Calibration of turbine flowmeter COX AN 8, S/N 36507 / Calibration d'un débimètre à turbine COX AN 8, S/N 36507

Grabe, W.; Carvish, J.

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Calibration of Turbine Flowmeter COX AN 8, S/N 36507

W. Grabe and J. Carvish

Calibration Analysis and Test Report

Rapport d'étalonnage d'analyse et d'essai

1991/11

IME-MET-CAT-003

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CALIBRATION OF TURBINE FLOWMETER COX AN 8, S/N 36507

CALIBRATION D'UN DÉBIMÈTRE A TURBINE COX AN 8, S/N 36507

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-003

M.S. Chappell, Head/Chef
Machinery and Engine Technology Program
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ABSTRACT

A turbine flowmeter, Model AN 8, Serial Number 36507, made by KETEMA, Schutte & Koerting Division, Cox Instrument, has been calibrated for Standard Aero Limited. 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 débitmetre à turbine, modèle AN 8, portant le numéro de série 36507, fabriqué par KETEMA, Schutte and Koerting Division, Cox Instrument, a été étalonné pour le compte de la société Standard Aero Limited. 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.

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CALIBRATION OF TURBINE FLOWMETER

COX AN 8, S/N 36507

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 ($1.17 \pm 0.05 \cdot 10^{-6}$ m^2/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 ±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 ±0.05% was confirmed, i.e., with few exceptions, calibration points fell within ±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 ±0.18%, with a precision error of ±0.05%, yielding a combined overall uncertainty of ±0.28% [1].

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

4.0 FLOWMETER CALIBRATION

Information pertinent to the calibration reported:

Job No.: FMC-91-11

Calibration Date: 07 November 1991

Customer: Standard Aero Ltd.

Flowmeter Data

Make/Model: Cox AN 8

Size: 1/2"

Serial No.: 36507

Pickoff Type: Magnetic

Pickoff Part No.: 82414A-1B3

Bearing Type: Ball

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

Relative Density (15.56/15.56°C): 0.7780

Fluid Temperature (Ave.), °C: 22.5

Viscosity at Fluid Temperature, Cst: 1.2623

Room Temperature (Ave.), °C: 21.2

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 24-inch straight inlet tube and a 12-inch straight outlet tube. The client requested calibration over the (flow) range of approximately 90 to 1500 Hz. In order to provide a good calibration curve definition, a total of 22 points was established, two of which were repeats [Fig. 2]. The calibration proceeded, generally, from the highest flow to the lowest, followed by the repeat points and by two points to define the spike at the low end of the flow range. 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 ±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-91-11 of the Cox AN 8 turbine flowmeter, S/N 36507, owned by Standard Aero Ltd., the following comments can be made:

- The calibration points formed a smooth curve on the universal viscosity plot [Fig.3]. The sharp "spike" at the low flow end was confirmed as being real by additional unreported calibration points. However, this excursion was only 0.2%.

- Points were within ±0.01% of a best-fit curve over a 10:1 range of the universal curve.

- Repeatability of the meter was very good in that the repeat points were within 0.01% of each other.

- The linearity of the flowmeter, i.e. the maximum deviation of any K-factor from the mean value, was ±0.115% over a 10:1 working range and ±0.26% over an extended range of 15:1. Some small shifting of calibration points, of the order of 0.1%, observed during a series of pre-calibration tests, would spread the linearity over the 10:1 range to about ±0.15%, still a very good value.

- No unusual symptoms of the meter were observed during calibration.

6.0 REFERENCES

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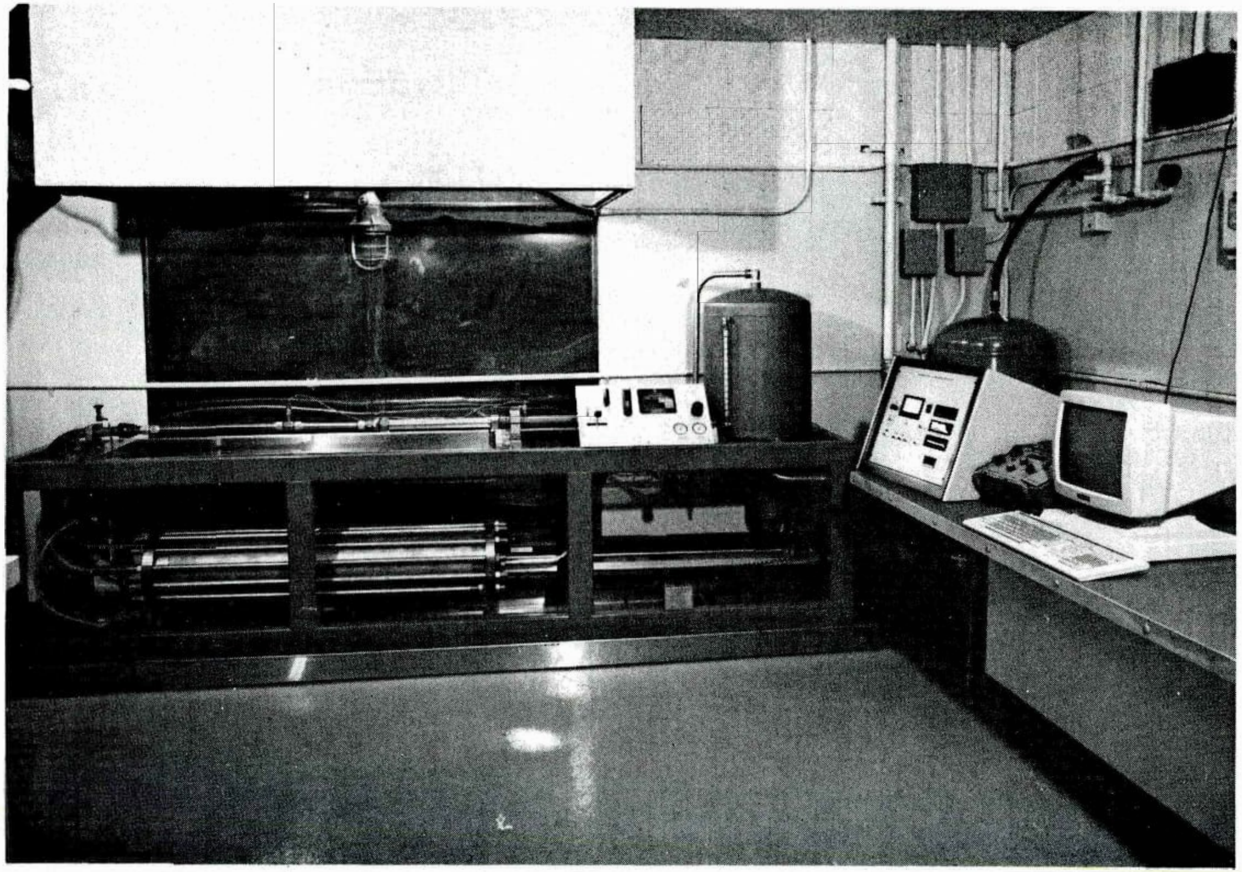

FIG. 1 OMNITRAK BALLISTIC FLOW CALIBRATOR INSTALLATION

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FIG.2

TURBINE FLOWMETER CALIBRATION

Customer: Standard Aero Ltd
Date: 7-NOV-91 Job #: FMC-91-11

CALIBRATOR DATA

Make: Flow Technology Omnitrak Calibrator System Model: OT-150 S/N: 83110022
Microtrak Constant: 62213 Volume Unit: U.S. Gallon
Calibration Fluid: MIL-C-7024C, Type 2
Specific Gravity(15.56/15.56 Deg.C): 0.7780
Fluid Temperature (Average)[Deg. C]: 22.52
Viscosity [cSt] : 1.2623
Room Temperature (Average)[Deg. C]: 21.23 Operating Pressure [Psig]: 80.00

FLOWMETER DATA

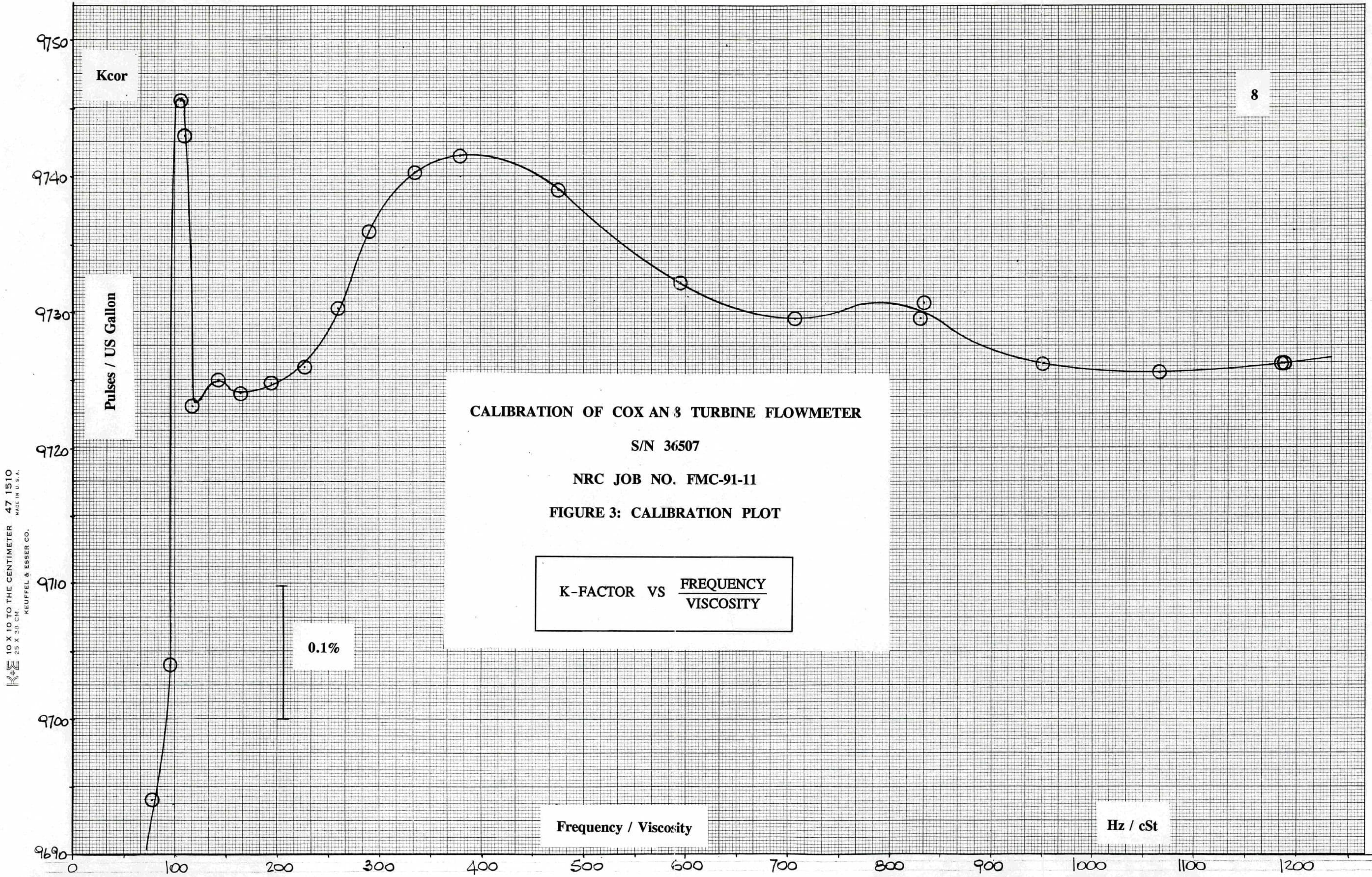
Make/Model : COX AN 8 Size : 1/2 Inch
S/N : 36507 Pickoff Type: Magnetic
Pickoff P/N: 82414A-1B3 Bearing Type: Ball

RUN	T VOL	T FMP	# FMP	VOL	FREQ	F RATE	Kcor	FREQ/VISC
1	1.3005	1.3008	1946.0	0.2	1496.0	9.2272	9726.3	1185.1
2	1.4448	1.4445	1945.0	0.2	1346.5	8.3056	9725.6	1066.7
3	1.6203	1.6207	1946.0	0.2	1200.7	7.4060	9726.2	951.21
4	1.8510	1.8506	1946.0	0.2	1051.6	6.4830	9730.7	833.04
5	2.1772	2.1781	1947.0	0.2	893.90	5.5117	9729.5	708.15
6	2.5954	2.5958	1947.0	0.2	750.06	4.6236	9732.1	594.20
7	3.2541	3.2540	1948.0	0.2	598.65	3.6877	9738.9	474.25
8	4.0805	4.0793	1948.0	0.2	477.53	2.9408	9741.4	378.30
9	4.6122	4.6114	1948.0	0.2	422.43	2.6018	9740.3	334.65
10	5.3144	5.3131	1947.0	0.2	366.45	2.2580	9735.9	290.31
11	5.9457	5.9477	1947.0	0.2	327.35	2.0183	9730.3	259.33
12	6.7613	6.7596	1945.0	0.2	287.74	1.7748	9726.0	227.95
13	7.9824	7.9814	1945.0	0.2	243.69	1.5033	9724.8	193.05
14	9.2985	9.2982	1945.0	0.2	209.18	1.2905	9723.9	165.71
15	10.827	10.831	1946.0	0.2	179.67	1.1083	9725.0	142.33
16	13.032	13.026	1944.0	0.2	149.24	0.92081	9723.0	118.23
17	16.332	16.339	1942.0	0.2	118.86	0.73475	9704.4	94.159
18	19.623	19.622	1939.0	0.2	98.818	0.61153	9694.1	78.284
19	1.2966	1.2969	1946.0	0.2	1500.5	9.2550	9726.3	1188.7
20	1.8538	1.8536	1946.0	0.2	1049.8	6.4732	9729.6	831.70
21	14.624	14.621	1949.0	0.2	133.30	0.82057	9745.6	105.60
22	14.019	14.020	1949.0	0.2	139.02	0.85598	9742.9	110.13

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.AcSt]

Calibrated by: ______________

Certified by: ______________



Kcor
8
Pulses / US Gallon
9750
9740
9730
9720
9710
9700
9690
CALIBRATION OF COX AN 8 TURBINE FLOWMETER
S/N 36507
NRC JOB NO. FMC-91-11
FIGURE 3: CALIBRATION PLOT
K-FACTOR VS FREQUENCY / VISCOSITY
0.1%
Frequency / Viscosity
Hz / cSt
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
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7 W. Grabe and J. Carvish

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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
Mr. M.S. Chappell
Machinery and Engine Technology Program
Institute for Mechanical Engineering
Montreal Road, Ottawa, Canada
20 K1A OR6 (613) 993-2425

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