Consumer and Corporate Affairs Canada   Consommation et Corporations Canada

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SPECIAL APPROVAL

Granted To: NOVA, an Alberta Corporation
P.O. Box 2330
Edmonton, Alberta
T5J 2R1

Attention: Mr. B.J. McConaghy
Measurement Supervisor

Subject: Real Time Measurement System- Empress "B" Meter Station.

Special Approval has been granted by the Legal Metrology Branch to NOVA an Alberta Corporation for the use of the delineated Real Time Gas Measurement System in trade.

The RTMS (Real Time Measurement System) is a measurement system which utilizes a micro processor based digital flow computer which in conjunction with auxiliary instruments effects on-site calculations of flow of natural gas in units of volume, energy, and mass on a 'real time' or instantaneous basis.

Location: SW ¼ Sec. 12 Twp 20 Rge 1 W4M

Details of the measurement system are as follows:

1. Five (5) Orifice Meters:

Manufacturer: Daniel Orifice Fitting Co.
Type: Senior Orifice Fitting

Run No.	Nominal Size	Inside Diameter	Pipe Schedule	Serial No.
1	24"	23.000"	EX-STR	705102H
2	24"	23.000"	EX-STR	705103H
3	24"	23.000"	EX-STR	705101H
4	24"	23.000"	EX-STR	715208H
5	24"	23.000"	EX-STR	715209H

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Orifice Plate Diameter:	"Variable"
Beta (d/D) ratio:	0.15 to 0.70
Pressure taps:	Flange, static pressure obtained from downstream tap.

2. Auxiliary Attachments:

(a) Static Pressure Transducers (5, one per run):

Manufacturer: Rosemount Instruments Ltd.
Type: 1151 GP Alphaline gage pressure
Calibrated Range: 0-1000 p.s.i.g.

Run	Model No.	Serial No.
1	1151GP8E22MBCE	C04599
2	"	C02813
3	"	C04600
4	1151GP9E22MBCE	C05416
5	"	C05414

(b) Differential Pressure Transducers (5, one per run):

Manufacturer: Rosemount Instrument Ltd.
Type: 1151 DP Alphaline differential pressure
Calibrated Range: 0-200" W.C.

Run	Model No.	Serial No.
1	1151DP5E22MBCE	C04641
2	"	C02836
3	"	C04630
4	"	C04627
5	"	C04632

(c) Temperature Transducer & Current Transmitter (1 only, run #2):

(i) Temperature Transducer:

Manufacturer: Honeywell Ltd.
Model Number: Vutronik RT/I 39102
Serial Number: L2455118001
Calibrated Range: 0-150°F

Note: Temperature transducer is connected to the flow computer via a current transmitter.

(ii) Current Transmitter:

Manufacturer: Moore Industries Ltd.
Type: SCT Signal Converter
Model Number: SCT/4-20mA/4-20mA/24VDC/STD

i.e. Input: 4-20mA into 50 ohms nominal
Output: 4-20mA into 0-1200 ohm load
Power Input: 24VDC
Enclosure: STD (Standard)

(d) Gas Gravitometer (run #1):

Manufacturer: UGC Industries, Inc.
Model Number: GR6-01 & 223 (analog transmitter)
Serial Number: 815/0139
Calibrated Range: 0.550 - 0.750

(e) Calorimeter & Transmitter (run #1):

(i) Calorimeter:

Manufacturer: Cutler-Hammer Inc.
Type: AB

(ii) Transmitter:

Manufacturer: Acromag Inc.
Model Number: 819-BX-LU
Calibrated Range: 31-45 MJ/m^3

(f) Gas Flow Computer:

Manufacturer: Waugh Controls Corp.
Model Number: 1110-2
Serial Number: 7948

(g) Electro Mechanical Counters (7):

Manufacturer: Sodeco
Model Number: RG082E
Number of Digits: 8, no reset
Max. Counting: 25 impulses/sec.
Operating Voltage: 24VDC

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Counter No.	Accumulates
1	Volume, run no. 1 (m^3)
2	" " " 2 "
3	" " " 3 "
4	" " " 4 "
5	" " " 5 "
6	Total station mass (10^3 kg)
7	" " energy (MJ)

(h) Minicomputer:

Manufacturer: DEC-Digital Equipment Corporation
Model Number: PDP8-AO

(i) Print-Out Unit:

Manufacturer: DEC-Digital Equipment Corporation
Model Number: LA36

In addition to the above instrumentation, the measurement system is equipped with approved devices such as pressure and temperature chart recorders. Five (5) pressure chart recorders are utilized, one per run. Each recorder is equipped with two (2) pens - one pen records the static pressure and the second records the differential pressure. Only one (1) temperature chart recorder is used (off the manifold) for all five runs. Recorders use 24 hour charts and each is equipped with an automatic chart changer.

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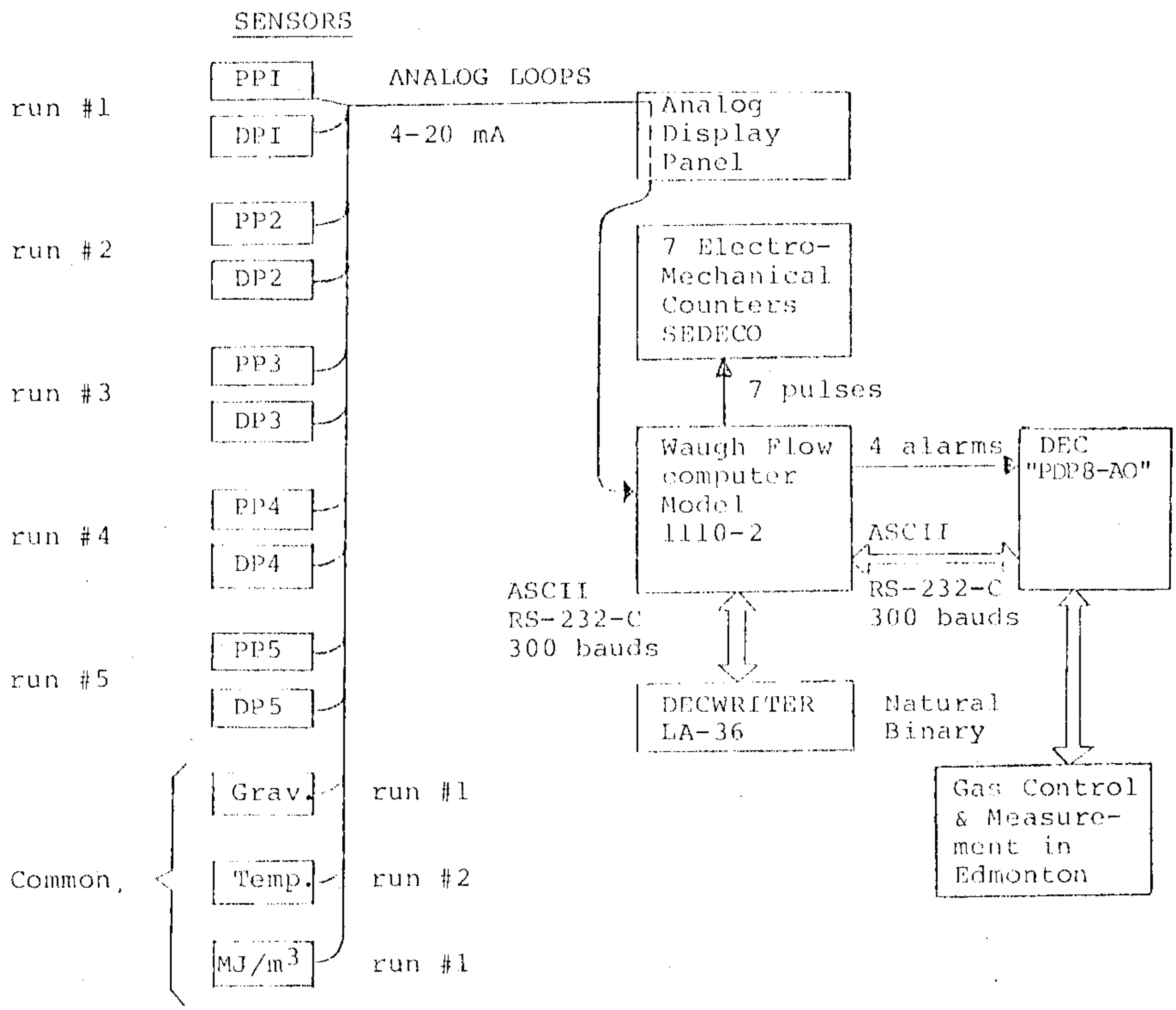
EMPRESS B

REAL TIME MEASUREMENT

SYSTEM

GENERAL CONFIGURATION



DESCRIPTION

The measurement equipment delineated above compose a system referred to as Real Time Measurement System, located at Empress B meter station. This system is used for Custody Transfer of natural gas utilizing five(5) orifice meters with associated instrumentation. Since the gas passing through these five orifice meter runs is from the same source, the quality of gas in each run is identical. This allows certain instrumentation as the gravitometer, calorimeter, and temperature transducer to be used as a common sensor whereby the information derived off one run is used to calculate the accumulated gas passed by all the five meter runs. The common sensors, the gravitometer and calorimeter, sample the gas on run no. 1, while the temperature information is derived off run no. 2.

All flow computations are performed by the Waugh Computer model 1110-2. The necessary additional information required for flow calculation, such as mode, AGA equations, number of runs, run and orifice size, etc., are entered via a keyboard on the flow computer itself. The computer has an 8 digit LED display to check entries, input values, intermediate calculated data, alarms, status, and accumulated flows and flow rates for volume, energy and mass.

Supercompressibility factor is computed by the computer in accordance with AGA Report NX-19, which requires knowledge of relative density and the mole percentage of CO_2 and N_2. CO_2 and N_2 content is determined by the analysis of a gas sample continuously collected over a seven-day period, which is then programmed into the computer (every seven (7) days). Relative density is a variable which is continuously fed into the computer by the gravitometer.

Energy Units, the gigajoules (GJ), are used in custody transfer sale.

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The computer updates the accumulated flow for each of the five(5) orifice meter runs within a total time span of 1½ seconds. This process is continuous.

Every hour the accumulated flows, as well as the total for all five(5) runs; and the static pressures, differential pressures, temperature, relative density and energy and the flow rates, at the time of the printout, are printed out.

Every 24 hours, at the conclusion of a print-out, the accumulated volume is reset to "zero" for each run as well as the total runs and the whole process is repeated.

The 24-hour print-out data records shall be retained for a minimum period of two(2) years.

Computer at any time can be called upon to display any accumulated flow or any parameter.

Automatic print-out is achieved by the use of the PDP8-AO minicomputer and the decwriter LA-36 printer.

Although the measurement system is totally "computerized", the pressure and temperature chart recorders still have a role to play in the system. Recorders are used to detect any irregularities in the computer read-outs when correlated against the information provided by the recorders. In addition, recorders are used for billing purposes during periods of verification of the computer, during which time the computer is totally disconnected from the system. Recorders will also be used for billing during periods where the computer may become incapacitated due to malfunction.

Conversion Factors:

Metric conversion factor applicable to computer computations shall be as delineated in Technical Gas Circular G-80-3, dated April 30, 1980.

Emergency Power:

The measurement system is equipped with an emergency power back-up system.

Sealing:

Because of the regular and routine NOVA Corporation and customer inspections and maintenance to ensure that accuracy is maintained by the flow computer, static pressure transducers, differential pressure transducers, and the temperature transducer, the sealing of these devices to prevent access to the adjustments is important. However, Nova shall maintain a log record for each device, showing dates and details of maintenance and calibration, "as found" and "as left" calibration results, standards used for calibration, their traceability and dates of certification of accuracy of these standards. Such log records shall be made available to the Government Inspector upon request.

Records of Measurement:

NOVA Corporation shall maintain records of all determinations of energy (gigajoules) upon which sales are based. These records shall be available for inspection upon request by the Department.

Verification of Measurement Station:

For field test procedure refer to the attached Appendix "A".

Re-Verification:

Computer: Re-verification of the computer shall be at one(1) year intervals. Verification process shall encompass an agreement between NOVA and District Inspector to a mutually agreeable time for the verification.

Gravitometer and Calorimeter: Frequency of verification of the gravitometer and calorimeter shall be as stipulated by Departmental Instructions - Part VID, Section 4; and Part VIC, Section 2, respectively.

Secondary Instruments: Frequency of re-verification of secondary instruments shall be as stipulated by Departmental Instructions - Part VIH, Section 2.3. Secondary instruments referred to consist of pressure and temperature transducers, and their signal transmitters.

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APPENDIX "A"

Ref: Special Approval SPG-263 May 1, 1981

FIELD TEST PROCEDURE

1. Orifice Meters:

Inspection of the primary elements is to be performed as delineated in the "Departmental Instructions for Inspection of Gas Meters and Auxiliary Devices" - Part VII, Appendix 1; Specification No. 7.

2. Transducers:

Performance verification of pressure and temperature transducers is accomplished with the evaluation of any one meter run at a time. Flow through the run being evaluated is shut OFF. Waugh computer is engaged into TEST mode. This isolates the meter run from the remaining runs whose flow the computer keeps processing. The transducers are isolated from the run with connections to the computer remaining intact.

Set the computer to display the required units of measurement: p.s.i.g., in W.C., or in °F, whichever one is applicable to the transducer being verified. Apply to the respective transmitter appropriate pressure or temperature from a Standard source and compare the applied value to the value displayed by the computer.

The computer is also able to display the analog signal (4-20 mA) it receives from the transducer.

Orifice runs #1 and #2 contain sensors which are "common" to all the remaining runs. The output signal from a common sensor is used for all of the five(5) runs. There are three(3) "common" sensors in the system, namely, temperature transducer in run #2, gravitometer and calorimeter in #1.

Prior to shutting OFF run #2, set the computer to accept a "fixed" temperature signal, only for the duration of the shut-down, to ensure the continuous data processing for the remaining runs in operation.

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Similarly, the outputs from run #1 common sensors, the gravitometer and calorimeter, as well are to be "fixed" into the computer prior to the shut-down of the run. This is delineated further in section 3 and 4, respectively.

At the conclusion of verifying runs containing the "common" sensors, and with all the sensors replaced in their respective runs, de-program the computer to revert back to instantaneous data processing state applicable to the said "common" sensors.

2.1 Static Pressure Transducer:

Calibrated range is 0-1000 p.s.i.g.

Transducer shall be checked at following test pressures:

-"Zero" (0) and in increments of 20% of full scale up to the full range of the transducer, or, if this is not possible, to and including the maximum pressure available on the system.

-Decreasing from the full scale pressure, or, if this is not possible, from the maximum pressure available to "zero" in equal decrements.

Compare pressure reading as indicated by computer with applied pressure from the Standard.

This procedure is repeated for each run.

2.2 Differential Pressure Transducer:

Calibrated range is 0-200" W.C.

Transducer shall be checked at following test differential pressures:

-Increasing differential pressures of 0, 30%, 60%, 90% and 100% of full scale.

-Decreasing differential pressures of 100%, 80%, 40%, 20% and 0 of full scale.

Compare pressure reading as indicated by computer with applied pressure from the Standard.

This procedure is repeated for each run.

2.3 Temperature Transducer:

Calibrated range is 0-150°F.

Transducer shall be checked at following test temperatures:

-At a point approximately equal to the flowing temperature of the gas.

-At a point less than and as far as practical from the flowing gas temperature.

-At a point greater than and as far as practical from the flowing gas temperature.

Compare temperature reading as indicated by computer with the indicated temperature by the Standard thermometer.

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3. Gravitometer:

As stated in section 2 above, a "fixed" factor for Relative Density, R.D., is programmed into the computer. The instantaneous R.D. signal becomes a "fixed" signal at the instant it is "frozen".

Calibrated range is 0.550 - 0.750.
Verification shall be in accordance with Departmental Instructions for Inspection of Gas Meters and Auxiliary Devices, Part VID, Section 3.
Relative density detected by the gravitometer can be displayed directly by the computer.

4. Calorimeter:

Similarly to section 3 above, a "fixed" factor or value for heating value is programmed into the computer. The instantaneous heating value becomes a "fixed" value at the instant it is "frozen".

Calibrated range is 31-45 MJ/m^3.
Verification shall be in accordance with Departmental Instructions . . . ., Part VIC, Section 3.
Calorific content detected by the calorimeter can be displayed directly by the computer.

5. Computer:

Verification of the computer requires that it be disconnected totally from the system. During the time period that the computer is disconnected, the existing chart recorders will be used to collect the data for billing purposes.

The verification of the computer will ascertain its capability to totalize the gigajoules (upon which billing is based) when subjected to varying simulated flow conditions. Process will encompass the use of the General Equation for computing flow through orifice meters together with the simulated flow parameter inputs provided by static pressure transducer, differential pressure transducer and temperature transducer (off run #2), and gravitometer and calorimeter (off run #1). Sources of pressure and temperature the transducers are subjected to shall be provided by appropriate pressure and temperature standards. Gravitometer and calorimeter shall use certified gas samples or plugged-in fixed values.

Supercompressibility factor shall be accounted for by programming into the computer the CO_2 and N_2 content of the certified gas sample used in verification. As mentioned above, the relative density may be the actual value provided by the same gas sample or a simulated constant fixed value plugged into the computer.

In total, there are five(5) flow parameters that are used in verifying the computer. They are static and differential pressure, temperature, relative density, and heating value.

Relative density and heating value are not variable when the certified gas sample is used for their determination. Pressures and temperature are variable and shall be held to within calibrated range of the transducers.

Orifice meter flow calculations shall be in accordance with the methods laid down in Section IV of AGA Gas Measurement Committee Report No. 3, 1969, as called for in Departmental Instructions Part VII, Appendix I, Section 4.

Calculated flow shall be expressed in energy units - the megajoule, which is to be correlated with the readings off the computer.

An example of calculations utilizing the orifice meter flow equation has been worked out in section 6 - Summary of Field Test Procedure . . .

5.1 Feed into the computer mA signals from the five(5) simulated flow parameters. Note the five parameters for inclusion into the orifice flow equation. Parameters for pressure and temperature may be as delineated in sections 2.1, 2.2, and 2.3.

Allow the computer to accumulate sufficient heat units (gigajoules) to produce a minimum resolution of ±0.2 per cent on the digital display, which is equivalent to computer cumulative read-out advancing by 500 GJ.

Note the (time) duration of the test run, in "hours". Actual test run will only last minutes, but the orifice flow equation calls for test time to be in hours. Insert this time, "hours", into the orifice flow equations and calculate the megajoules that should have been passed by the computer.

Compare the calculated gigajoules to the accumulated gigajoules as displayed by the computer, as follows:

Per cent error for the computer is

$$\frac{GJc - GJT}{GJT} \times 100$$

where GJc are gigajoules as displayed by computer, GJT are true gigajoules as calculated by orifice flow equation.

Note: Allowable computer error is $\pm 2.0\%$.

5.2 Repeat 5.1, but choose a different temperature (refer to 2.3) with other parameters kept the same.

5.3 Repeat 5.1 and 5.2, but choose a different static pressure (refer to 2.1) with other parameters kept the same.

5.4 Repeat 5.1, 5.2 and 5.3, but choose a different differential pressure (refer to 2.2) with other parameters kept the same.

Verificaton of the computer concluded and found satisfactory, computer along with the transducers, gravitometer and calorimeter are re-connected back into the measurement system. Also, the prevailing CO_2 and N_2 content of the gas flow passing through the system are re-programmed back into the computer.

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6. Summary of Field Test Procedure for Verification of Orifice Meter Installation and Computer:

6.1 Primary Elements:

The orifice plate and the installation shall be examined and dimensional measurement made to verify the conformity with Specification No. 7 for Approval of Type of Orifice Gas Meters and their Installation.

6.2 Computer:

(a) During the verification tests it is important for the flow conditions to be stable.

(b) For verification tests simulate the flow conditions by applying appropriate temperature, static and differential pressures; relative density and heating value off a standard gas sample, to the computer.

(c) Allow the cumulative read-out on computer advance by 500 GJ to achieve the 0.2% resolution.

(d) Insert the five(5) parameters into the following orifice gas equation based upon the existing orifice meter(s). The numerical following sample shows the method of calculation for the assumed average flow conditions. The same process of calculations is to be made for the parameter values at which verification tests are to be performed.

Test No.	T	P	P	RD	MJ/m^3
1	T1	P1	P1	RD1	$MJ/m^3$1
2	T2	P1	P1	RD1	$MJ/m^3$1
3	T2	P2	P1	RD1	$MJ/m^3$2
4	T2	P2	P2	RD1	$MJ/m^3$2
5	T1	P2	P1	RD2	$MJ/m^3$2
6	T1	P2	P2	RD2	$MJ/m^3$1
7	T2	P1	P2	RD2	$MJ/m^3$1
8	T2	P2	P2	RD2	$MJ/m^3$1

The above RD and MJ/m^3 parameters may be supplied by a certified gas sample or plugged-in constants.

(e) EXAMPLE:

Conditions at Meter	Value of Factor
Meter Equipped with Flange Taps.	
d = diameter of orifice = 14.000 in.	
D = internal dia. of meter tube = 23.000 in.	Fb = 43015
Static pressure obtained downstream of meter	
hw = average assumed differential pressure = 150 in. W.C.	
Pf = average assumed static pressure = 600 p.s.i.g. (613.46 p.s.i.a.)	
Average atmospheric pressure = 13.46 p.s.i.a.	
B = d/D = 14.000 ÷ 23.000 = 0.609	
$\sqrt{hwPf}$ = pressure extention = $(150 \times 613.46)^{\frac{1}{2}}$ = 303.346	
for B = 0.609 and D = 23.000 in.; b = 0.0341,	
Fr = 1 + [B ÷ $(hwPf)^{\frac{1}{2}}$] = 1 + [0.0431 ÷ 303.346] = 1.0001	Fr = 1.0001
Differential ratio hw ÷ Pf = 150 ÷ 613.46 = 0.2445	Y2 = 1.0013
Pb = base pressure = 14.73 p.s.i.a.	Fpb = 1.0000
Tb = temperature base = 60°F	Ftb = 1.0000
Tf = assumed flowing temperature -35°F,	
$Ftf = \sqrt{\frac{60 + 460}{Tf + 460}}$	Ftf = 1.0249
RD = assumed relative density = 0.58	Fg = 1.3131
Supercompressibility factor for 600 p.s.i.g., 35°F and 0.58 RD:	Fpv = 1.0529

Supercompressibility factor, Fpv, for relative density other than 0.600 can be determined by the A.G.A. method as delineated in AGA Report No. 3 or NX-19.

Relative Density	= 0.58
CO_2 content (Mc), (assumed)	= 0.37 mol %
N_2 content (Mn), (assumed)	= 2.00 mol %
Static pressure (Pf)	= 600 p.s.i.g.
Flowing temperature (Tf)	= 35°F

Calculate Kp and Kt

Kp = Mc - 0.392 Mn
= 0.37 - 0.392 (2.00)
= 0.37 - 0.784
= -0.414

Kt = Mc + 1.681 Mn
= 0.37 + 1.681 (2.00)
= 0.37 + 3.362
= 3.732

Find pressure and temperature adjusting factors F_p and F_T for:

Relative density	= 0.58
Kp	= -0.414
Kt	= 3.732

(a) By AGA Report No. 3; Appendix B Section 13:

$$Fp = \frac{156.47}{160.8 - 7.22\ RD + Kp},$$

$$Ft = \frac{226.29}{99.15 + 211.9\ RD - Kt}$$

Thus,

$$Fp = \frac{156.47}{160.8 - 7.22\ (0.58) + (-0.414)} = 1.0017$$

$$Ft = \frac{226.29}{99.15 + 211.9\ (0.58) - 3.732} = 1.0365$$

<u>OR</u>

(b) By AGA Report NX-19; Tables 1 and 2:

By direct table look-up:

Fp = 1.0017
Ft = 1 0365

Calculate the adjusted pressure and temperature:

Adjusted Pressure = Pf Fp
= 600 x 1.0017
= 601 p.s.i.g.

Adjusted Temperature = Tf Ft - 460
= (35 + 460) 1.0365 - 460
= 513 - 460
= 53°F

From Table 16 of AGA No. 3 or Table 3 of AGA NX-19, find Fpv factor for:

Adjusted Pressure = 601 p.s.i.g.
Adjusted Temperature = 53°F
..Fpv = 1.0529

Orifice thermal expression factor, Fa, for stainless steel:

Fa = 1 + [0.0000185 (Tf - 68)]
= 1 + [0.0000185 (35 - 68)] = 0.9994   Fa = 0.9994

Orifice Constant, C', corresponds to expression:

C' = Fb x Fr x Y x Fpb x Ftb x Ftf x Fg x Fpv x Fa

Then,

C' = 43015 x 1.0001 x 1.0013 x 1.0000 x 1.0000 x 1.0249 x 1.3131 x 1.0529 x 0.9994
= 43015 x 1.4181
= 61000.5

For an average pressure extension,

$\sqrt{hwPf} = (150 \times 613.46)^{\frac{1}{2}} = 303.346$, the flow rate would be,

$Qh = C' \sqrt{hwPf} = 61000.5 \times 303.346 = 18504258\ ft^3/h$

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The above equation, $Qh = C'\sqrt{hwPf}$ can be converted to an equation where all three variable parameters are included in the solution of the flow equation, namely,

$$Qh = C' \sqrt{hwPf} \times Ftf \quad .... (1)$$

where Qh = rate of flow in cu.ft. per hour at base conditions,

C' = orifice flow constant as designated in AGA Report No. 3.

$$C'' = \frac{C'}{Ftf}$$

Ftf = gas flowing temperature factor.

The equation (1), above, can be adapted to include the measured period of test time during which the difference in readings of the integrating register between the start and finish of the test is utilized.

Thus, $Q = C'' \sqrt{hwPf} \times Ftf \times t$, ... (2)
where Q = accumulated flow in cu.ft. at base conditions (60°F and 14.73 p.s.i.a.).
t = time duration of test in hours.

In order to obtain calculated accumulated heating units in gigajoules, GJ, equation (2) requires the inclusion of the heating value of the gas sample used in the verification of the computer.

Equation (2) then can be re-arranged to produce accumulated GJ:

$$GJ = Q \times MJ/m^3 \times \frac{0.02832784}{10^3} \quad ....(3)$$

where MJ/m^3 is the heating value of the dry gas analyzed per cubic metre at 101.325 kPa (abs) and 15°C.

(f) Obtain reading of accumulated flow in GJ off the totalizing computer for an accurately measured period of time. The magnitude of the accumulated GJ shall be sufficiently large (500 GJ min.) so that a resolution of 0.2% can be achieved.

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(g) Compare this observed result with the calculated GJ (equation 3) over the same time duration, t, as in para. (f), namely,

$$GJ = C'' \sqrt{h_w P_f'} \times F_{tf} \times t \times MJ/m^3 \times \frac{0.02832784}{10^3}$$

Assuming heating value of dry gas is 36.97 MJ/m^3, and duration of test is 5 minutes or 5/60 hours, then the accumulated energy units are

$$GJ = (18504258 \times \frac{5}{60}) \times 36.97 \times \frac{0.02832784}{10^3}$$

$$= 1614.9 \text{ gigajoules}$$