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Technical Note 196

REPORT OF THE INVESTIGATION OF SLOW-FLOW METERS FOR FUEL OIL DISTRIBUTION SYSTEMS

D. R. MACKAY

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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Contents

Report of the Investigation of Slow-Flow Meters for Fuel Oil Distribution Systems

Donald R. Mackay

A recent development in the retail distribution of fuel oil to individual residences and to mobile homes involves the use of small, slow-flow meters. A technical investigation was conducted by the Office of Weights and Measures to develop testing equipment and test procedures that could be used to evaluate the accuracy characteristics of these meters. This report describes the testing systems and test procedures that were developed, as well as the data that were obtained during the course of the investigation.

1. Introduction

A new method of distributing fuel oil from a single central storage facility to a number of individual residences has recently been developed by fuel oil distributors. This method involves the delivery of fuel through distribution lines to individual homes where small meters (figure 1) are installed to measure the flow of fuel as actually consumed by the burner. This system of oil distribution is most suitable for new housing developments and trailer parks where the installation costs can be held to an economically feasible level. This type of fuel-oil distribution system seems rapidly to be gaining acceptance throughout the country because of the reported advantages of the system: (1) the elimination of individual home storage tanks, (2) the reduction of oil deliveries, (3) the elimination of the need for fuel inventories in individual homes, and (4) the simplification of billing procedures.

A so-called "slow-flow" meter is a commercial measuring device because the indications of fuel flow provided by the meter are used as the basis for charging a home owner for the oil consumed by his burner. The State of Pennsylvania requested assistance from the Office of Weights and Measures, National Bureau of Standards, in evaluating the commercial application and operation of such meters, in August of 1962. Representatives of several meter companies also contacted the Office of Weights and Measures for technical advice and assistance.

A technical investigation of slow-flow meters was initiated by OWM in September 1962 (1) to devise one or more satisfactory testing systems with all of the necessary control and indication elements, (2) to develop specific testing procedures, (3) to determine the accuracy of various commercially available meters of this type, and (4) to develop technical requirements that could be recommended to the Committee on Specifications and Tolerances of the National Conference on Weights and Measures. This report will be concerned with the first three objectives of this investigation.

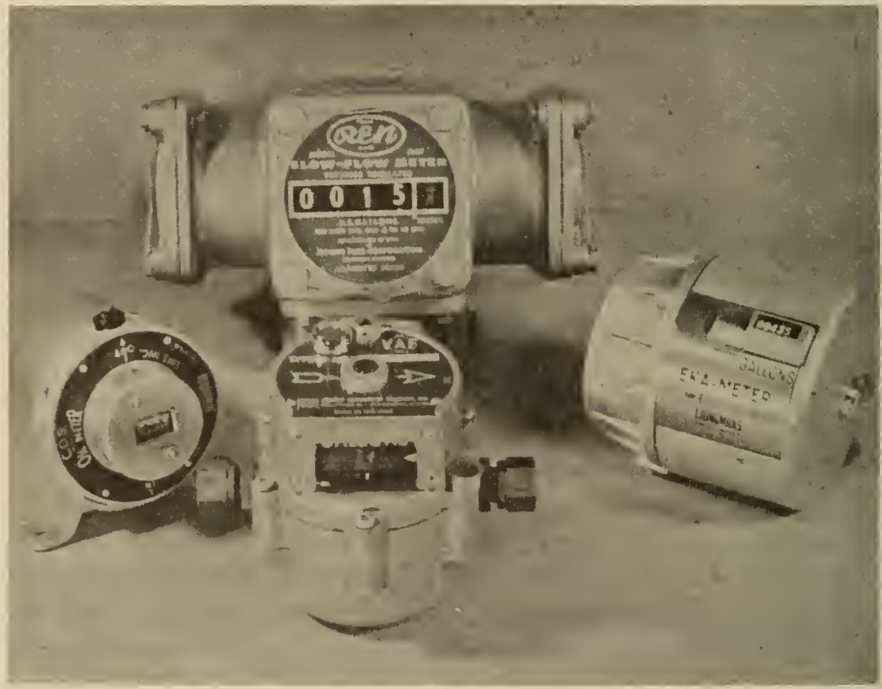

Figure 1. Four Slow-Flow Meters.

Four slow-flow meters were available when the study began; two were made in the United States and two in Europe. All were piston-type, positive-displacement meters--three with single, double-acting pistons, and one with four pistons.

2. Test Conditions

It was decided in advance that the tests of meter accuracy would be conducted under conditions as similar as practicable to actual service conditions. For this reason a careful study was made to determine the probable applications for these meters. It was learned that the meters would be used to measure kerosene flow to pot-type burners such as space heaters in mobile homes, garages, and utility buildings, and to measure No. 2 fuel oil flowing to gun-type burners in residences and larger buildings. It was also learned that systems utilizing gravity flow from overhead storage tanks would be installed, as well as systems utilizing pumps to deliver fuel from underground tanks.

2.1. Test Fluids

Since kerosene, because of its low flashpoint, creates a hazardous environment when used for testing purposes in normal laboratories, Stoddard Solvent (varsol) was chosen as a simulant for kerosene. Stoddard Solvent is a petroleum distillate with a minimum flashpoint of 100°F and a minimum boiling point of 358°F. The product is normally used as a drycleaning solvent and for the wet-cleaning of metal parts. It has physical properties approximating those of kerosene with the exception of the flashpoint. The varsol used in this investigation conformed to the requirements of the Federal Specification P-S-66b and Commercial Standard CS3-40.

No. 2 fuel oil was used during the tests conducted to approximate the conditions in which the meters would be used to measure flow of fuel to gun-type burners. This fuel-oil product, with a rather high flashpoint, is relatively safe to use in a laboratory where normal safety precautions are observed.

2.2. Test Flow Rates

It was determined, through a review of commercial literature, that the flow rates encountered in the operation of kerosene-fired pot-type burners may vary from 0.01 to 0.05 gallon per hour (gph) for pilot flow rates, and from 0.50 to 1.0 gph for heating flow rates. It was decided that the tests would include both low and high flow rates; thus a minimum test flow rate of 0.05 gph and a maximum test flow rate of 1.0 gph were chosen for the majority of the tests simulating the measurement of kerosene for pot-type burners.

It was also determined through study of commercial literature that flow rates encountered in the operation of gun-type burners using No. 2 fuel oil may vary from 0.5 gph to approximately 2.5 gph. Thus, it was decided that the tests simulating the measurement of No. 2 fuel oil to gun-type burners would generally be conducted at flow rates of 1.0 and 2.0 gph.

2.3. Test Line Pressure

Line pressures in systems utilizing slow-flow meters may vary from 4 or 5 pounds per square inch, gage (psig), the minimum pressure developed in gravity flow systems, to 25 or 30 psig, which could be created in systems employing pumps. Most of the slow-flow meters available were designed to operate under pressures of from less than 2 psig to approximately 35 psig. It was decided that a pressure of 10 psig would be used throughout the investigation, since it appeared from the design of the meters that accuracy would be virtually unaffected by any pressure differences within this range.

2.4. Special Test Conditions

Initially it was felt that, in order to duplicate actual operating conditions, tests would have to be conducted which involved both pilot and heating flow rates for pot-type burners and on-off cycling of the flow rates for gun-type oil burners. These so-called "intermittent" tests were conducted using a timeclock-controlled solenoid valve. In the varsol tests, a pilot flow rate of 0.05 gph and a heating rate of 1.0 gph were used generally. These intermittent tests were conducted with a cycle of either one or two minutes at the heating rate followed by one minute at the pilot flow rate. For the No. 2 fuel oil tests, a cycle of one or two minutes at the 2.0 gph rate followed by one minute of zero-flow was employed.

Special tests were also conducted to determine the effect of low temperature on the accuracy of the meters, since meters in certain localities would be subject to low winter temperatures. These tests were conducted in a controlled-temperature chamber. Approximately 20 feet of tubing from the test panel was coiled within the box (2 feet x 2 feet x 3 feet) to provide exposure to the 0°F (±4°F) air temperature before the test fluid entered the meter, which was mounted within the control chamber. The measuring flask was also situated in the low-temperature environment, to permit measurement of the fluid in the flask at the same temperature as the measurement

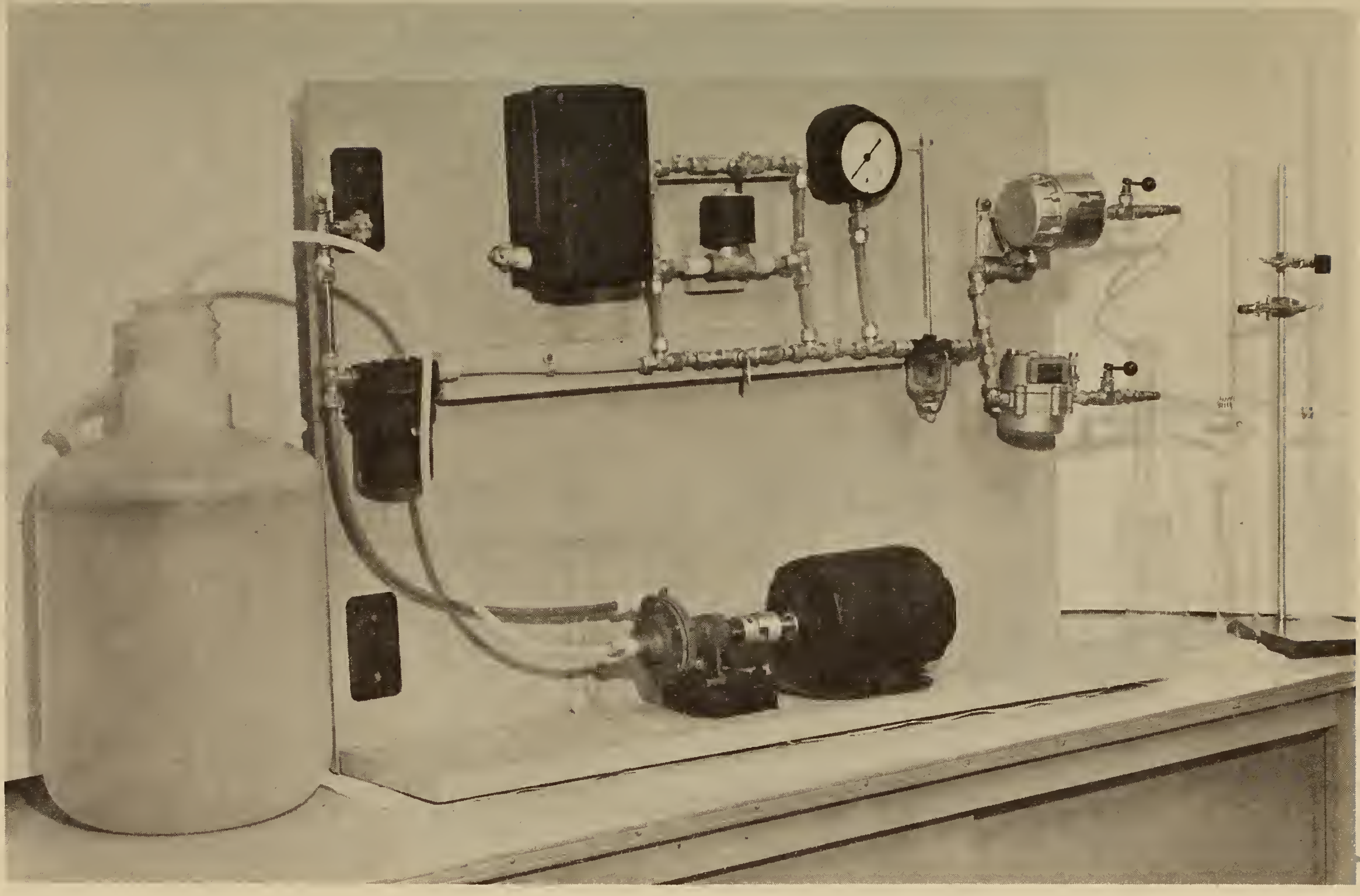

Figure 2. Test Panel Using Pump and Motor.

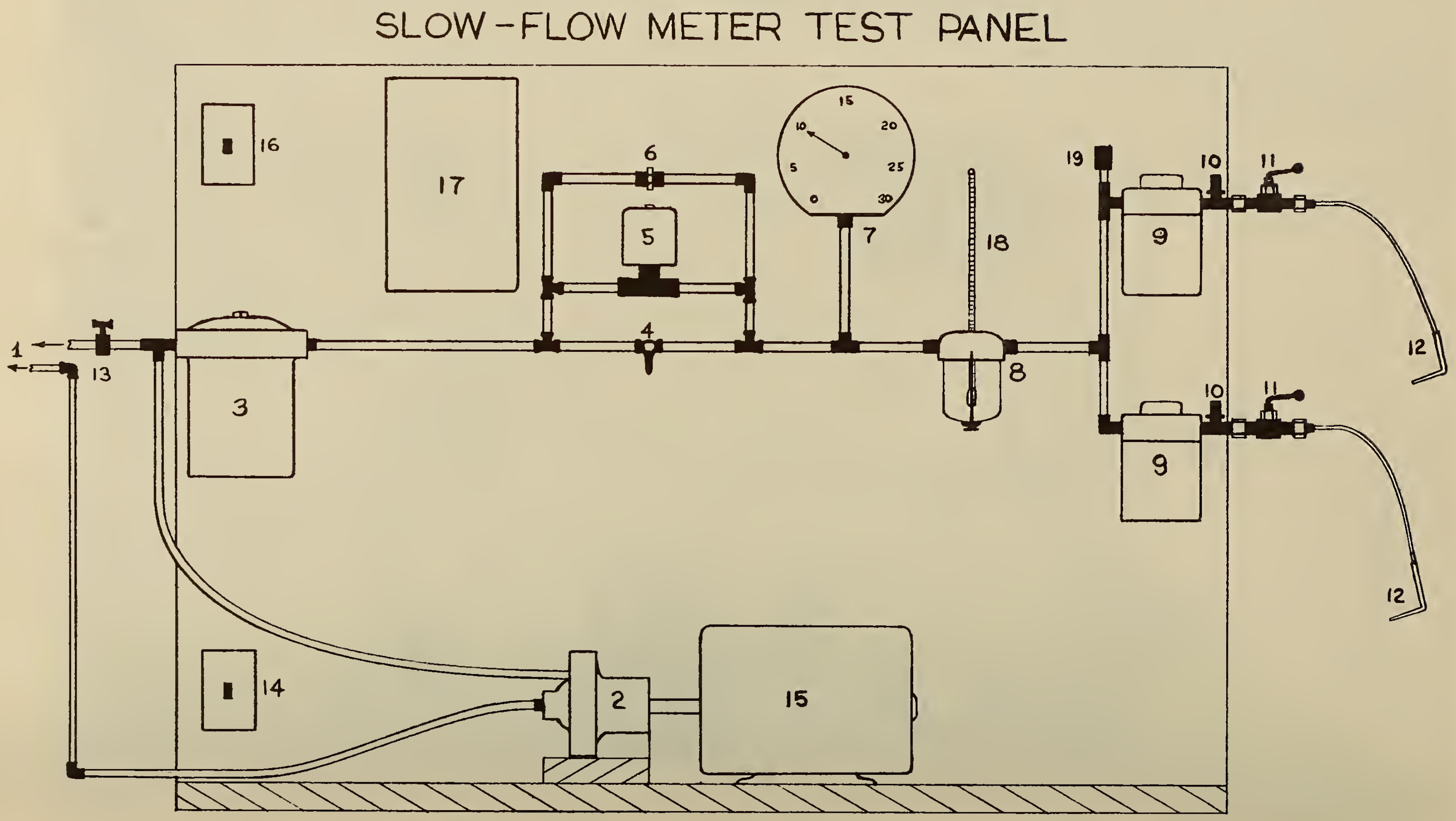
SLOW-FLOW METER TEST PANEL
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Figure 3

of the fluid by the meter. Varsol was used throughout the low-temperature tests, as it was recognized that it would provide a more difficult measurement situation than the No. 2 oil under similar conditions.

3. Test Equipment

A test panel was designed to include all of the control mechanisms that were deemed necessary to conduct performance tests on the meters. The equipment was assembled in a manner that duplicated, as nearly as practicable, actual meter-installation conditions.

The test-panel equipment, as shown photographically in figure 2 and schematically in figure 3, included: (1) a polyethylene carboy to provide a 5-gallon supply of test fluid, (2) a centrifugal pump to provide flow under pressure, (3) a filter to remove any foreign particles from the test fluid, (4) a two-way globe valve to control flow rates, (5) a solenoid valve controlled by a timeclock (17) to provide intermittent flows, (6) a needle valve to control pilot flow rates, (7) a pressure gage to indicate line pressures, (8) a thermometer well to provide liquid temperature, (9) the meter under test, (10) a needle valve to control the flow rate on the outlet side of the meter, (11) a toggle valve to start and stop each test, (12) a glass nozzle to limit the drainage of test fluid from the lines on the downstream side of the meter, (13) a bypass valve to control line pressure, (14) an electrical switch to control the pump operation, (15) an electric motor to power the pump, (16) an electrical switch to energize the solenoid valve circuit, and (17) a timeclock to control the operation of the solenoid valve, (18) a mercury thermometer to observe fluid temperature, and (19) an air-bleed valve to remove entrapped air. The bypass valve was adjusted to provide 10 psig in the system.

Another testing system, involving a tank pressurized by a source of compressed air (figure 4), was later substituted for the pump system. This provided noise-free testing and is to be recommended for use wherever a source of compressed air is readily available. (This system does not necessarily eliminate the need for the pump, as the test liquid must be returned to the supply tank from time to time.)

A third system utilizing gravity flow from an overhead storage tank was not attempted, due to lack of necessary ceiling height. Such a system is entirely feasible where a sufficient height is available to provide the required head pressure.

4. Test Standards

Volumetric standards were used to measure accurately the amount of liquid delivered by each meter during the tests. These standards were glass flasks, with graduated necks, and ranged in size from 1 gill to 1 gallon--the same type flasks as those recommended for use in checking the contents of packaged liquid commodities. The flasks were obtained from a glass apparatus supply company and were calibrated by the Mass and Volume Section of the National Bureau of Standards and reported to be well within the tolerances established for such glassware.

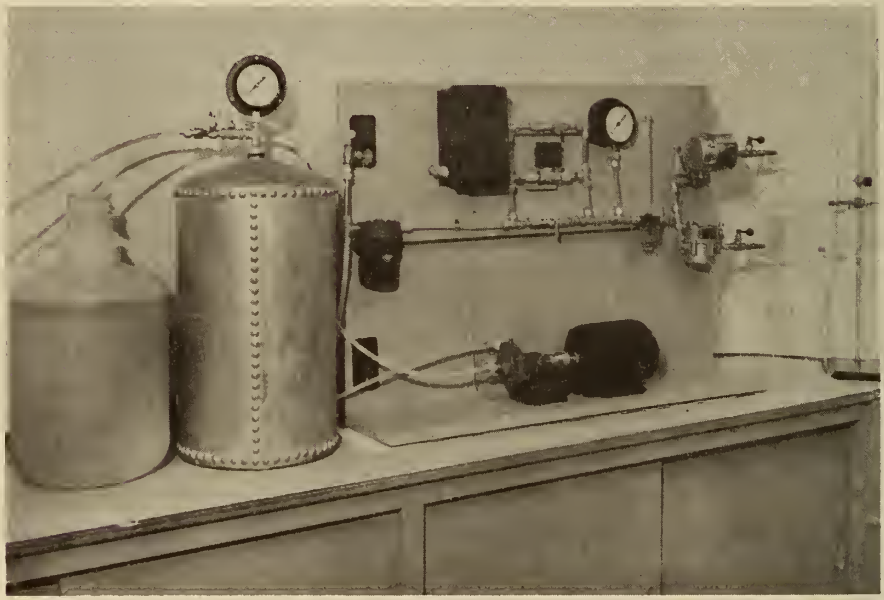

Figure 4. Test Panel Using Compressed Air.

In order to determine precisely the meter error during each test, a 120-minim measuring buret with 1-minim graduations, and a 1-ounce measuring buret with 10-minim graduations were utilized. The liquid measured by the meter and delivered into the flask usually produced a meniscus between two flask graduations. Sufficient measured liquid was then introduced from the buret to raise the meniscus to the next higher graduation. The meter error was then determined to the nearest minim.

The standards were calibrated "to deliver" with a 10-second drain period, which was observed throughout the tests. All glassware was wetted and drained prior to use, rinsed daily with suitable solvents, and washed weekly with a detergent for laboratory glassware.

5. Test Procedures

The test procedures, as refined experimentally and used throughout the majority of the tests, are described in detail in Appendix I. The test volume selected for the various tests was generally equal to at least four times the minimum volume that could be measured and indicated by the meter. It was found that in the case of meters with a large minimum visual indication, such as 0.1 gallon, a long period of time was required to conduct the tests at the lower flow rates. It was determined, through a thorough study of the design and operation of certain of these meters, that a distinct audible signal was produced by the measuring mechanism at the end of each measurement cycle--a volume equal to a half or a quarter of the visibly indicated interval. Thus, it became possible to reduce the volume and the time of the test through the use of these audible signals from certain meters.

6. Test Results

The results of the tests conducted at room temperature using varsol as a substitute for kerosene are summarized in Appendix II. The information shown includes a meter identification number, the flow rate, the test volume, and the average error in percentage of test volume. It can be seen from the data that the average errors at the pilot flow rates were generally positive, indicating underregistration of the meter, while the average errors at the heating flow rates were generally negative, indicating overregistration. Also, it can be seen that the average errors at the pilot flow rate were considerably larger than the errors at the heating flow rates. The average error for all pilot flow rate tests was +2.33 percent, while the average error for all heating flow rate tests was -0.36 percent.

The results of the tests conducted using No. 2 fuel oil at room temperatures, summarized in Appendix III, demonstrate that the average errors observed at the lower flow rates were generally in the direction of underregistration, while those observed at the higher flow rates were generally in the direction of overregistration. The average error for all tests conducted at flow rates approximating 1 gph was +0.11 percent, while the average error for all tests conducted at flow rates approximating 2 gph was -0.06 percent. It can also be seen from the data that the meter errors with No. 2 fuel oil were considerably smaller than those with varsol.

The results of the intermittent tests which were conducted using varsol indicated that these are unnecessary if tests are conducted at both the pilot and heating flow rates. The intermittent tests conducted using No. 2 oil provided results which also clearly indicated that such tests were unnecessary under normal circumstances. These results are found in Appendix IV.

The tests at low temperatures using varsol as the test fluid were conducted on only one meter from each manufacturer. The results of these tests, found in Appendix V, indicate there is very little apparent difference in meter performance between the results at low temperature and those at room temperature.

7. Conclusions

The results clearly indicate that the majority of the meters performed quite accurately. Errors in only two of the thirteen meters tested were greater than 1.0 percent at flow rates above 0.05 gph. (It should be pointed out, however, that three meters, each of different manufacture, originally included in the investigation were found to have unreasonably large errors, indicating a defective assembly, a malfunctioning component, or an improperly manufactured part. These meters were removed from the test series and returned to the manufacturer or supplier, and the data obtained through the use of these meters were eliminated from the test results.)

The results also indicated that neither low-temperature nor intermittent tests are normally necessary if a meter is tested at both maximum and minimum flow rates.

It was obvious that any one of the three testing systems would be entirely satisfactory--the pump system, the pressure tank system, or the gravity flow system.

The testing panel and specific procedures employed during the tests to determine the accuracy of the slow-flow meters proved to be entirely satisfactory.

8. Recommendations

The design of the test panel, as shown schematically in figure 3, is recommended as being satisfactory for testing slow-flow meters.

The specific test procedures listed in Appendix I are suggested for use with the panel in conducting tests of the accuracy of slow-flow meters.

The use of calibrated glass test measures and measuring burets is recommended. The ratio of the size of the test measure to the minimum delivery indication (visible or audible) of the meter should be at least four to one.

The author wishes to acknowledge the assistance received from 1) J. H. Griffith, Division 17.0, for conducting the tests, 2) M. W. Jensen, Division 17.0, for his guidance and contributions, and 3) the various companies that provided the meters and technical information concerning their meters.

Appendix I

Test Procedures

Pre-Test Operations

1. Position meters as per manufacturer's instructions.
2. Eliminate air from system by bleeding line and meters.
3. Obtain 10 psig line pressure under test flow conditions.
4. Adjust flow rate of liquid through meters under test.
5. Wet test measures, and drain for 10-second period.
6. Stop flow when meter indication reaches desired test starting point.
7. Run one preliminary test to check and stabilize all conditions.

Test Procedures

1. Record initial meter reading, meter number, and test number.
2. Start fluid flow and stopwatch simultaneously.
3. Record liquid temperature during first quarter of test.
4. Check flow rate and pressure; adjust if necessary.
5. Determine end-of-test meter reading.
6. Record liquid temperature during last quarter of test.
7. Stop fluid flow and stopwatch at end of test.
8. Record final meter reading and apparent error.
9. Use buret to determine actual error in minims.
10. Record actual error in minims.

Appendix II

Summary of Varsol Tests

Meter No.	Flow Rate	Volume	Average Error[1]	Number of Tests
	(gal/hour)		(percent)	
12	1.4	1 pint	-0.4	2
12	0.05	1 gill	+4.8	2
13	1.2	1 pint	-0.14	7
13	0.05	1 gill	+1.93	5
14	1.2	1 pint	+0.34	2
14	0.05	1 gill	+1.31	6
32	0.9	1 quart	-0.31	3
32	0.05	1 quart	+4.0	1
33	1.0	1 quart	-0.34	6
33	0.05	1 quart	-0.24	1
34	1.0	1 quart	-1.17	9
34	0.05	1 quart	+8.61	2
41	1.0	1 quart	-0.33	4
41	0.05	1 quart	+1.68	2
42	1.0	1 quart	-0.58	3
42	0.05	1 quart	+0.12	2
43	1.0	1 quart	-0.28	5
43	0.05	1 quart	+0.66	2
44	1.0	1 quart	-0.34	3
44	0.05	1 quart	+0.65	2

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[1] Error as percent of nominal test draft--minus (-) figures indicate meter overregistration, plus (+) figures indicate underregistration.

Appendix III

Summary of No. 2 Oil Tests

Meter No.	Flow Rate (gal/hour)	Volume	Average Error (percent)	Number of Tests
12	2.3	1 pint	0.00	7
12	1.0	1/2 pint	+0.04	4
13	2.6	1 pint	-0.15	7
13	1.0	1/2 pint	+0.05	7
14	2.0	1 pint	+0.20	13
14	1.3	1/2 pint	+0.08	7
14	0.7	1/2 pint	+0.36	8
21	3.6	1 gallon	+0.12	2
21	1.5	1 quart	+0.37	2
22	2.1	1 gallon	+0.15	3
22	0.7	1 quart	+0.11	2
32	1.0	1 quart	+0.10	3
33	1.9	1 quart	-0.37	3
34	2.0	1/2 gallon	-0.47	3
41	1.9	1/2 gallon	-0.36	3
41	1.0	1 quart	-0.16	3
42	1.9	1/2 gallon	-0.18	3
42	1.1	1 quart	+0.05	2
43	1.9	1/2 gallon	+0.30	3
44	1.8	1/2 gallon	+0.18	3


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Appendix IV

Summary of Intermittent Tests

Varsol

Meter No.	Flow Rates	Time Interval	Volume	Average Error	Number of Tests
	(gal/hour)	(min.)		(percent)	
12	0.75	1	1/2 pint	+0.57	5
	0.05	1			
32	1.0	1	1 quart	-0.22	3
	0.05	1			
33	1.0	1	1/2 gal.	-0.42	3
	0.05	1			
43	1.0	1	1 quart	-0.31	4
	0.05	1			
44	1.0	1	1 quart	-0.41	3
	0.05	1			

No. 2 Oil

12	1.4	2	1 quart	-0.10	6
	0	1			
14	1.4	2	1 pint	+0.18	8
	0	1			
21	1.2	1	1 quart	-0.11	3
	0	1			
22	1.1	1	1 quart	-0.03	2
	0	1			
32	1.0	1	1 quart	+0.23	6
	0	1			
33	1.0	1	1 quart	-0.06	3
	0	1			
43	1.1	2	1 quart	-0.06	5
	0	1			
44	1.1	1	1 quart	-0.09	5

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THE NATIONAL BUREAU OF STANDARDS

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Appendix V

Summary of Low Temperature Tests--

Varsol Fluid

Meter No.	Flow Rate (gal/hour)	Fluid Temperature	Volume	Average Error (percent)	Number of Tests
12	2.0	5°F	1 pint	+0.50	4
	1.0	4°F	1 quart	+0.06	3
	0.05	0°F	1 pint	+3.62	2
21	6.0	30°F	1 quart	+0.48	3
	2.0	30°F	1 quart	+0.46	3
	0.5	20°F	1 pint	+0.50	6
34	2.0	27°F	1 quart	+0.94	5
	1.0	15°F	1 quart	+9.73	3
43	2.0	7°F	1 quart	+0.76	2
	1.0	10°F	1 quart	-0.01	4
	0.05	7°F	1 quart	-0.01	2

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