysteresis loop formed shall be measured. Gain plus the dead band hysteresis shall be measured.

6.2.1 At the beginning of the second 5 minutes of operation under rated conditions, the initial charge of contaminant shall be placed in the circuit following the procedure outlined in paragraph 3.4.

6.2.2 During the first part of the second 5 minutes of valve cycling operation, valve No. 2 shall be opened and valves numbers 1 and 3 shall be closed.

6.2.3 With a rubber syringe sufficient fluid shall be withdrawn from the contamination chamber to permit pouring the slurry containing the contaminant into the chamber. The chamber shall then be recapped in preparation for the next 1/2 hour contaminant test.

6.2.4 Without shutting the unit or test circuit down, an identical amount of contaminant shall then be placed in the contaminant chamber by removing the AN820-16 cap.

6.2.5 During the latter part of the second five minutes of the 1/2 hour test, valves Nos. 1 and 3 shall then be opened and valve No. 2 shall be closed.

6.2.6 During the last five minutes of each 1/2 hour operation, 100 ML samples of fluid shall be taken from the inlet and outlet lines of the unit under test. When the sampling valves are open fluid shall be bled through these valves for a period of 5 seconds prior to obtaining the 100 ML sample. This is to permit a more representative sample of fluid for contaminant measurement. The total contaminant in each of these 100 ML samples shall then be determined either by the particle count method, outlined in paragraph 4.1.2, or by a gravimetric weight method. A total of 25 one half hour running periods, which include the introduction of contamination and contamination sampling, shall be made unless otherwise outlined in the detailed specification.

6.3 Class C Units - Short Life Components: The procedure outlined in paragraphs 6.1 and 6.2 may be used for Class C units, with changes made in the running times to correspond to the rated life of the unit under test. In each case the same amount and type of contaminant shall be used, but over a shorter or longer running period.

7. TYPE AND AMOUNT OF CONTAMINANT:

7.1 Class A Units - Pumps, Motors, Actuators, Accumulators, Reservoirs and Non-Metering Valves: The contamination to be used in this test shall be equal parts of Arizona Road Dust, Iron Filings and Ferrous Oxide, together with a lesser amount of Cotton Linters, which are defined in detail below:

7.1.1 Each of the first three samples will consist of 4 mgs. per gallon. The amount of cotton linters or fibers shall be 1 mg. per gallon. This means that for each 5 hour test there would be 4 mg. per gallon each of road dust, iron oxide and iron filings, with 1 mg. per gallon of cotton linters, for a total of 13 mg. per gallon.

7.1.2 Road dust equivalent to standardized fine air cleaner test dust. This may be obtained from the AC Spark Plug Division, at Flint, Michigan, and consists of the following size particles:

0 - 5 Microns	39±2%
5 - 10 Microns	18±3
10 - 20 Microns	16±3
20 - 40 Microns	18±3
40 - 80 Microns	9±3

7.1.3 Iron Oxide 1010 microns (XXP-36C)
#340 London Red Rouge, James Rhodes & Co.,
Chicago, Illinois

7.1.4 Iron filings equivalent to National U.S. Radiator Corporation, Plastics Metal Division, Johnstown, Pennsylvania, plast-iron powder minus 325 mesh grade A-230 very soft.

These flakes will pass through an approximate 40 micron filter.

7.1.5 Cotton linters (fibers) equal to U.S. Standard Staple No. 7 prime cotton linters. The size shall be as ground in a No. 4 Wiley Mill and screened through a 4 mm screen.

7.1.6 For the amount of contaminant during the 50 hour test, a total of 130 mgs. per gallon (10 tests X 13 mg./gallon per test) of combined contaminant shall be introduced to the system. This means that at the beginning of each 5 hour test 1/10 of this amount, or 13 mgs. per gallons of combined contaminant shall be mixed in a slurry and placed in the chamber prior to each 5 hour test. Care shall be used to make sure that no contaminant or slurry is lost during this operation.

7.2 Class B Units - Servo Valves and Metering Valves: The contamination to be used in this test shall consist of 50% AC fine dust by volume and 50% type SF carbonyl iron powder as obtained from: A C Spark Plug Division, General Motors Corporation, 3100 North Dort Highway, Flint, Michigan; and General Dyestuff Corporation, Antara Chemical Division, 435 Hudson Street, New York, New York, respectively.

7.2.1 The total combined amount of contaminant added each 1/2 hour to the system shall be 0.2 mg per 100 ml, or .0075 grams per gallon, in the hydraulic circuit. This amount of contaminant will be put in 25 times, which means at the end of 12-1/2 hours of operation, a total of 5.0 mg per 100 ml, or .1875 grams per gallon, will have been put into the circuit.

7.2.2 This contaminant shall be placed in a slurry and placed in the chamber prior to each 1/2 hour test. Care shall be used to make sure that no contaminant or slurry is lost during this operation.

7.3 Class C Units - Short Life Components: This Class shall be chosen from either the Class A or B contaminant. The same amount of contaminant will be used, with a modification of the test time period, if required.

8. METHOD OF MEASURING CONTAMINANT:

8.1 At the completion of each specified test period (5 hours for Class A, and 1/2 hour for Class B), 100 ml samples shall be taken from the unit inlet and outlet as outlined in paragraph 4.1.2.

8.2 The amount of contaminant taken from each sample shall be determined by either ARP 598, particle count, or by the gravimetric total weight method. Whichever method is used should be standardized and used throughout the entire test condition.

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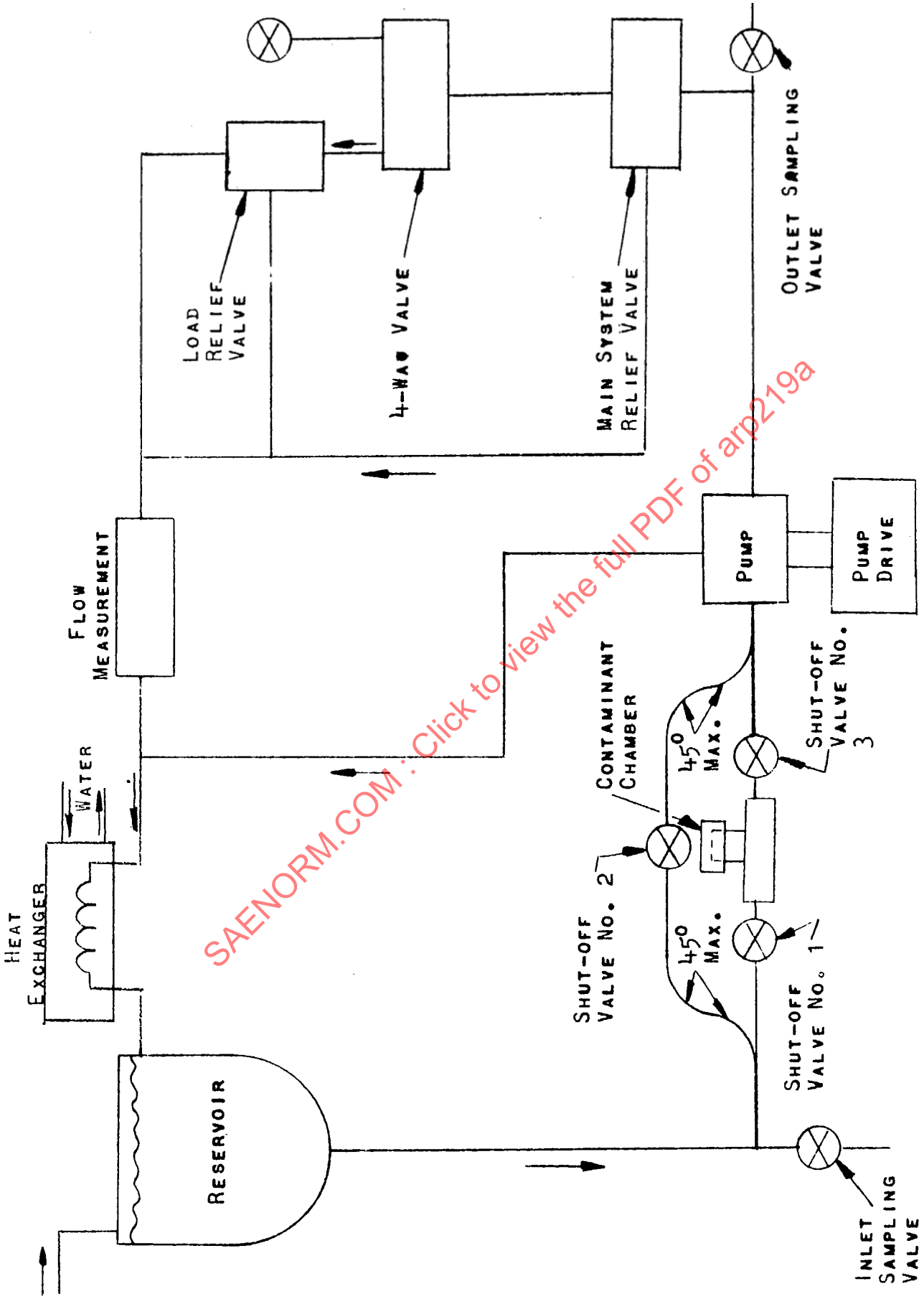

FIGURE 1 (CLASS A) PUMPS

HYDRAULIC CIRCUIT FOR CONTAMINATION CONTROLLED TESTS