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WORLDWIDE EXPERIENCE WITH SMALL VOLUME PROVERS

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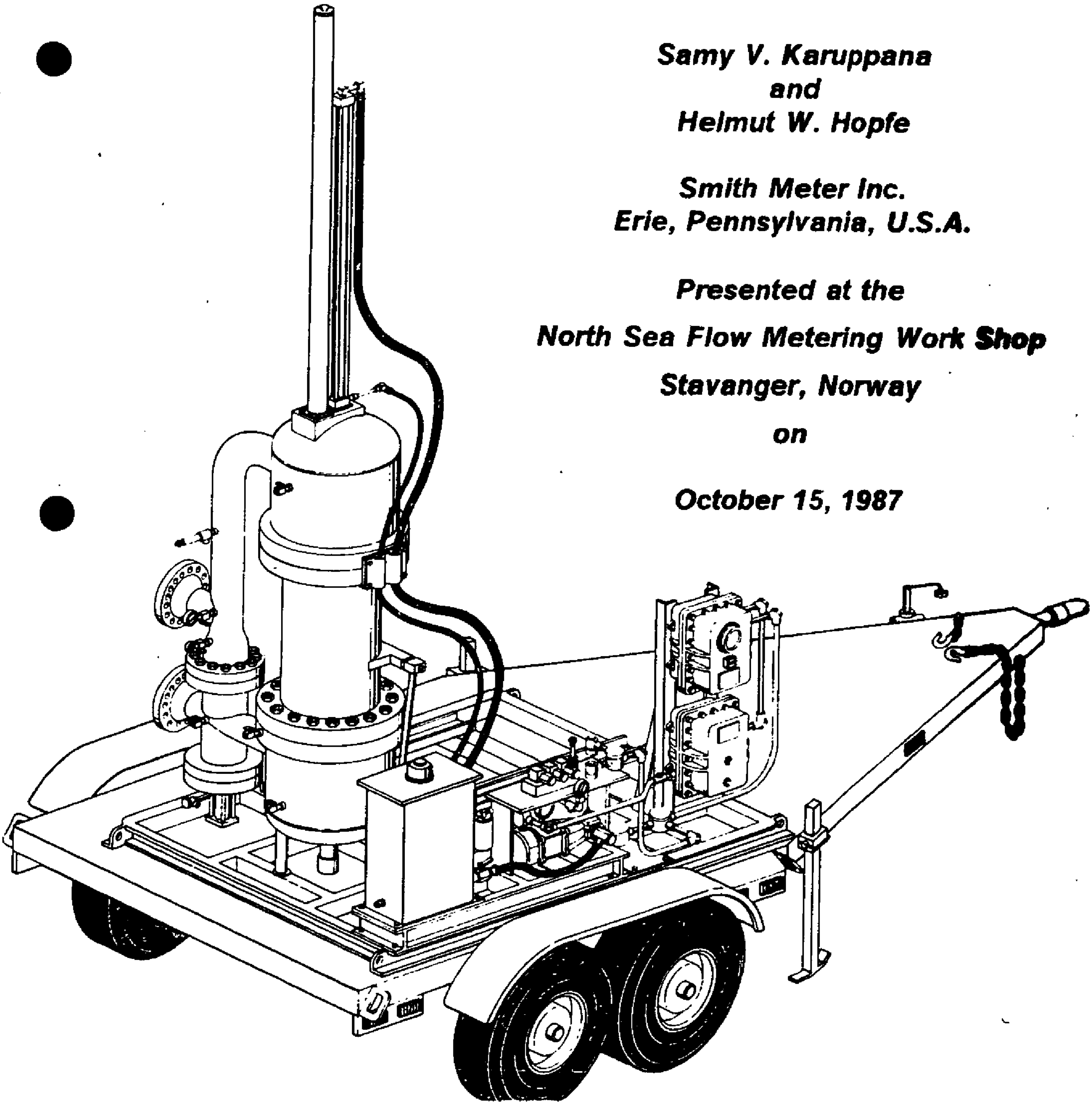


SUMMARY

This paper discusses some of Smith Meter's worldwide experience with small volume provers. Accuracy, repeatability, reliability, cost, safety requirements and approvals, and weights and measures approvals are subjects of discussion in this paper.

INTRODUCTION

At present, throughout the world, small volume provers are being accepted as one of the standard pieces of equipment for calibrating liquid flow meters. The universal acceptance of small volume provers is relatively new and the industry is continuing to learn more about their application.

ACCURACY

Waterdraw Test Measures

The absolute accuracy of the volume of an SVP is only as good as the test measure used to calibrate the SVP. Table 1 shows the typical uncertainty of waterdraw test measures used in practice today. Figure 1 shows a 15 gallon test measure typically used in the U.S.A., designed and manufactured by Seraphin Test Measure Company and calibrated by the National Bureau of Standards. Figure 2 shows a 57 liter (42 gallons) test measure typically used in the Federal Republic of Germany, designed and manufactured by Smith Meter GmbH and calibrated to PTB (Physikalisch-Technische Bundesanstalt) standards by local weights and measures authorities. There are many reasons for the uncertainty in the U.S.A.'s measure being ten times higher than the test measure used in the Federal Republic of Germany, and it is beyond the scope of this paper to discuss those reasons in detail. Manufacturers, regulatory agencies, and users throughout the world are working together to design, calibrate, and use test measures with the least uncertainty to ge: .he best possible measurement accuracy.

COUNTRY OF ORIGIN	***VOLUME DELIVERED***	***ESTIMATED UNCERTAINTY***
U.S.A.	*14.9959 Gallons at 60°F.*	*+/- 1.08 cu.in. (+/- .031%)*
U.S.A.	*41.9924 Gallons at 60°F.*	*+/- 3.6 cu.in. (+/- .037%)*
FED. REP. OF GERMANY	*57 L (15 Gallons) at 20°C.*	*+/- 2 ml (+/- .004%)*
FED. REP. OF GERMANY	*159 L (42 Gallons) at 20°C.*	*+/- 5 ml (+/- .003%)*

Table 1: Typical Uncertainty of Waterdraw Test Measures

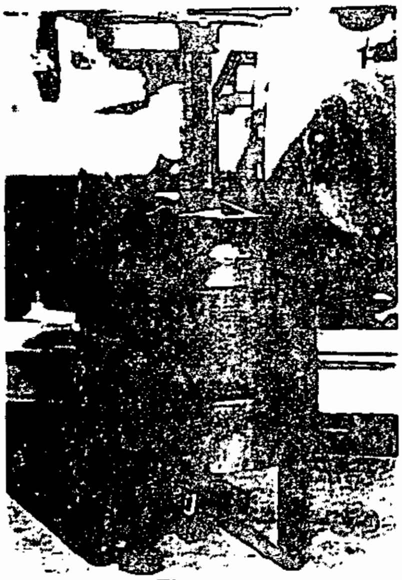


Figure 1

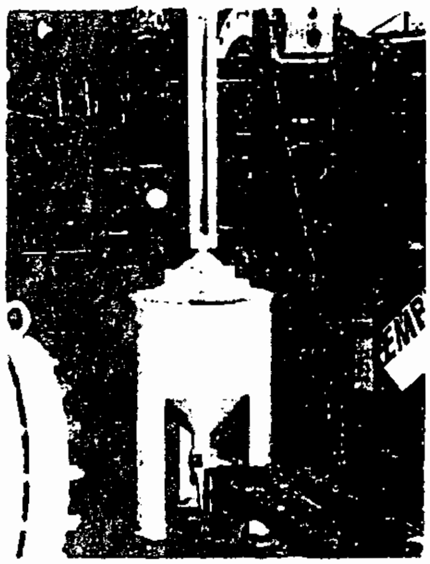


Figure 2

Temperature Effect During Waterdraw Calibration

It is commonly known that a reliable calibration of any prover, conventional ball prover or small volume prover, requires stabilized temperature conditions. Therefore, the water is circulated multiple times through the prover before calibration, during which time the ambient and water temperatures must remain constant. The purpose of this procedure is to minimize the temperature difference between the prover's hardware (pipe) and the water if the ambient temperature deviates from the temperature of the test liquid used for calibration (see Figure 3).

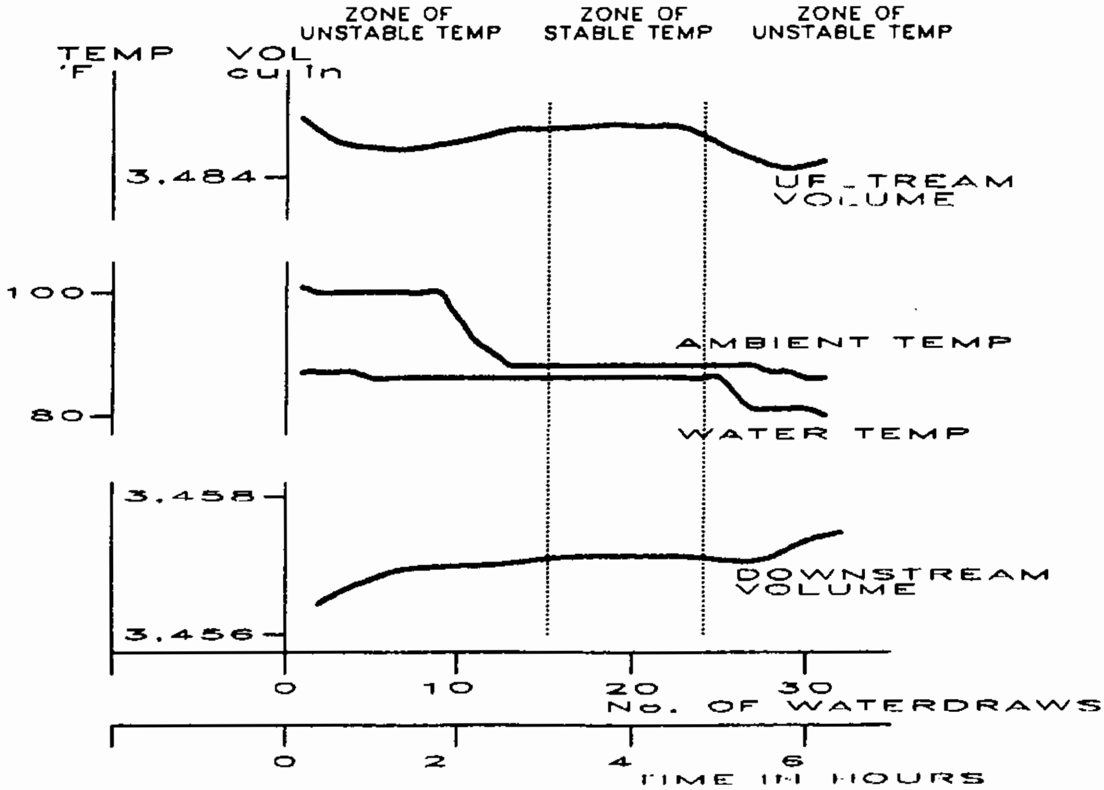


Figure 3

The calibration of an SVP is more significantly affected by temperature difference, that is ambient temperature versus water temperature, in comparison with conventional provers. The reasons for this are the natures of the SVP's design and operation. The more stringent temperature requirements for SVP calibration can be explained as follows:

1. Detector Rod Expansion or Contraction

   Most SVP's feature a detector rod connected with the displacer and extended through a journal bearing externally to the prover vessel. This kind of arrangement exposes the detector rod partially to ambient and partially to water, the liquid generally used for calibration. The degree of exposure to either medium is a function of the displacer's position. At waterdraw velocity, approximately .001 to .01 ft./sec., the rod's exposure changes constantly. If the ambient temperature differs from the water temperature, the rod is either contracting or expanding during the calibration process. This causes the rod's target flag (used to actuate the detector switches) to travel faster or slower than the prover's displacer, resulting in faulty calibration. Therefore, the ideal temperature condition during calibration is established when the ambient temperature is equal to the water temperature. A temperature difference up to 5°F may be acceptable based on test data and the following example.

   Example of calibration error:

Stroke of Detector Rod:	27.25"
Dia. of Measurement Section:	12.75"
Volume:	15 Gallons
Water Temperature:	T°F
Ambient Temperature:	T° +/-5°F

   $\text{delta } L_{Det.\ Rod}$ = L x delta T x linear coefficient of thermal expansion of rod
   $\text{delta } L_{Det.\ Rod}$ = 27.25 inch x 5°F x .0000063 inch/inch°F
   $\text{delta } L_{Det.\ Rod}$ = .00086 inch

   The rod's expansion or contraction of .00086 inch is equivalent to a calibration uncertainty of +/-0.11 cu.in., or +/-.0032%. The results may vary, depending on the prover's nominal volume and the actual distance between the detector switches.

2. Expansion or Contraction of Prover's Piping

   In general, SVP's require more metal per unit of calibration volume compared to conventional provers, necessitating a longer time for temperature stabilization. The total calibration error due to non-stabilized temperature conditions is a superimposition of the following:

   - Volume error due to expansion or contraction of the SVP's piping
   - Volume error due to expansion or contraction of the detector rod.

   Calibration values achieved at different temperature conditions (Figure 3) indicate that the magnitude of error due to unstable piping temperature is much greater than the computable error due to length changes of the detector rod. Recommended practice is to bring the water temperature to be within +/-5°F of the ambient temperature.

Temperature Effect During Meter Proving

What is the impact on meter factor accuracy due to expansion and contraction of detector rod and piping when product temperature is different from ambient temperature? The theoretical analysis and experiments indicate that no noticeable error due to this expansion or contraction phenomenon exists when proving at normal flow range. For example, let us study the data in Table 2. The ambient temperature during these tests was 75°F. Hence, the temperature difference between ambient and product varied from 11.7°F to 29.6°F. But, in all these conditions, the meter factors derived from the SVP agree with meter factors derived from the conventional prover. At these flow rates, the proving time is short and, hence, there is not sufficient time to expand or contract.

The effect of this phenomenon at very low flow rates is under study now. A well insulated prover and other means, which keep the detector rod very close to the product temperature, will eliminate this concern. The results of this study will be published in a future technical paper.

Effect of Using Flexible Hoses

The application of hoses to facilitate the connection of an SVP to a flow meter run may result in unreliable meter factors and decreased repeatability values. The magnitude of the meter factor errors is influenced by the following:

- pressure rating of hose
- length of hose
- line pressure
- hose arrangement

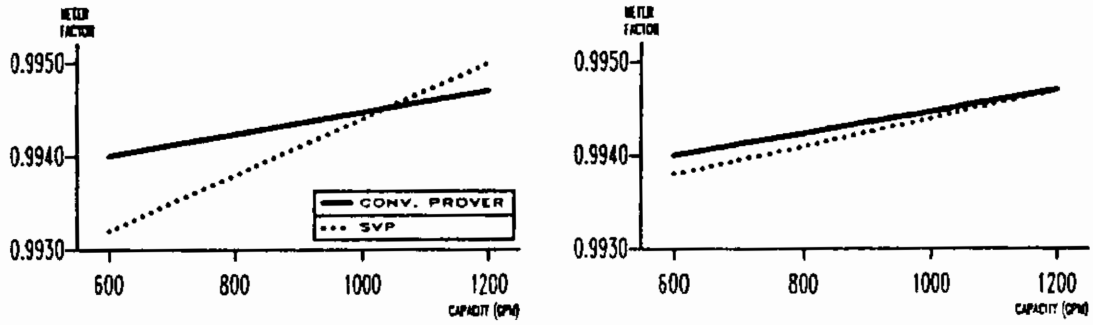
To determine the impact of this error, actual tests were performed using an SVP with the following arrangements:

A. SVP interconnected with hoses
B. SVP interconnected with hard piping.

In addition, a conventional ball prover was installed in series with the SVP and the flow meter to establish meter factors under identical conditions.

Test Conditions:

Test Arrangement:	See Figure 5
SVP Type:	15 Gallon Volume, 12.75″ Bore
Conventional Prover Type:	Unidirectional Ball Prover, Volume 2,269.5 Gallons
Meter Type:	6″ P.D. Meter, Non-Cyclic
Test Liquid:	Kerosene
Product Pressure:	35 PSIG @ 600 GPM, 50 PSIG @ 1200 GPM
Product Temperature:	39 to 42°F
Flow Rates:	600 GPM and 1200 GPM
Type of Hose:	6″ Fuel Discharge Hose, 6″ I.D., 6.781″ O.D., 16′ Long Applied Upstream & Downstream to SVP, 150 PSI Max. W.P.



Test Arrangement A with hoses

Test Arrangement B with hard piping

Figure 4

As Figure 4 indicates, when hard piping is used, the meter factors derived using an SVP and a unidirectional prover were almost identical. Whereas, when hoses are used, the meter factor derived using an SVP is off as much as 0.1%. Hence, the need to use hard piping is more critical in an SVP application than that of a large conventional prover.

REPEATABILITY

A typical SVP is a very repeatable piece of equipment. It is common practice to expect, when proving a meter, a system repeatability of .05% or better for five consecutive runs.

Many of the commonly used meters, positive displacement meters with various accessories and even some turbine meters, may not meet these requirements. Decreasing the cyclic output of the meter has been the focus of attention. For turbine meters, controlling the manufacturing tolerance produced meters with acceptable non-cyclic output. The situation is much more complex for P.D. meters. A combination of (1) redesign, e.g., eliminate "Hooks" type coupling, (2) tight manufacturing tolerances, e.g., more uniform gears, (3) changes in operating procedure, e.g., application of electronic meter factor correction, (4) changes in proving procedure, e.g., group proving, may provide satisfactory performance.

Figure 5 shows a test setup used to study the repeatability and meter factor accuracy of an SVP proving versus conventional proving. Table 2 summarizes the results of a turbine meter test. Table 3 summarizes the results of a P.D. meter test. The following conclusions can be derived from Tables 2 and 3.

- Repeatability of .05% or better can be achieved by 5 consecutive proving runs.
- Meter factor agreement of .05% or better can be achieved between SVP proving and conventional proving using 5 consecutive runs.
- Two groups of ten consecutive runs produces much improved correlation between meter factors.

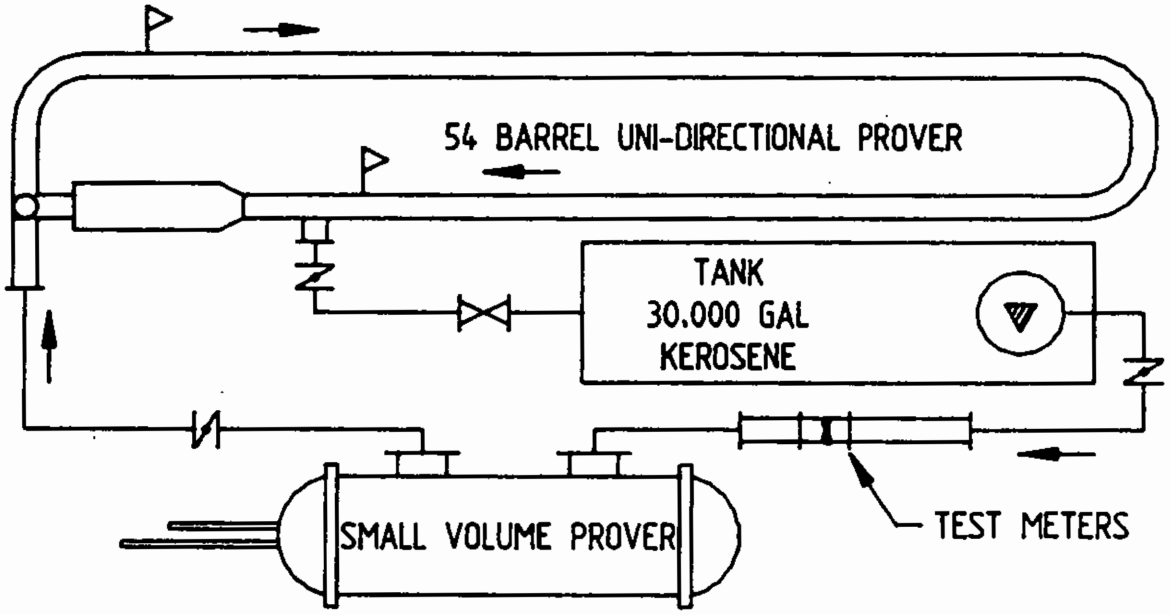


Figure 5: SVP vs. Unidirectional Prover Test Arrangement

FLOW RATE (BPH)	PROVER TYPE	TEMP. DEG.F	SVP - 2 GROUPS OF 10 CONS. RUNS UNI - 3 CONSECUTIVE RUNS			SVP - 5 CONSECUTIVE RUNS UNI - 3 CONSECUTIVE RUNS		
			REPEAT. (%)	METER FACTOR	DEVIATION (%)	REPEAT.(%) 5 CONS. RUNS	METER FACTOR	DEVIATION (%)
TEST #1								
1,484	SVP	86.7	.0073	1.0075	0	.0090	1.00768	.018
	Unidirect. Prover	87	.0132	1.0075		.0132	1.00750	
TEST #2								
7,103	Unidirect. Prover	101	.0132	1.0060	0	.0132	1.00600	.007
	SVP	102.8	.0000	1.0060		.0400	1.00593	
TEST #3								
7,103	Unidirect. Prover	103.5	.0099	1.0060	0	.0099	1.00600	.008
	SVP	104.6	.0067	1.0060		.0479	1.00608	

54 Barrel Unidirectional Prover, 42 Gal. SVP, 10" Smith Sentry Series Turbine Meter Test Setup per Figure 5.

Table 2: SVP3 Repeatability & Accuracy Test

FLOW RATE (BPH)	PROVER TYPE	TEMP. DEG.F	SVP - 10 CONSECUTIVE RUNS UNI - 3 CONSECUTIVE RUNS			SVP - 5 CONSECUTIVE RUNS UNI - 3 CONSECUTIVE RUNS		
			REPEAT. (%)	METER FACTOR	DEVIATION (%)	REPEAT.(%) 5 CONS. RUNS	METER FACTOR	DEVIATION (%)
TEST #1								
867	SVP	37.5	.0245	.9957	.02	.0079	.99564	.014
	Unidirect. Prover	39.5	.0303	.9955		.0303	.99550	
TEST #2								
1,656	SVP	42	.0192	.9984	.01	.0133	.99837	.007
	Unidirect. Prover	42.5	.0220	.9983		.0220	.99830	

54 Barrel Unidirectional Prover, 15 Gal. SVP, 6" Smith Non-Cyclic P.D. Meter Test Setup per Figure 5.

Table 3: SVP1 Repeatability & Accuracy Test

RELIABILITY

This subject can be subdivided into two categories. The first category is the reliability of the mechanical, hydraulic, and electronic hardware, and the computer software. The second category is the reliability of the calibration data derived from the use of the SVP. Like many new products, the SVP experienced some reliability problems during its initial stage. Now, most of these problems have been recognized, understood, and corrected. The longevity of the main displacer seal has been significantly improved by using improved seal material, refining the details of mechanical design, and operating the prover in a vertical position when the product is not clean.

The new generation of SVP's has the means to monitor all seals, including the main displacer seals, and bypass valve seals during each proving cycle, which helps to improve the reliability of data obtained from SVP proving. There are hundreds of small volume provers in all parts of the world. With few exceptions, all these provers are functioning reliably.

COST

Cost is a very important factor in buying and using a particular piece of equipment to perform a useful service. Figure 6 shows a cost comparison between small volume provers and conventional bidirectional provers. The graphical presentation shows that the initial cost of a small volume prover is slightly higher than the conventional bidirectional prover. The size, weight, ability to prove at very low flow rates, and compatibility to a wide range of products are some of the reasons that small volume provers are preferred.

Small volume provers have more parts and complex mechanisms than conventional provers. Hence, the maintenance cost of a typical small volume prover may be higher than a conventional prover.

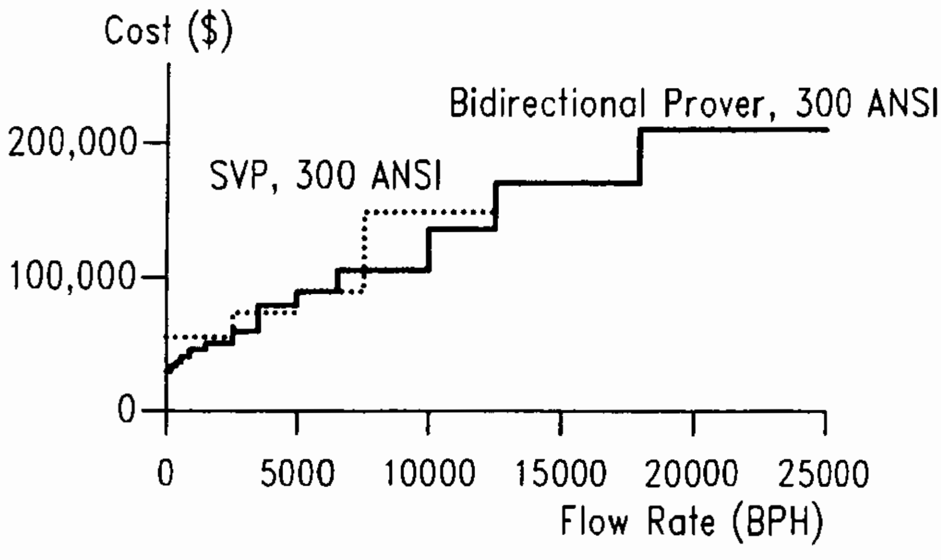


Figure 6: Small Volume Prover Cost

SAFETY REQUIREMENTS AND APPROVALS

This subject can be subdivided into two categories. The first category is the safe use of an SVP as a pressure vessel. The second category is the electrical safety, that is, the safe use of an SVP in hazardous locations. What are the requirements? What are the design codes, manufacturing procedures, and Quality Assurance standards to be met? What are the regulatory approvals required?

Tables 4, 5, and 6 show some typical examples of current practices related to SVP safety requirements and approvals. Currently, SVP's are being accepted based on meeting appropriate pressure vessel codes and the use of electrical components which are approved individually. So far, there is no market demand necessitating an electrical safety approval of the SVP as a system. The acceptance of design codes for pressure containing parts and the type of approval required for electrical components varies from country to country.

GEOGRAPHICAL AREA	TYPE OF CODE	REMARKS
North America	*Standard: ANSI B31.4.* *Option: ANSI B31.3 and others.*	*Accepted in U.S.A., Canada, Australia, and South America.*
Federal Republic of Germany	*Standard: According to Specifications of "AD-MERKBLAETTER", to TUEV standards.* *Option: - TRBF.* *- ASME Certified by TUEV.* *- Other European Pressure Vessel Codes.*	*Generally Accepted throughout the European Community.*

Table 4: SVP Pressure Vessel Requirements, Codes, and Approvals

GEOGRAPHICAL AREA	TYPE OF APPROVAL	REMARKS
North America	*Standard: UL, FM, or CSA.*	
Federal Republic of Germany	*Standard: UL.* *Option: CENELEC (including flexible cable interconnection of electrical components).*	

Table 5: SVP Electrical Safety Approvals

GEOGRAPHICAL AREA	TYPE OF APPROVAL	REMARKS
North America	*Exemption Notice #DOT-E9728 U.S. Government Department of Transportation Office of Hazardous Materials Transportation.*	*This issue is under review by DOT.*

Table 6: United States Department of Transportation Requirements for SVP

WEIGHTS AND MEASURES APPROVALS

The SVP is a calibration device used to calibrate meters and large provers which are used in commerce as standards of measurement. Hence, almost all SVP's are subject to the approval of the weights and measures authorities. Generally, weights and measures are controlled by government agencies. Each country has its own agency and, hence, manufacturers and users must obtain weights and measures approval from each country where the prover will be used. Generally, there has been no problem in obtaining weights and measures approval. Table 7 shows some typical examples of current practices related to SVP weights and measures approvals.

GEOGRAPHICAL AREA	**TYPE APPROVAL**	**REMARKS**
North America	*No type approval required. The SVP's calibration is considered to be verified through its traceability to test measures certified by NBS (National Bureau of Standards) and CCA (Consumer and Corporate Affairs, Canada).*	*Accepted in Canada, Australia, and South America.*
Federal Republic of Germany	*PTB - Certificate Issued. Waterdraw traceable to Federal Republic of Germany national standards.*	
Netherlands	*Weights and Measures Acceptance Test complete.* *- Certificate to be issued.*	
Norway	*Weights and Measures Acceptance Test complete.* *- Certificate to be issued.*	
United Kingdom	*Weights and Measures Certificate issued.*	

Table 7: SVP Weights and Measures Approvals

CONCLUSION

In this paper, the authors shared with you some of Smith Meter Inc.'s worldwide experience in designing, manufacturing, and operating small volume provers. Our experience indicates that the SVP is a very useful device and further enhancements, which are now underway, will make it even better.

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.