

NRC Publications Archive Archives des publications du CNRC

**Calibration of turbine flowmeter Fischer & Porter 10C1510 S/N 901
1B2098/1/B1 / Calibration d'un débitmètre à turbine Fischer & Porter
10C1510, S/N 9011B2098/1/B1**
Grabe, W.; Carvish, J.

For the publisher's version, please access the DOI link below./ Pour consulter la version de l'éditeur, utilisez le lien DOI ci-dessous.

Publisher's version / Version de l'éditeur:

<https://doi.org/10.4224/40003586>

*Calibration Analysis and Test Report (National Research Council Canada.
Institute for Mechanical Engineering); no. IME-MET-CAT-007, 1992-07*

NRC Publications Archive Record / Notice des Archives des publications du CNRC :

<https://nrc-publications.canada.ca/eng/view/object/?id=02d05185-7c15-4134-a5c8-c57a9d17c2f7>

<https://publications-cnrc.canada.ca/fra/voir/objet/?id=02d05185-7c15-4134-a5c8-c57a9d17c2f7>

Access and use of this website and the material on it are subject to the Terms and Conditions set forth at

<https://nrc-publications.canada.ca/eng/copyright>

READ THESE TERMS AND CONDITIONS CAREFULLY BEFORE USING THIS WEBSITE.

L'accès à ce site Web et l'utilisation de son contenu sont assujettis aux conditions présentées dans le site

<https://publications-cnrc.canada.ca/fra/droits>

LISEZ CES CONDITIONS ATTENTIVEMENT AVANT D'UTILISER CE SITE WEB.

Questions? Contact the NRC Publications Archive team at
PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca. If you wish to email the authors directly, please see the
first page of the publication for their contact information.

Vous avez des questions? Nous pouvons vous aider. Pour communiquer directement avec un auteur, consultez
la première page de la revue dans laquelle son article a été publié afin de trouver ses coordonnées. Si vous
n'arrivez pas à les repérer, communiquez avec nous à PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca.



**National Research
Council Canada**

Institute for
Mechanical Engineering

Machinery and
Engine Technology

**Conseil national
de recherches Canada**

Institut de
génie mécanique

Technologie des
machines et des moteurs

**DECLASSIFIED
DÉCLASSIFIÉ**

NRC-CMRC

**Calibration of Turbine Flowmeter
Fischer & Porter 10C1510
S/N 9011B2098/1/B1**

W. Grabe and J. Carvish

Calibration Analysis
and Test Report

1992/07

CONTROLLED
UNCLASSIFIED

Rapport d'étalonnage
d'analyse et d'essai

IME-MET-CAT-007

CONTRÔLÉE
NON CLASSIFIÉE

Canada

INSTITUTE FOR MECHANICAL ENGINEERING PUBLICATIONS

- DM (Institute for Mechanical Engineering Report)**
Scientific and technical information considered important, complete and a lasting contribution to existing knowledge.
- TR (Technical Report)**
Information less broad in scope, but a substantial contribution to existing knowledge.
- CTR (Controlled Distribution or Security Classified Technical Report)**
A technical report with controlled distribution for national security industrial, proprietary or other reasons.
- LM (Laboratory Memorandum)**
Preliminary or exploratory information with controlled distribution.
- CAT (Calibration Analysis and Test Report)**
Information on minor laboratory projects or services.

PUBLICATIONS DE L'INSTITUT DE GÉNIE MÉCANIQUE

- DM (Rapport de l'Institut de génie mécanique)**
Informations scientifiques et techniques jugées importantes, complètes et susceptibles de contribuer de façon durable à l'avancement des connaissances courantes.
- TR (Rapport technique)**
Informations de moindre importance, mais pouvant contribuer substantiellement à l'avancement des connaissances actuelles.
- CTR (Rapport technique à distribution contrôlée ou classification sécuritaire)**
Rapport technique à distribution contrôlée pour des raisons de sécurité nationale, de propriété intellectuelle et autres.
- LM (Mémoire de laboratoire)**
Informations préliminaires ou de nature exploratoire à distribution contrôlée.
- CAT (Rapport d'étalonnage d'analyse et d'essai)**
Informations sur de petits projets ou des services de laboratoire.

W. GRABE



National Research
Council Canada

Conseil national
de recherche Canada

Institute for
Mechanical Engineering

Institut de
génie mécanique

Machinery and
Engine Technology

Technologie des
machines et des moteurs

DECLASSIFIED
DÉCLASSIFIÉ

CALIBRATION OF TURBINE FLOWMETER
FISCHER & PORTER 10C1510
S/N 9011B2098/1/B1

W. Grabe and J. Carvish

Calibration Analysis
and Test Report

1992/07

CONTROLLED
UNCLASSIFIED

Rapport d'étalonnage
d'analyse et d'essai

IME-MET-CAT-007

CONTRÔLÉE
NON CLASSIFIÉE

CONTROLLED
UNCLASSIFIED

DECLASSIFIED
DÉCLASSIFIÉ

CONTROLÉE
NON-CLASSIFIÉE

**CALIBRATION OF TURBINE FLOWMETER
FISCHER & PORTER 10C1510, S/N 9011B2098/1/B1**

**CALIBRATION D'UN DÉBIMÈTRE A TURBINE
FISCHER & PORTER 10C1510, S/N 9011B2098/1/B1**

W. Grabe, J. Carvish

Institute for Mechanical Engineering
Calibration Analysis
and Test Report

Institute de génie mécanique
Rapport d'étalonnage
d'analyse et d'essais

IME-MET-CAT-007

G. Krishnappa, Head/Chef
Machinery and Engine Technology Program
Programme de technologie des machines et des moteurs

Copy/Copie 7

ABSTRACT

A turbine flowmeter, Model 10C1510, Serial Number 9011B2098/1/B1, made by Fischer & Porter Company, Warminster, PA, has been calibrated for Hawker Siddeley Canada INC., Orenda Division. Besides the flowmeter calibration results, with some comments, the report contains a brief description of the calibration facility, and a delineation of expected uncertainties, based on NRC and external calibrations.

RÉSUMÉ

Le débitmètre à turbine, modèle 10C1510, portant le numéro de série 9011B2098/1/B1, fabriqué par Fischer & Porter Company, PA, a été étalonné pour le compte de la société Hawker Siddeley Inc., Orenda Division. Le présent rapport renferme, outre les résultats de l'étalonnage et certaines observations, une description de l'installation utilisée pour l'étalonnage et les marges d'erreur prévues se fondant sur des étalonnages effectués au CNRC et par un organisme indépendant.

CONTENTS

		Page
	ABSTRACT	i
	RÉSUMÉ	ii
	LIST OF FIGURES	iii
1.0	INTRODUCTION	1
2.0	DESCRIPTION OF CALIBRATOR	1
3.0	CALIBRATION UNCERTAINTY	2
4.0	FLOWMETER CALIBRATION	3
5.0	COMMENTS	4
6.0	REFERENCES	5
	Documentation Page	

LIST OF FIGURES

Figure

1	Omnitrak Ballistic Flow Calibrator Installation	6
2	Calibration Sheet	7
3	Calibration Plot, K-factor vs. Frequency/Viscosity	8

CALIBRATION OF TURBINE FLOWMETER

Fischer & Porter 10C1510, S/N 9011B2098/1/B1

1.0 INTRODUCTION

The Machinery & Engine Technology Program, Institute for Mechanical Engineering, is the custodian of an Omnitrak ballistic calibrator, designed specifically for the calibration of turbine-type flowmeters. After a period of several years, in which the calibrator had been exclusively used for NRC meter calibrations, the service is now extended to include outside clients. A high degree of accuracy is ensured by periodic internal calibrations, traceable to Canadian standards, and by participation in calibration programs, such as the one carried out by the National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards (NBS), Gaithersburg, MD.

This report contains a description of the calibration facility, the expected uncertainty, with traceability, and the test procedure. The test results for the client's flowmeter are presented in tabular form, and the K-factor, corrected for temperature and pressure effects, is plotted as a function of frequency over kinematic viscosity.

2.0 DESCRIPTION OF CALIBRATOR

The flowmeter has been calibrated on an Omnitrak calibrator system, Model OT-150, S/N 83110022, manufactured by EG&G Flow Technology Inc. (formerly Flow Technology, Inc.) Phoenix, AZ [Fig. 1]. It is a very precise volumetric calibration device, a detailed description of which can be found in the supplier's manual (FTI 1982). To facilitate electronic data storage, custom print-outs, plotting, and some further data reduction, the output was interfaced to a Digital Equipment Corporation MicroVAX II computer.

A summary of pertinent specifications is:

- Flow Range: 0.15 to 150 USGPM or 0.0095 to 9.5 l/s
(approximately 60 to 60,000 lbm/h of aviation fuel)
- Flowmeter Size Range: 1/2" to 1½" (13 to 38 mm)
- Flowmeter Assembly
Maximum Length: 48" (1219 mm) between 1½", 37° flared tube fittings.

Although various fluids may be used, it was decided to perform all calibrations with MIL-C-7024C, Type II, the widely accepted calibrating fluid for aircraft fuel system components. Its specified viscosity is 1.17 ± 0.05 Cst ($1.17 \pm 0.05 \cdot 10^{-6}$ m²/s) at 25°C.

3.0 CALIBRATION UNCERTAINTY

When considering the accuracy, or uncertainty, of a calibration, the whole system must be taken into account, and that includes the meter itself. It is obvious that a turbine flowmeter with worn bearings or damaged blades will not lend itself to accurate, repeatable performance. Hence, as a basis for a good calibration, it must be assumed that the test specimen is functioning to specifications.

The Omnitrak calibrator was factory-calibrated when bought. The volumetric resolution, or K-factor, for this model, was specified as approximately 62,200 pulses per US gallon (PPG). Prior to delivery, the actual calibration constant for this particular calibrator was established by the manufacturer as 62,202 PPG. A careful recalibration by the former Engine Laboratory yielded an Omnitrak K-factor of 62,213 PPG (Grabe and Carvish 1988). In two calibration tests, each consisting of eight water draws, the averaged K-factors, reduced to standard conditions, came to within 0.5 PPG, or $\pm 0.0008\%$, of each other. A check revealed that the K-factor increased systematically along the draw tube of the calibrator by 0.08%, well within the manufacturer's specified limit of 0.1%.

Over the course of some 120 calibrations, on 15 in-house turbine flowmeters, the manufacturer's claimed repeatability of $\pm 0.05\%$ was confirmed, i.e., with few exceptions, calibration points fell within $\pm 0.05\%$ of a best-fit curve.

Finally, the former Engine Laboratory, now incorporated into the Machinery & Engine Technology Program, participated in a round-robin calibration program conducted by the National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards (NBS), Gaithersburg, MD. This program was primarily in response to requests by the Department of Defence (US), industrial users, and manufacturers. The data were evaluated by NIST by means of Youden plots (Mattingly 1988). At the high flow point, which yielded more consistent results all around, NRC had a bias, or systematic, error of 0.18% with respect to the median of all calibrators. When compared only with calibrators of the same principle as the Omnitrak, i.e. meter pulse counts related to volume displacement, the bias error was 0.05%. The precision error was less than 0.05% in either case. This good agreement with the median of 12 other major North American calibrators, including two from NIST, was considered to be a confirmation of the accuracy of NRC's calibration equipment and procedures. It is the intention of NRC to maintain the established link with NIST and continually test the accuracy of its flowmeter calibrator by participation in future calibration programs.

On the basis of the above described uncertainty analyses, the bias error of the calibration, relative to the true value, is expected to be within $\pm 0.18\%$, with a precision error of $\pm 0.05\%$, yielding a combined overall uncertainty of $\pm 0.28\%$ ¹.

¹The uncertainty establishment and terminology follows Abernethy, R.B., et al., 1973.

4.0 FLOWMETER CALIBRATION

Information pertinent to the calibration reported:

Job No.: FMC-92-09

Calibration Date: 24 July 1992

Customer: Hawker Siddeley Canada Inc., Orenda Division

Flowmeter Data

Make/Model: Fischer & Porter 10C1510

Size: 1 1/2"

Serial No.: 9011B2098/1/B1

Pickoff Type: Carrier

Pickoff Part No.: 9011B2098/1/B1

Bearing Type: Ball

Calibration Fluid: MIL-C-7024C, Type II

Relative Density (15.56/15.56°C): 0.7779

Fluid Temperature (Ave.), °C: 23.2

Viscosity at Fluid Temperature, Cst: 1.2516

Room Temperature (Ave.), °C: 20.7

Operating Pressure, psig: 80.0

Kpa: 552

The flowmeter was visually inspected for any possible damage and installed in the calibrator with NRC-supplied tubing, which consisted of a 36-inch straight inlet tube and a 12-inch straight outlet tube. The F&P oscillator/preamplifier was supplied by the client. The client requested calibration over the (flow) range of approximately 2.0 to 125 gpm, which could be accommodated. In order to provide a good calibration curve definition, a total of 20 points was established, two of which were repeats [Fig. 2]. The calibration proceeded, from the highest flow to the lowest, followed by the repeat points. The room and fluid temperatures were averaged from readings taken at every calibration point. Both

temperatures appear in the correction of the K-factor. In addition, the fluid temperature was used for the calculation of its viscosity. A display of each calibration point on an uncorrected universal plot on the control CRT, immediately after it had been generated, provided a good visual assessment of the calibration as it progressed. Finally, the raw and reduced data were printed out as given in Figure 2.

The K-factor, K_{cor} , has been corrected from the standard pressures and temperatures of the Omnitrak calibration to those actually present at the meter calibration (Grabe 1991). As a visual aid in assessing the repeatability and linearity of the calibration, the K-factor has been plotted against frequency divided by the average viscosity of the calibration fluid [Fig. 3]. This plot is commonly referred to as the universal viscosity curve, an indispensable tool in the accurate assessment of flow.

A complete description of the application of the K-factor, and other components of fuel flow measurement by a turbine flowmeter, has been given by Grabe (1988). That report also includes an uncertainty analysis for a complete fuel flow measuring system. Depending on a series of conditions, it has been demonstrated that an overall system uncertainty of $\pm 1.0\%$ of corrected flow is achievable, taking into consideration uncertainties in relative density (specific gravity) and net heat of combustion (lower heating value) establishments, among other factors.

5.0 COMMENTS

With regard to the calibration FMC-92-09 of the Fischer & Porter Model 10C1510 turbine flowmeter, S/N 9011B2098/1/B1, owned by Hawker Siddeley Canada Inc., Orenda Division, the following comments can be made:

- The calibration points formed a smooth curve on the universal viscosity plot [Fig.3].
- Points were within $\pm 0.02\%$ of a best-fit curve over the whole range of the universal curve.
- Repeatability of the meter was very good in that the repeat points were within 0.01% of each other at the high end of the flow and 0.04% at the low end.
- The linearity of the flowmeter, i.e. the maximum deviation of any K-factor from the mean value, was $\pm 0.51\%$ over the total 60:1 range of the calibration, and $\pm 0.45\%$ over a 10:1 turndown ratio.
- No unusual symptoms of the meter were observed during calibration.

6.0 REFERENCES

Abernethy, R.B., et al., Thompson, J.W., Jr. 1973. Revised 1980. Handbook, Uncertainty in Gas Turbine Measurements. Engine Test Facility, Arnold Engineering Development Center, Air Force Systems Command, Arnold AFS, TN.

Grabe, W., and Carvish, J. 1988. Calibration of an FTI Omnitrak Ballistic Flow Calibrator System, National Research Council Canada, Engine Laboratory, TR-ENG-002.

Grabe, W. 1988. Fuel Flow Measurement in Gas Turbine Testing, National Research Council Canada, Engine Laboratory, TR-ENG-001.

Grabe, W. 1991. Turbine Flowmeter Calibration, National Research Council Canada, Engine Laboratory, CAT-ENG-013.

Installation, Operation and Maintenance Manual Omnitrak. October 1982. Flow Technology, Inc., 4250 East Broadway Road, Phoenix, AZ 85040.

Mattingly, G.E. 1988. A Round Robin Measurement Testing Program Using Hydrocarbon Liquids: Results for First Phase Testing. US Department of Commerce, National Institute of Standards and Technology (formerly National Bureau of Standards), National Engineering Laboratory, Center for Chemical Engineering, Fluid Flow Group, Chemical Process Metrology Division, Gaithersburg, MD 20899, NISTIR 88-4013.

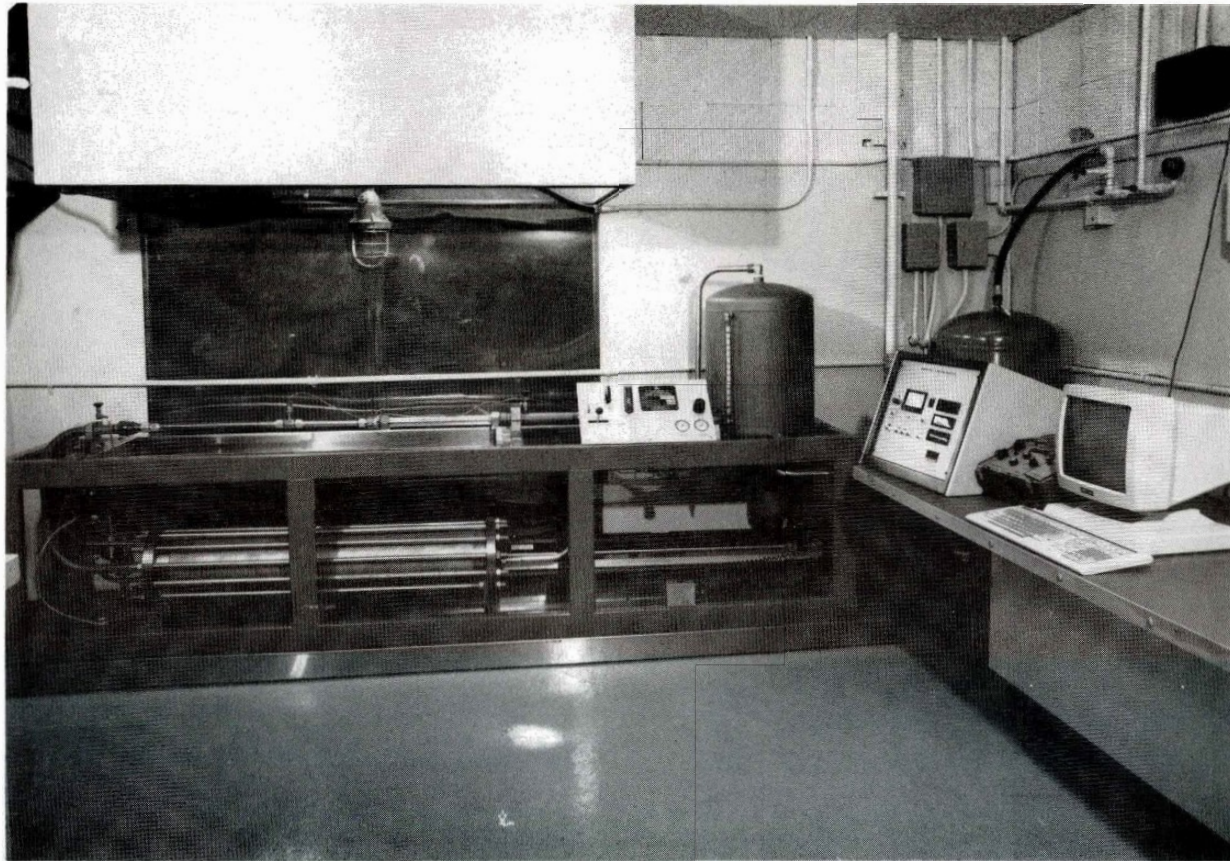


FIG. 1 OMNITRAK BALLISTIC FLOW CALIBRATOR INSTALLATION

NATIONAL RESEARCH COUNCIL CANADA
INSTITUTE FOR MECHANICAL ENGINEERING

TURBINE FLOWMETER CALIBRATION

FIG.2

Customer: HAWKER SIDDELEY CANADA
Date: 24-JUL-92

Job #: FMC-92-09

CALIBRATOR DATA

Make: Flow Technology Omnitrak Model: OT-150 S/N: 83110022
Calibrator System
Microtrak Constant: 62213 Volume Unit: U.S. Gallon
Calibration Fluid: MIL-C-7024C, Type 2
Specific Gravity(15.56/15.56 Deg.C): 0.7779
Fluid Temperature (Average)[Deg. C]: 23.16
Viscosity [cSt] : 1.2516
Room Temperature (Average)[Deg. C]: 20.67 Operating Pressure [Psi]: 80.00

FLOWMETER DATA

Make/Model : Fischer & Porter 10C1510 Size : 1 1/2 Inch
S/N : 9011B2098/1/B1 Pickoff Type: CARRIER
Pickoff P/N: 9011B2098/1/B1 Bearing Type: Ball

RUN	T VOL	T FMP	# FMP	VOL	FREQ	F RATE	Kcor	FREQ/VISC
1	0.48170	0.48150	1033.0	1.	2145.4	124.56	1033.3	1714.1
2	0.49700	0.49730	1034.0	1.	2079.2	120.72	1033.2	1661.3
3	0.53240	0.53220	1033.0	1.	1941.0	112.70	1033.2	1550.8
4	0.58540	0.58510	1033.0	1.	1765.5	102.49	1033.4	1410.6
5	0.67030	0.67000	1033.0	1.	1541.8	89.512	1033.3	1231.9
6	0.73640	0.73610	1033.0	1.	1403.3	81.477	1033.3	1121.2
7	0.84150	0.84150	1034.0	1.	1228.8	71.301	1033.8	981.75
8	0.98310	0.98290	1034.0	1.	1052.0	61.031	1034.0	840.52
9	1.2435	1.2431	1034.0	1.	831.79	48.251	1034.2	664.58
10	1.4547	1.4547	1034.0	1.	710.80	41.246	1033.8	567.91
11	1.6907	1.6920	1034.0	1.	611.11	35.488	1033.0	498.26
12	1.9498	1.9493	1032.0	1.	529.42	30.772	1032.1	423.00
13	2.3660	2.3660	1031.0	1.	435.76	25.359	1030.8	348.16
14	2.7820	2.7815	1029.0	1.	369.94	21.567	1029.0	295.58
15	3.5476	3.5480	1027.0	1.	289.46	16.913	1026.7	231.27
16	5.8180	5.8181	1024.0	1.	176.00	10.313	1023.8	140.62
17	12.306	12.307	1024.0	1.	83.205	4.8757	1023.7	66.479
18	28.454	28.447	1024.0	1.	35.997	2.1087	1024.1	28.761
19	28.478	28.488	1025.0	1.	35.980	2.1069	1024.5	28.747
20	0.48680	0.48700	1034.0	1.	2123.2	123.25	1033.4	1696.4

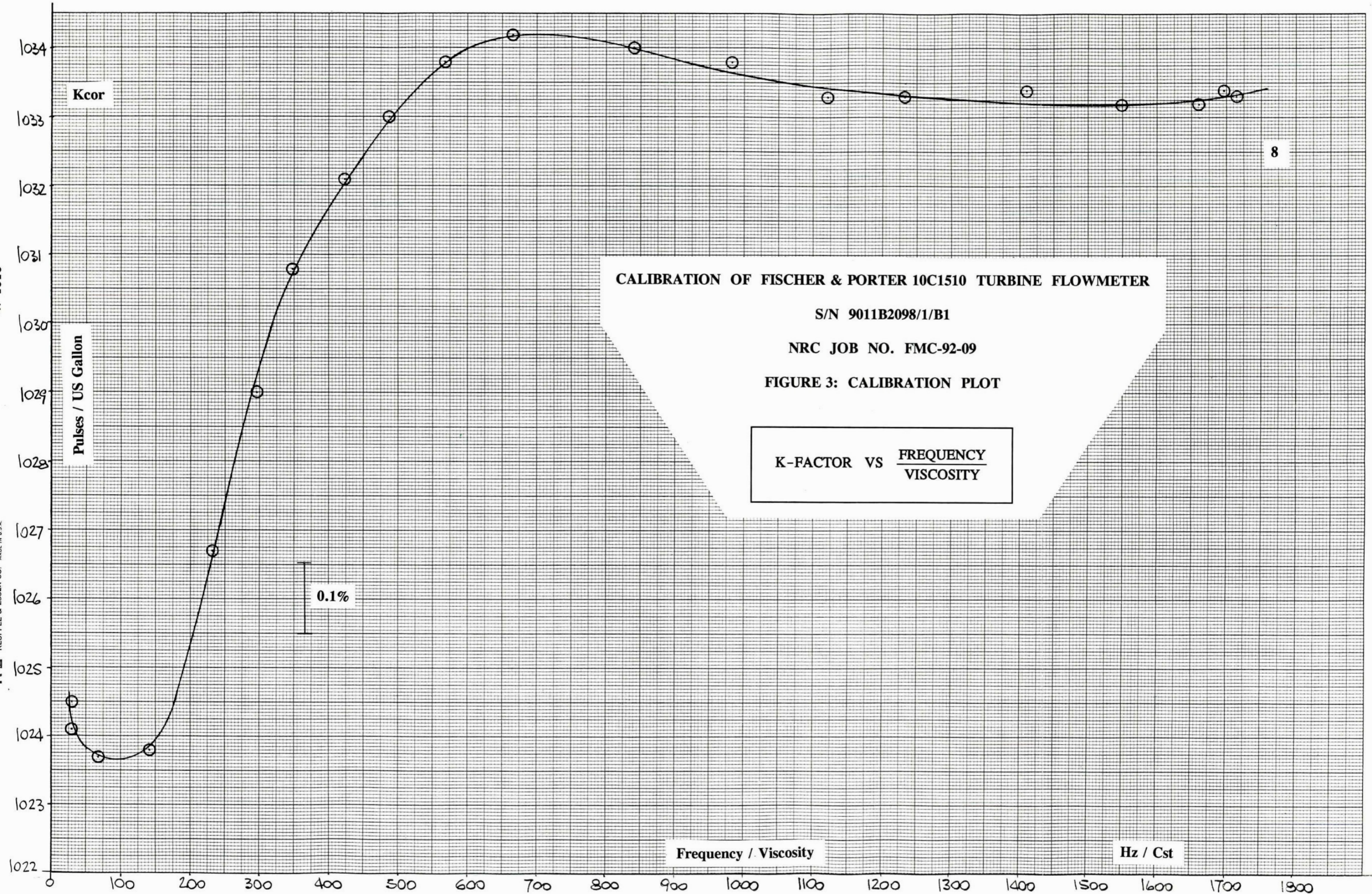
T VOL=Time for Displaced Volume [Sec.] T FMP=Time for Flowmeter Pulses [Sec.]
FMP=Number of Flowmeter Pulses [] VOL=Volume of Fluid Displaced [U.S. Gal.]
FREQ=Frequency of the Flowmeter [Pulses/Sec.] F RATE=Flowrate [U.S. Gal./Min.]
Kcor=K-Factor of the Flowmeter Corrected to Standard Conditions [Pulses/U.S. Gal.]
FREQ/VISC=Frequency Divided by the Viscosity of the Fluid at the Temperature of the Run [Pulses/Sec.*cSt]

Calibrated by: Jim Carrish

Certified by: H. Grabe

47 1510

K&E 10. X 10. TO THE CENTIMETER #25 X 38 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.



REPORT DOCUMENTATION FORM/FORMULAIRE DE DOCUMENTATION DE RAPPORT

REPORT No./ NO DU RAPPORT 1 IME-MET-CAT-007		REPORT No./ NO DU RAPPORT 2		SECURITY CLASSIFICATION/ CLASSIFICATION DE SÉCURITÉ 3 <input type="checkbox"/> Top Secret/Très secret <input type="checkbox"/> Secret <input type="checkbox"/> Confidential/Confidentiel <input type="checkbox"/> Protected/Protégée <input checked="" type="checkbox"/> Unclassified/Non classifiée	
DISTRIBUTION/DIFFUSION <input checked="" type="checkbox"/> Controlled/Contrôlée 4 <input type="checkbox"/> Unlimited/Illimitée					
DECLASSIFICATION: DATE OR REASON/DÉCLASSEMENT: DATE OU RAISON 5					
TITLE, SUBTITLE/TITRE, SOUS-TITRE 6 Calibration of Turbine Flowmeter Fischer & Porter 10C1510, S/N 9011B2098/1/B1					
AUTHOR(S)/AUTEUR(S) 7 W. Grabe and J. Carvish					
SERIES/SÉRIE 8					
CORPORATE AUTHOR/PERFORMING ORGANIZATION/ AUTEUR D'ENTREPRISE/AGENCE D'EXÉCUTION National Research Council of Canada 9 Institute for Mechanical Engineering					
SPONSORING OR PARTICIPATING AGENCY/AGENCE DE SUBVENTION OU PARTICIPATION 10					
DATE 11 1992/07	FILE/DOSSIER 12	SPECIAL CODE/ CODE SPÉCIAL 13	PAGES 14 iii, 8	FIGURES 15 3	REFERENCES 16 6
NOTES 17					
DESCRIPTORS (KEY WORDS)/MOTS-CLÉS 18 Calibration, Turbine Flowmeter, Fuel Flow Measurement					
SUMMARY/SOMMAIRE 19 Describes the calibration of a turbine flowmeter, used in fuel flow measurement, for a client.					
ADDRESS/ADRESSE Dr. G. Krishnappa Machinery and Engine Technology Program Institute for Mechanical Engineering Montreal Road, Ottawa, Canada 20 K1A OR6 (613) 993-9900					