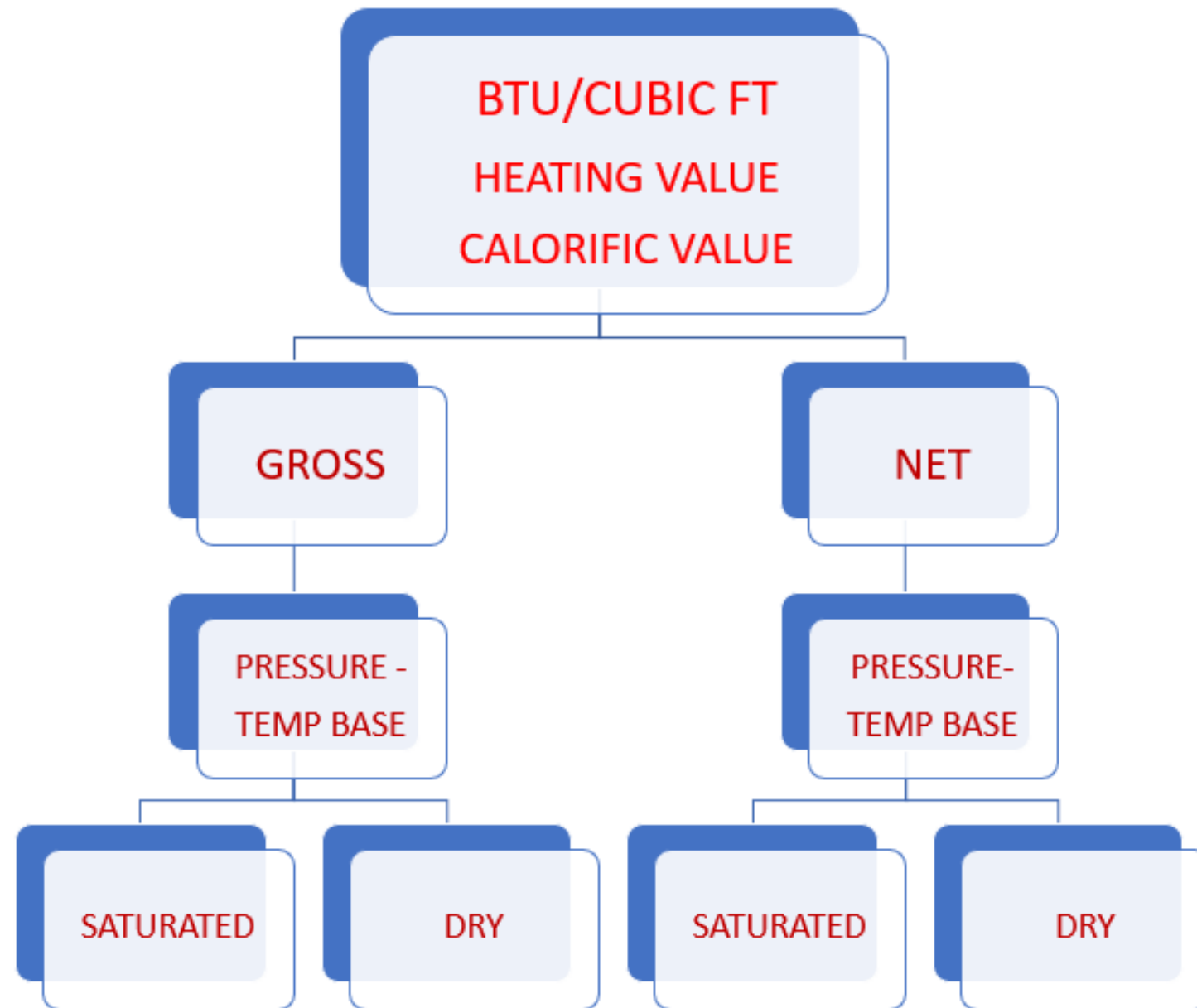


*DEFINING AND MEASURING
FUEL GAS HEATING VALUES*

ASGE 2018 TECHNICAL CONFERENCE

PRESENTED BY DAVE LACH---RELIABLE MEASUREMENT



WOBBE?—REAL BTU?---IDEAL BTU?

WHAT IS HEATING VALUE—WHY IS IT IMPORTANT

- HEATING VALUE, ALSO REFERRED TO AS CALORIFIC VALUE, BTU

VALUE, AND HEAT OF COMBUSTION, IS DEFINED AS THE AMOUNT OF HEAT RELEASED FROM THE COMBUSTION OF A GAS EXPRESSED IN UNITS PER VOLUME OF THE GASEOUS FUEL.

- COMMON EXAMPLES OF HEATING VALUE UNITS OF MEASUREMENT ARE:

BTU/CUBIC FOOT

MEGAJOULES/CUBIC METER

KILOCALORIES/CUBIC METER

**NOTE: ALL HEATING VALUE MEASUREMENTS IN THE U.S. ARE
EXPRESSED IN BTU/CUBIC FT**

DEFINITION OF BTU---THERM---DEKATHERM

- ONE BTU IS DEFINED AS THE AMOUNT OF HEAT NECESSARY TO RAISE
TO RAISE THE TEMPERATUR OF ONE POUND OF WATER ONE DEGREE
FAHRENHEIT FROM 58.5 TO 59.5 AT STANDARD PRESSURE
- ONE THERM IS DEFINED AS 100,000 BTU
- ONE DEKATHERM IS DEFINED AS 1,000,000 BTU
- ASSUMING A NOMINAL 1000 BTU/CF NATURAL GAS SAMPLE, ONE
- ONE HUNDRED CUBIC FEET OF GAS EQUALS ONE THERM
- 1000 CUBIC FEET EQUALS ONE DEKATHERM
- ONE BTU=1055.06 JOULES = .252 KILOCALORIES
- ONE CUBIC FT = .0283 CUBIC METER –ONE CUBIC METER = 35.3 CF
- 1000 BTU NATURAL GAS =37.2 MEGAJOULES/M3=8896 KILOCAL/M3

WHY IS HEATING VALUE IMPORTANT

- HEATING VALUE IS AN IMPORTANT FACTOR IN EQUATIONS USED IN THE
- APPLIANCE INDUSTRY TO RATE MODELS, AND TO DETERMINE EFFICIENCIES
- SOME AGENCIES IN OTHER COUNTRIES SPECIFY RANGES OF HEATING VALUE

INTO WHICH TESTING MUCH TAKE PLACE

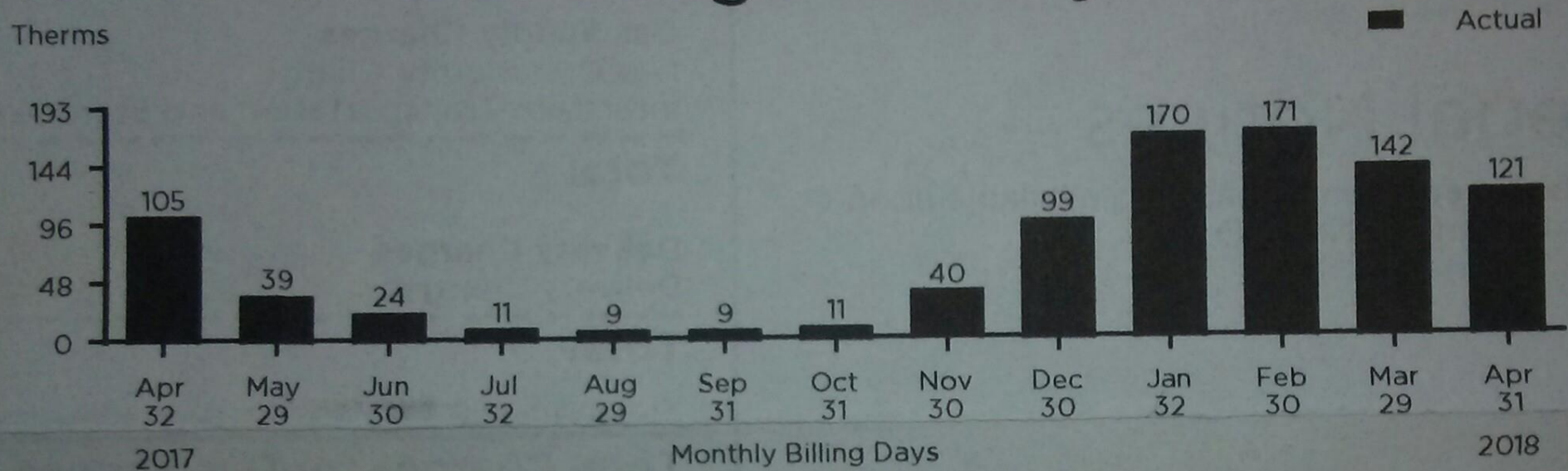
- THERE CAN BE SIGNIFICANT DIFFERENCES IN HEATING VALUE OF NATURAL GAS BASED ON GEOGRAPHY, PIPELINE CHARACTERISTICS, TIME OF YEAR
- VITUALLY ALL SALES OF NATURAL GAS BOTH WHOLESALE AND CONSUMER

RETAIL ARE BASED ON UNITS OF ENERGY(THERMS), TAKING INTO ACCOUNT

NOT JUST VOLUMES, BUT AVERAGE HEATING VALUES AS WELL

- IN THE PETROCHEMICAL INDUSTRY, NEW RULES WILL REQUIRE FLARE-OFFS OF WASTE GASES TO MAINTAIN A MINIMUM BTU VALUE FOR ENVIRONMENTAL REASONS
- ALL TYPES OF GAS MIXING OPERATIONS BOTH COMMERCIALY AND FOR TEST PURPOSES REQUIRE FINAL MIXTURE TO BE WITHIN ACCEPTABLE HEATING VALUE LIMITS
- KNOWING THE BTU VALUE OF A GAS ENABLES A CALCULATION OF
- WOBBE NUMBER(MORE ON THAT LATER), VALUABLE IN COMPARING THE HEAT THROUGH-PUT IIN BURNERS OF DIFFERENT GAS MIXTURES

13 Month Gas Usage History



Meter Number:
9952796

Service Address:
368 W Lakeview Dr
Lowell IN 46356-1261

Meter Readings - 31 Billing Days

Actual Reading on 04/02		8062
Actual Reading on 03/02	-	7945
Gas Used (Ccf)		117
Conversion to Therms	x	1.038
Total Gas Used (Therms)		121.4

Usage Comparison - Therms

Month	Therms	Avg Temp	Therms Per Day
Apr 17	105.1	40.6°	3.3
Mar 18	142.6	31.7°	4.9
Apr 18	121.4	36.3°	3.9

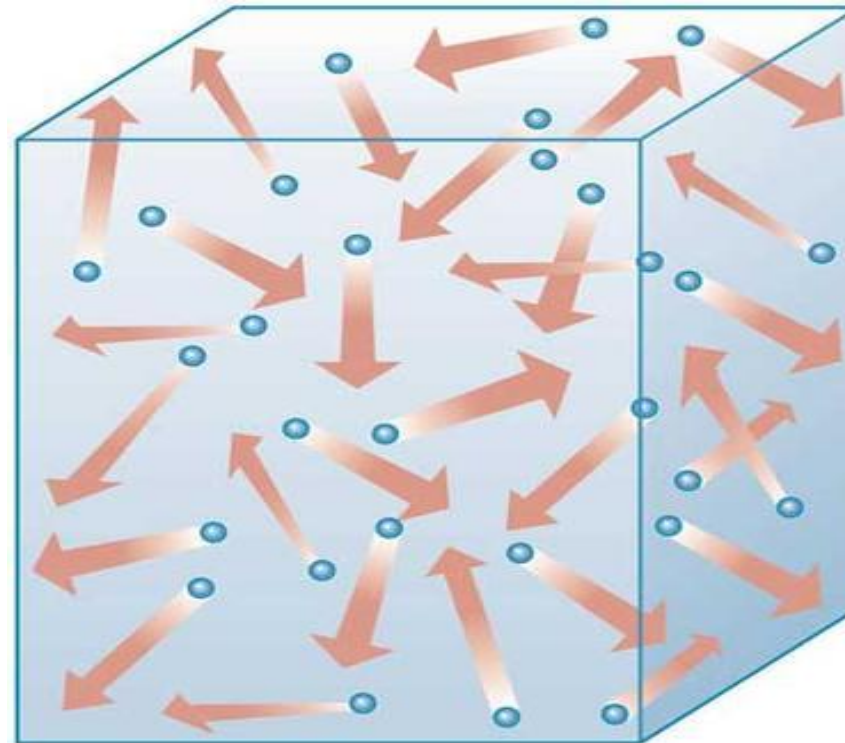
Your next scheduled meter reading date is between 05/01/2018 - 05/03/2018.

SOME VERY BASIC CHEMISTRY AND PHYSICS OF COMBUSTION

- DURING COMBUSTION, HYDROCARBONS, LIKE THOSE COMPOSING NATURAL GAS, COMBINE WITH OXYGEN TO PRODUCE
WATER, CARBON DIOXIDE, AND HEAT
- FOR METHANE $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + \text{HEAT}$
- WHEN THE WATER PRODUCED IS CONDENSED TO LIQUID, APPROXIMATELY 10% MORE HEAT IS RELEASED (THIS VARIES WITH THE GAS BURNED)
- MEASURING AND INCLUDING THIS HEAT RESULTS IN WHAT IS CALLED THE GROSS HEATING VALUE—MORE IN A MINUTE—THE STANDARD MEASUREMENT CHARACTERISTIC USED IN VIRTUALLY ALL BTU MEASUREMENT
- THEREFORE, ANY GAS APPLIANCE MUST CONDENSE THE WATER PRODUCED FROM COMBUSTION BACK TO LIQUID TO ACHIEVE NOMINALLY MORE THAN
- 90% EFFICIENCY

VERY IMPORTANT
DEFINING "BASE OF MEASUREMENT"
ALSO CALLED "STANDARD CONDITIONS"

ONE
CUBIC FOOT



- WHEN MEASURING THE BTU VALUE PER CUBIC FOOT OF A GAS, THE CUBIC FOOT MUST BE DEFINED IN TERMS OF THE 3 FACTORS AFFECTING THE
- NUMBER OF MOLECULES CONTAINED IN THAT CUBIC FOOT
- **PRESSURE:** THE BASE DEFINED MUST SPECIFY THE PRESSURE IN THE CUBIC
- FOOT, AS THE NUMBER OF GAS MOLECULES VARIES GREATLY WITH PRESSURE
- **TEMPERATURE:** THE BASE MUST SPECIFY THE TEMPERATURE OF THE CUBIC FOOT, SINCE THIS ALSO AFFECTS THE NUMBER OF MOLECULES
THIS ONE IS EASY, AS 60 DEG F IS GENERALLY THE STANDARD EVERYWHERE
- **AMOUNT OF MOISTURE:** THE BASE MUST SPECIFY THE AMOUNT OF MOISTURE IN THE CUBIC FOOT, AS EACH WATER MOLECULE REPLACES A GAS MOLECULE, PER AVOGADRO'S LAW, WHICH STATES THAT A GIVEN VOLUME AT THE SAME TEMP AND PRESSURE MUST CONTAIN THE SAME NUMBER OF MOLECULES, REGARDLESS OF SIZE.
THE ONLY 2 CONDITIONS USED FOR MOISTURE ARE SATURATED OR DRY, NO IN BETWEEN

WHY DEFINING THE BASE OF MEASUREMENT IS SO IMPORTANT

- THE SAME GAS CAN HAVE SIGNIFICANTLY DIFFERENT HEATING VALUES WHEN MEASURED AT DIFFERENT BASES
- EVERY BTU MEASURING ANALYZER IS DESIGNED IN SOME WAY TO MEASURE AT A SPECIFIC BASE OF MEASUREMENT---EITHER BY ADJUSTING THE CALIBRATION GAS VALUE TO THE BTU AT THE DESIRED BASE, OR USING THE ANALYZER'S INTERNAL PROGRAMMING TO PRODUCE THE DESIRED BASE RESULTS INTERNALLY

THE MOST IMPORTANT POINT ABOUT BASE OF MEASUREMENT IS THAT

WHEN COMPARING BTU VALUES AMONG AGENCIES, THEIR CUSTOMERS, AND

OTHER LABS, THE COMPARISONS MUST BE MADE AT THE SAME BASE.

THE MOST COMMON ERRORS OCCUR WHEN ONE PARTY IS MEASURING ON A DRY BASE AND THE OTHER IS ON A SATURATED BASE, OR VICE VERSA.

PRESSURE BASE DIFFERENCES ARE ALSO A COMMON SOURCE OF ERROR

EXAMPLES OF THE BTU VALUES OF THE SAME GAS AT DIFFERENT BASES

- PURE METHANE---1014.4 BTU AT BASE OF 14.73PSIA-60 DEG-DRY
- PURE METHANE---996.8 BTU AT BASE OF 14.73PSIA-60 DEG-SATURATED

THE GENERAL MULTIPLYING FACTOR FOR ALL GASES TO CONVERT FROM SATURATED BASE TO DRY IS 1.0177. OBVIOUSLY, FROM DRY TO SAT, MULTIPLY BY 0.9826

EXAMPLE: YOUR BTU ANALYZER AT SATURATED BASE READS 1020 BTU

YOU WISH TO CONVERT IT FOR COMPARISON REASONS TO A DRY BASE

1020 BTU X 1.0177 YIELDS A BTU VALUE OF 1038 BTU AT THE DRY BASE

ALSO IMPORTANT: MEASURING A SAMPLE GAS AT A CERTAIN BASE OF MEASUREMENT

DOES NOT MEAN THAT THE SAMPLE GAS IS AT THOSE CONDITIONS

IT MEANS THAT THE BTU VALUE OF THAT GAS IS BEING MEASURED AS IF THE SAMPLE

GAS WERE AT THOSE CONDITIONS

NOTE: THE TERM “BASE OF MEASUREMENT” IS THE SAME AS “STANDARD CONDITIONS”

ALSO, PRESSURES ARE SOMETIMES EXPRESSED IN “INCHES OF MERCURY”—NOT PSIA

14.735 PSIA = 30 INCHES OF MERCURY PRESSURE

CAUTIONS REGARDING THE ORDERING AND USE OF CALIBRATION GASES

- THE MOST COMMON CALIBRATION GAS USED FOR COMBUSTION-TYPE BTU ANALYZERS IS UHP(ULTRA HIGH PURITY) METHANE, USUALLY PP.99% PURE OR BETTER. IT IS A MAJOR COMPONENT OF NATURAL GAS, AROUND 88% ON AVERAGE—THE BTU AND SPECIFIC GRAVITY ARE WELL-KNOWN, AND IS NORMALLY READILY AVAILABLE FROM SUPPLIERS
- IF YOU RELY ON YOUR GAS SUPPLIER FOR CAL GAS INFORMATION, BE SURE THE BTU VALUE THEY SPECIFY IS AT THE BASE OR STANDARD CONDITIONS YOU SPECIFY
- NOTE THAT SOME CALIBRATION GAS IS STILL CERTIFIED AT A SELDOM USED PRESSURE BASE OF 14.696 PSIA—IF SO YOU MUST CORRECT TO YOUR DESIRED PRESSURE BASE
- ALSO STILL SPECIFIED OCCASIONALLY IS THE BTU VALUE AT “IDEAL” CONDITIONS, MEANING THE VALUE AT “0” PRESSURE BASE. THIS IDEAL VALUE IS ONLY USED IN RESEARCH LABS FOR SPECIAL TESTS
- YOU WILL ALWAYS USE THE “REAL” GAS BTU VALUE, MEANING A PRESSURE BASE ABOVE 0

ALWAYS BE SUSPICIOUS OF A NEW BOTTLE OF CAL GAS TO REPLACE AN EXISTING ONE WHICH HAS A BTU CERTIFICATION MUCH DIFFERENT THAN THE OLD ONE
CHECK THE BASE CONDITIONS OF THE NEW BOTTLE, CORRECT IF NECESSARY

GROSS VS NET HEATING VALUE

- GROSS HEATING VALUE REFERS TO THE BTU VALUE INCLUDING THE HEAT OBTAINED

FROM CONDENSING THE WATER PRODUCED DURING COMBUSTION

- NET HEATING VALUE REFERS TO THE BTU VALUE WITHOUT ACCOUNTING FOR THIS HEAT
- VIRTUALLY ALL BTU MEASUREMENTS IN THE APPLIANCE, PIPELINE, AND
- UTILITY INDUSTRIES USE ONLY THE GROSS HEATING VALUE
- THE NET BTU VALUE IS USED ONLY IN RESEARCH AND SPECIFIC INDUSTRIES

WOBBE NUMBER---WHAT THE HECK IS IT?

- THE “WOBBE” NUMBER IS BEING SEEN AND USED IN MORE ESTING SPECS LATELY.
- THE WOBBE NUMBER OF A GAS IS TECHNICALLY DEFINED AS THE HEATING VALUE DIVIDED BY THE SQUARE ROOT OF THE SPECIFIC GRAVITY OF A GAS.
- THE WOBBE NUMBER OF PURE METHANE AT 14.73PSIA—60DEG---SATURATED IS 1338. THE WOBBE NUMBER CAN BE GIVEN AT ANY BASE CONDITIONS BY USING THE BTU VALUE IN THE EQUATION AT THE DESIRED BASE.
- THE WOBBE NUMBER , THOUGH OFTEN EXPRESSED IN BTU’S, IS JUST A REFERENCE NUMBER, WITH NO UNITS ATTACHED
- THE MAIN USE OF WOBBE IS IN GAS MIXING SITUATIONS, AND COMPARING THE HEAT THROUGH-PUT OF DIFFERENT MIXTURES

IT IS USEFUL BECAUSE DIFFERENT GAS MIXTURES WHICH HAVE THE SAME”WOBBE” NUMBER WILL DELIVER THE SAME AMOUNT OF BTU’S THROUGH THE SAME SIZE

ORIFICE. A 1400 BTU BUTANE/AIR MIX FOR EXAMPLE, WILL DELIVER THE SAME AMOUNT

OF ENERGY THROUGH A GIVEN ORIFICE AS NATURAL GAS, BECAUSE THEY HAVE SIMILAR

WOBBE #

TYPES AND MODELS OF BTU ANALYZERS

- BTU IS A DIFFICULT MEASUREMENT REGARDLESS OF THE TYPE OF ANALYZER, SINCE YOU ARE EITHER MEASURING VERY SMALL DIFFERENCES IN TEMPERATURE, OR MEASURING VERY SMALL DIFFERENCES IN SAMPLE GAS COMPONENTS, DEPENDING ON THE TYPE OF ANALYZER USED
- BTU ANALYZERS FALL INTO 2 MAIN GROUPS, COMBUSTION & CHROMATOGRAPH TYPES, BUT RECENTLY THERE ARE SOME OTHERS BEING MARKETED

COMBUSTION CALORIMETERS

THESE ACTUALLY BURN A SAMPLE OF THE GAS, AND ACCURATELY MEASURE THE HEAT GIVEN OFF, USUALLY THROUGH A STREAM OF AIR. MORE MECHANICAL IN NATURE, CAN BURN DIFFERENT GASES, WORK BEST IN TEMP STABLE ROOM, REQUIRES SINGLE COMPONENT CAL GAS

CHROMATOGRAPHS

THESE DO NOT BURN THE GAS, BUT CARRY THE GAS THROUGH A SERIES OF CHEMICALLY TREATED COLUMNS, OR SMALL TUBING, WHICH SEPARATE IT INTO ITS COMPONENTS, ADDING UP COMPONENTS, CALCULATING BTU HELIUM & MULTICOMPONENT CAL GAS REQUIRED

TYPES AND MODELS OF BTU ANALYZERS

COMMON BRANDS/MODELS

COMBUSTION CALORIMETERS

CUTLER-HAMMER-----UNION

COSA---FLO-CAL

CHROMATOGRAPHS

ABB---DANIELS

AGILANT---PERKIN-ELMER

RECENTLY, BTU ANALYZERS USING LIGHT TO DETERMINE BTU---NEW TECHNOLOGY

WHEN CONSIDERING A NEW HEATING VALUE ANALYZER, MAKE CERTAIN IT MEETS

CERTIFYING AGENCY REQUIREMENTS, IF APPLICABLE

ALSO, CHECK SPECS TO VERIFY USE ON ALL THE SAMPLE TYPES YOU REQUIRE

COMMON CONVERSION FACTORS BETWEEN DIFFERENT BASES
OF MEASUREMENT (STANDARD CONDITIONS)

THE MULTIPLICATION FACTORS LISTED BELOW ASSUME A STARTING BASE OF
14.735 PSIA(30 INCHES HG)—60 DEG F---SATURATED
TO CALCULATE THE BTU AT ONE OF THE BASE CONDITIONS BELOW, MULTIPLY BY FACTOR

DESIRED BASE	FACTOR
14.735-60-DRY	1.0177
14.73-60-SATURATED	0.9996
14.73-60 DRY	1.0173
14.696-60-SATURATED	0.9973
14.696-60-DRY	1.0149