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Measuring Equipment for Energy Auditors

Diverging opinions exist on what extent measuring equipment is needed, when it should be used, how it should be used during energy audits. Some of our readers object to having stringent requirements regarding the use of measuring equipment during energy audits, while others feel these requirements are beneficial and provide a marketing advantage to their energy auditing firms.

It is understood that one may detect many cases of energy inefficiency in a firm without using measuring equipment and quantifying energy consumption. There are always obvious cases of energy wastage where anybody with common sense and no formal training or experience can identify saving potentials. However, this should not be taken as an excuse to promote walk through audits with no systematic approach involving measuring equipment as needed.

To encourage the systematic and appropriate use of measuring equipments in energy audits, we have started gathering information about measuring equipment as a service to energy auditors and managers under section **Energy audit instruments**. However , information provided by equipment suppliers is only half of the coin. More important is to get feedback from users about field experience using such equipment.

Measuring electrical parameters does not seem to be much of a problem except for total harmonic distortions and transients, or the occasional blowing of fuse because screw drivers and bus bars are a bad mix.

However, other more common measuring tasks such as flows of gases and liquids, as well as stack gas composition are more challenging and riddled with problems, even if one uses expensive and sophisticated equipment.

As a beginning we therefore ask practitioners in the field about their experience with regard to :

(i) Measuring flow of air, steam and water with online and mobile, intrusive or non-intrusive equipment.
(ii) Measuring % O_2, % CO_2, or % CO in the stack gas of combustion systems

We hope our subscriber base will share their field experience with others by stating measuring equipment used for a particular task and what problems or advantages concerning accuracy, handling, reliability, suitability as well as repair and maintenance costs are associated with the instrument.

Answer

Many varieties of equipments can be used for a particular task. Problems or advantages concerning accuracies, handling, reliability, suitability as well as repair and maintenance costs associated do vary. The issue concerns particularly

(i) Measuring flow of air, steam, water with online and mobile intrusive or non-intrusive equipment.
(ii) Measuring % O_2 , % CO_2 or % CO in the stack gas of combustion systems.

1 Flow of air

Measurement of flow of air (only fans and blowers are considered) in industrial and commercial establishments will vary from **few tens and hundred of cfm to over a lakh of cfm**. Some of the important air flow measuring requirements and the use of specific instruments are summarized in **Appendix 1**

Anemometer

Problems and advantages

Flow is derived by measuring inlet velocity. normally, rectangular or circular cross section exists. Measurement points vary from 5 to 10 across the cross section to have more reliable data. Measured velocity is the average value. Velocity reading should be read holding the probe about 15mm from the surface.

Though instrument error will have variation of 1%, measured flow accuracy varies between 5% to 10%. Easy to handle and reliable. Annual repair and maintenance costs vary in the range of 2% to 3 %.

Pitot tubes

Industrial

Problems	**Advantages**
Unable to get a proper and approachable point for measurement. (in almost 50 % of the cases except cement plants) ; If sampling point is available, inaccessibility in most of the cases	Higher preparation time for establishing sampling point
No reading or improper reading in dusty atmosphere i.e cement & fertilizer plants	More accurate and reliable reading by traverse method
	Low repairs and maintenance cost

Commercial buildings

Problems	Advantages
Unable to get a proper and approachable point for measurement. (in almost 100 % of the cases)	More accurate and reliable reading by traverse method
	Low repairs and maintenance cost

% O_2, % CO_2 & CO measurement only

Fyrite

% O_2, % CO_2 measurement

Equipment	Accuracy	Reliable	Suitabilty	Problems	Advantages
Low capacity boilers & combustion system	Accurate	Reliable	Suitable	Getting proper sample point. Delay in procurement of spare liquids	Both O_2 & CO_2 measurement possible.
Medium capacity boilers & combustion system	Not so accurate	Reliable	Suitable	Getting proper sample point. Absence of sufficiently long sampling probe	Both O_2 & CO_2 measurement possible.

Note : Fyrite reading is taken as the base.

Orsat Apparatus

% O_2, % CO_2 & CO

Equipment	Accuracy	Reliable	Suitabilty	Problems	Advantages
All types of boilers	Accurate	Reliable	Suitable	Getting proper sample point. Very highly skilled manpower requirement Delay in procurement of spare liquids	Very accurate readings for O_2, CO_2 & CO possible. Applicable for all combustion systems Low repairs and maintenance cost

Microprocessor based instrument

Equipment	Accuracy	Reliable	Suitabilty	Problems	Advantages
All types of boilers	Accurate	Reliable	Suitable	Getting proper sample point. Insufficient length of sampling probe Very highly skilled manpower requirement Very frequent replacement of electro chemical cells (say once in six months) Annual repair and maintenance cost about 20% to 25% of the equipment cost	Very accurate readings for O_2, CO_2 & CO possible. Applicable for all combustion systems Most suitable and economical for medium and large capacity boilers

Water Flow Measurement

A brief

Ultrasonic flow meter (works on doppler principle) is one of the popular instruments for measuring the flow of liquids, especially water. How accurate, reliable, suitable these instruments are for industrial applications and what repairs and maintenance costs are associated along with problems and advantages have been discussed.

Though ultrasonic flow meter can be considered a panacea for non availability of on line flow meter, experiences with the usage of the instrument (Polysonic make, Panametrics make) reveals this instrument is not the end of the solution. ***Case 1*** & ***Case 2*** discussed below show two totally contrasting results.

Advatages

Measurement of flow is dependent not just on the accuracy of the instrument but more with regard to :

- Appropriate location
- Surface preparation
- Installation

Ensuring all the above conditions are properly met, gives replicable readings. However, there are other disadvantages associated are higher cost of usage.

Disadvantages

- On an average, about eight to ten flow measurements only can be made in a day with prior planning.
- One helper is required for surface preparation.
- One skilled instrument technician is required for usage of the instrument at field

All the above would cost on average Rs 5000/ per day on hiring basis. At the end of the day, all the measurements can turn out to be of expected level, or the readings may not turn to be of expected level due to non compatibility of sound signals etc.

Since we have used the instrument for almost 5 years, we have not incurred more than Rs 40000/- (Rupees forty thousand only) that works out to about approximately 10 % for 5 years or 2 % per annum.

The case 1 presented below has

CASE 1

A large industrial complex manufacturing iron aniline, iron oxides and other by products was studied for carrying out water balance.

Observations with respect to use of Poly-sonic make (flow meter)

Location	:	Eastern India
Plant	:	More than 30 years old
Flow measurement	:	Cooling water flow measurement
Plant equipment	:	Inlet water to plant, Reducer, Nitrator, Distillation column, reactors
Pipe line	:	more than 30 years old
Cooling water supply	:	Raw water
Treatment	:	No cooling water treatment observed

Plant reference	Pump kW	Pipe size	Measurement location	Remarks
Nitrate reactor cooling water	7.5	3 inches	Horizontal pipe Vertical pipe	No stable readings
Reducer cooling water line	7.5	3 inches	Horizontal pipe Vertical pipe	No stable readings
Distillation cooling column	7.5	4 inches	Horizontal pipe Vertical pipe	No stable readings
Inlet water to the plant (raw water)	10	4 inches	Horizontal pipe Vertical pipe	Stable reading

Note : all measurement locations were as per the needs of the measuring device

Other precautions observed

- Two sample locations chosen for the same pipe.
- Adequate surface preparation
- All possible troubleshoot debugged

Possible reasons for non performance

- Uniform scale over the entire pipe work
- Extent of impurities may generate the sound signals over the range of the instrument capability
- No full flow of water

Conclusion

Utility of the equipment has failed to perform in cooling water environment indicating not a universal solution.
Raw water, being less hard than the cooling water, instrument performed due to availability of right signals.

Case 2

An industrial complex manufacturing caustic soda and chlorine iron and other by products was studied for carrying out water balance.

Observations with respect to use of Panametrics - make (flow meter)

Location	:	Southern India
Plant	:	More than 18 years old
Flow measurement	:	Cooling water flow measurement
Plant equipment	:	HCL plant, Cell house, condensers etc
Pipe line	:	more than 18 years old
Cooling water supply	:	Raw water

Main cooling tower

Application area	**Pipe dia (inches)**	**Velocity (m/sec)**
Cooling water supply to cell house – I area	8	1.91
Cooling water supply to cell house – II area	10	0.83
Cooling water supply to concentration plant	6	2.18
Cooling water supply to surface condenser –1	6	0.61
Cooling water supply to surface condenser –II	6	1.35
Cooling water supply HCl plant	6	1.46

Other precautions observed

- Two sample locations chosen for the same pipe.
- Adequate surface preparation
- All possible troubleshoot debugged

Conclusion

Utility of the equipment has performed excellent in cooling water environment indicating a universal solution.

Steam Flow Meter

1 Principle of operation

The steam flow measuring devices employed in industrial practice are largely of the following designs.

- Orifice
- Vortex

2 Advantages and Problems associated with accuracy, reliability, suitability and repair and maintenance.

Selection and location of steam flow meter apart, *the accuracy, reliability and suitability are dependent* on number of user side variations such as usage pattern, equipment employed and their performance i.e (type of turbine, its loading pattern), sizing of the steam pipes and location of steam flow meter in these lines (extraction and exhaust steam), fluctuation in steam pressure due to steam demand requirements etc.

- Continuous and steady usage will give more accurate and reliable values.

- Steam flow meters have limitations in that their reliable repeatability in actual measurement is a function of pressure fluctuations. The variation in pressure fluctuation is in turn a function of loading of the boiler. i.e at higher loading a more steady pressure and lower load accompanied by higher fluctuations in pressure.

Advantages or problems associated with the flow meters with respect to accuracy, reliability, suitability and repair and maintenance costs can be categorized as follows.

Application	***Meter***	***Remarks***
Process boiler generating saturated steam up to 10 to 17 ata and low to moderate capacity i.e 1 to 10 ton /hr	*Orifice / vortex*	*Reliable and Suitable* for main steam line flow and user areas when the fluctuations in steam demand is in the narrow range of plus or minus 10% to 15%. Investment cost being high & repair and maintenance costs *being high i.e about 10 to 20%, and lack of skilled instrument technicians not frequently observed in industrial practice.*

Higher pressure & higher capacity steam generating boiler with extraction, back pressure & condensing turbines (i.e about 15 ton / hr to 30 ton/hr and pressure of 22 ata to 62 ata)	*Orifice / vortex*	• *Reliable and Suitable* for main steam line flow • Extraction and back pressure variation being high due to fluctuations in user quantities and hence the pressure, though suitable for *indication purpose, not reliable* with respect to measured values. • *Flow meters installed in steam mains are* normally reliable, *but installed at* extraction pressure *and exhaust pressure are reliable to the extent of allowable variations.* • If the sizing of the extraction and exhaust steam main are of smaller size, and if the meter is located at the user end, due to higher pressure drop, the *reading would be erroneous*
Higher pressure & higher capacity steam generating boiler with extraction, back pressure & condensing turbines (i.e about 30 ton / hr to 100 ton/hr and pressure of 62 and above)	*Orifice / vortex*	• *Reliable and Suitable* for main steam line flow • Extraction and back pressure variation being steady due to minimum fluctuations in user quantities suitable for both *indication purpose and reliable* with respect to measured values. • Since the sizing of the extraction and exhaust steam main are of suitable size, the *reading would be reliable*
Power station steam system	*Orifice / vortex*	• Since they are of standard design and operations are study, the *readings are reliable*

Costs associated with steam unaccounted for being much higher than the costs of repair and maintenance, about 15% to 20% cost associated does go a long way.

An experience with regard to overall steam balance in a large fertilizer complex

A large integrated fertilizer complex manufacturing Ammonia, Urea, methanol, nitric acid, sulfuric acid, triple super phosphate etc had a large steam net work at 6 different pressure levels namely, 105 ata, 70 ata, 40 ata, 20 ata, 10 ata, 3.5 ata. Steam flow meters were available in almost all the plants at their battery limits and as well in the steam generating plant. The total steam generation for the entire complex was about 230 – 240 tons /hr as there were 3 boilers of 90 tons / hr in operation.

An attempt was made by noting down all the steam flow meter readings (almost simultaneously with separate troops stationed at various plants) for establishing the un accounted vented steam. It was found that almost 20 tons / hr steam was unaccounted as vented steam while in actuality it was hardly 2 to 3 ton /hr.

Such observances are not uncommon in large steam generating and distributing network. The reasons for such large variations are :

- Failure to recognize the steam lost through condensation in a large distribution network.
- Steam lost due to malfunctioning of traps
- Improper performance of steam flow meter due to pressure fluctuations

When the first two were accounted, difference narrowed down considerably.

Appendix 1

Industrial

Application	Equipment	
	Mobile	**online**
▪ Primary, secondary & combustion air fans in boilers, furnaces, hot air dryers and other combustion systems	▪ Anemometer ▪ Pitot tubes (for large systems)	▪ Orifice (for medium & large fans)
▪ Primary air fan, secondary air fan & Induced draft fans of cogeneration / power station boilers.	▪ Pitot tubes (for large systems)	▪ Orifice (for medium & large fans)

Commercial buildings & establishments

Application	Equipment	
	Mobile	**online**
▪ Primary, secondary & combustion air fans in boilers, and combustion air fan for vapor absorption machines	▪ Anemometer ▪ Pitot tubes (for large systems)	▪ Orifice ▪ Orifice
▪ Heating, ventilating & air conditioning fans	▪ Anemometer ▪ Pitot tubes (for large systems)	