**PDHonline Course M370 (3 PDH)**

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# Ignition Sources for Atmospheric Gas B urners


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# AGSE NATIONAL TECHNICAL CONFERENCE

## AMERICAN SOCIETS OF GAS ENGINEERS

MGM GRAND HOTEL-LAS VEGAS

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ROBERT P. JACKSON, PE

# AGENDA



- REFERENCES
- FUNDAMENTALS OF GASEOUS FUELS
- BURNER CHARACTERISTICS
- IGNITION SYSTEMS
- IGNITION SYSTEM TROUBLE-SHOOTING

# REFERENCES



THE FOLLOWING REFERENCES WERE USED TO DEVELOP SLIDES FOR THE "GASEOUS FUELS" PORTION OF THIS PRESENTATION. WITH ONE EXCEPTION, THE WORK BY DR. LOUIS SHNIDMAN, ALL OF THE REFERENCES ARE IN PRINT AND MAY BE FOUND EITHER ON-LINE, AT BOOKSTORES OR IN ENGINEERING LIBRARIES. THE LAST PUBLICATION OF "GASEOUS FUELS" WAS PRINTED IN 1954, AND EVEN THOUGH A VALUABLE ADDITION TO ANY LIBRARY, "THE GAS ENGINEERS' HANDBOOK" CONTAINS MUCH OF THE INFORMATION FOUND IN "FUELS" WRITTEN BY DR. SHNIDMAN.

# REFERENCES




1. "Household Cooking—Gas Appliances", American National Standard—ANSI Z21.1—2000
2. "Household Cooking—Gas Appliances", American National Standard—ANSI Z 21.1 Addenda to ANSI Z21.1—1996 & 1997
3. "Fundamentals of Gas Combustion", American Gas Association Laboratories, Copyright 1973
4. "Orifice Capacity Charts for Harper Metered Orifices", Harper-Wyman Company
5. "Gaseous Fuels", Louis Shnidman, Published by Mack Printing Company, Copyright 1954
6. "Gas Engineers Handbook", Published by Industrial Press, Copyright 1965
7. "Combustion and Gas Appliances" Carl Suchovsky, Published by Gas Consultants, Cleveland Ohio, Copyright May 2004
8. "National Fuel Gas Code", ANSI Z223.1/NFPA 54
9. "Engineering Fundamentals", 4th Edition, by Michael R. Lindburg, PE, Published by: Professional Publications, Inc. Copyright 1998.
10. "Thermodynamics", by Gordon J. Van Wylen, Published by John Wiley & Sons, Inc, Copyright 1959.

# FUNDAMENTALS OF GASEOUS FUELS

# INTRODUCTION TO GASEOUS FUELS



A VERY BRIEF OVERVIEW OF GASEOUS FUELS IS NECESSARY BEFORE WE PROCEED TO A DISCUSSION OF IGNITION SYSTEMS AND TROUBLE-SHOOTING THOSE SYSTEMS. PROBLEMS WILL ALWAYS ARISE WITH MECHANICAL COMPONENTS AND HOW TO FIND, REPLACE OR FIX IS AN IMPORTANT PART OF AN ENGINEER'S JOB. UNDERSTANDING THE VERY BASICS OF GAS-FIRED COMBUSTION WILL BE A GREAT HELP IN DIAGNOSING A PROBLEM.

IN THE UNITED STATES, THERE ARE BASICALLY THREE PREDOMINANT GASES USED FOR RESIDENTIAL AND COMMERCIAL PURPOSES. THESE ARE AS FOLLOWS:

- NATURAL GAS
- PROPANE GAS
- MANUFACTURED GAS

IN THE CARIBBEAN, SOUTH AMERICA AND PARTS OF THE PACIFIC RIM, BUTANE IS THE FUEL OF CHOICE. FOR THAT REASON, I AM ADDING TO THIS DISCUSSION DATA AND INFORMATION RELATIVE TO THAT FUEL.

ALSO, WITH ENERGY AND CONSERVATION BEING VERY IMPORTANT, THERE IS A HUGE RESURGENCE OF MANUFACTURED AND MIXED GAS. THESE GASES ARE BECOMING MORE AND MORE AVAILABLE; THEREFORE, MANUFACTURED GAS IS DISCUSSED IN THIS PRESENTATION ALSO.

# NATURAL GAS



NATURAL GAS IS BY FAR THE MOST USED FUEL IN THE UNITED STATES. IT IS ESTIMATED THAT 98 PERCENT OF ALL GASEOUS FUELS BURNED BY DOMESTIC AND COMMERCIAL PROCESSES IS NATURAL GAS. PROPANE (LIQUEFIED PETROLEUM ) IS THE SECOND-MOST CONSUMED AND IS USED FOR THE FOLLOWING PURPOSES:

1. A BACKUP SYSTEM TO NATURAL GAS
2. FUELS FOR GAS GRILLS
3. INDUSTRIAL PROCESSES WHERE NATURAL GAS PIPELINES ARE NOT AVAILABLE
4. COMBUSTION SYSTEMS THAT REQUIRE PORTABILITY AND THE ABILITY TO MOVE WITH THE EQUIPMENT

PROPANE AND BUTANE ARE USED EXTENSIVELY IN THE CARIBBEAN AND SOUTH AMERICA AGAIN , WHERE NATURAL GAS PIPELINES ARE NOT AVAILABLE.

THE FOLLOWING SLIDES WILL INDICATE FACTS CONCERNING NATURAL GAS, PROPANE, BUTANE AND MANUFACTURED GAS. PLEASE NOTE THAT THE SPECIFIC GRAVITY AND HEATING VALUE OF EACH GAS IS GIVEN AND PLEASE UNDERSTAND THAT THESE ARE CRITICAL CHARACTERISTICS AND MUST BE CONSIDERED WHEN SELECTING A COMBUSTIBLE FUEL.

# ANSI TEST GASES



CHARACTERISTICS OF ANSI TEST GASES

| | HEATING VALUE | | |
|---|---|---|---|
| | Btu/Ft^3) | MJ/ M^3) | Specific Gravity |
| GAS A (Natural) | 1075 | 40.1 | 0.650 |
| GAS B (Manufactured) | 535 | 19.9 | 0.380 |
| GAS C (Mixed) | 800 | 29.8 | 0.500 |
| GAS D (N-Butane) | 3200 | 119.2 | 2.000 |
| GAS E (Propane HD5) | 2500 | 93.1 | 1.550 |
| GAS F (Propane-Air) | 700 | 26.1 | 1.160 |
| GAS G (Butane-Air) | 1400 | 52.2 | 1.420 |
| GAS H (Propane-Air) | 1400 | 52.2 | 1.300 |

**THESE TEST GASES ARE TAKEN FROM ANSI Z21.1 FOR HOUSEHOLD COOKING APPLIANCES. OTHER PRODUCTS REQUIRING CSA OR INTERNATIONAL APPROVAL MAY HAVE DIFFERENT TEST GASES. ALL OF THESE TEST GASES ARE USED IN QUALIFYING AND CERTIFYING DOMESTIC AND COMMERCIAL COOKING AND HEATING PRODUCTS.**

# ANSI GAS TEST PRESSURES



| ANSI INLET TEST PRESSURES | TEST PRESSURE Inches W.C.(kPa) | | |
|---|---|---|---|
| | REDUCED | NORMAL | INCREASED |
| GAS A (Natural) | 3.5(0.87) | 7.0(1.74) | 10.5(2.61) |
| GAS B (Manufactured) | 3.0(0.75) | 6.0(1.49) | 9.0(2.24) |
| GAS C (Mixed) | 3.0(0.75) | 6.0(1.49) | 9.0(2.24) |
| GAS D (N-Butane) | 8.0(1.99) | 11.0(2.74) | 13.0(3.23) |
| GAS E (Propane HD5) | 8.0(1.99) | 11.0(2.74) | 13.0(3.23) |
| GAS F (Propane-Air) | 3.0(0.75) | 6.0(1.49) | 9.0(2.24) |
| GAS G (Butane-Air) | 3.5(0.87) | 7.0(1.74) | 10.5(2.61) |
| GAS H (Propane-Air) | 3.0(0.75) | 6.0(1.49) | 9.0(2.24) |

**THESE TEST PRESSURES ARE TAKEN FROM ANSI Z21.1 FOR HOUSEHOLD COOKING APPLIANCES. OTHER PRODUCTS REQUIRING CSA OR INTERNATIONAL APPROVAL MAY HAVE DIFFERENT TEST GASES. THE TEST PRESSURES ABOVE INSURE PROPER IGNITION, CARRY-OVER AND EXTINCTION OF THE GASES USED. IT IS CRITICAL THAT ALL TEST PRESSURES, RELATIVE TO THE GAS USED, BE TESTED.**

# NATURAL GAS



There are six basic areas of our country in which Natural Gas is Found

1.) Appalachian
2.) Indiana
3.) Mid-continent
4.) Texas
5.) Rocky Mountains
6.) California

## GROUP CLASSIFICATIONS FOR NATURAL GAS

| GROUP | NITROGEN (%) | SPECIFIC GRAVITY | % METHANE | HEATING VALUE |
|---|---|---|---|---|
| High Inert Type | 6.3--16.20 | 0.660--0.708 | 71.9--83.2 | 958--1051 |
| High Methane Type | 0.10--2.39 | 0.590--0.614 | 87.6--95.7 | 1008--1071 |
| High Btu Type | 1.20--7.50 | 0.620--0.719 | 85.00--90.10 | 1071--1124 |

**The "High Inert" classification comes from the percentage of Nitrogen in the sample. Please note that there is a variation in the heating value and the specific gravity depending upon the region in which the gas was mined and the percentage of nitrogen and methane.**

# CHEMICAL CONSTITUENTS IN NATURAL



NATURAL GAS WILL CONTAIN SEVERAL FLAMMABLE CONSTITUENTS. THESE ARE GENERALLY METHANE, ETHANE, PROPANE, ISO-BUTANE AND POSSIBLY HEAVIER HYDROCARBONS. THE "MIX" WILL VARY, BUT ALL WILL BE CLASSIFIED WITHIN THE PARAFFIN FAMILY OF COMBUSTIBLES. THE NEXT SLIDE WILL SHOW TWELVE SAMPLES OF NATURAL GAS TAKEN FROM EACH OF THE SIX LOCATIONS IN THE UNITED STATES. AS YOU CAN SEE, THE CONSTITUENTS VARY BUT THE MAJOR CONSTITUENT IS ALWAYS CH(4), METHANE.

# MAJOR CONSTITUENTS



## TYPICAL COMPOSITION OF NATURAL GAS

| SAMPLE NUMBER | PERCENT OF VARIOUS COMPONENTS | | | | |
|---|---|---|---|---|---|
| | CH(4) (METHANE) | C(2)H(6) ETHANE | N(2) NITROGEN | CO(2) CARBON DIOXIDE | 0(2) OXYGEN |
| 1 | 88.20 | 3.20 | 7.68 | 0.16 | 0.14 |
| 2 | 81.91 | 17.51 | 0.11 | 0.31 | 0.16 |
| 3 | 98.59 | 0.00 | 0.94 | 0.31 | 0.16 |
| 4 | 82.56 | 16.51 | 0.16 | 0.31 | 0.16 |
| 5 | 94.73 | 2.64 | 1.89 | 0.30 | 0.44 |
| 6 | 66.31 | 31.70 | 1.21 | 0.47 | 0.31 |
| 7 | 89.04 | 5.63 | 4.68 | 0.21 | 0.44 |
| 8 | 90.52 | 4.56 | 4.29 | 0.21 | 0.42 |
| 9 | 98.40 | 1.00 | 0.50 | 0.00 | 0.10 |
| 10 | 82.60 | 7.20 | 7.10 | 2.70 | 0.40 |
| 11 | 74.20 | 18.50 | 7.30 | | |
| 12 | 67.90 | 26.10 | 6.00 | | |

# LIQUIFIED PETROLEUM



LIQUIFIED PETROLEUM IS DEFINED AS BEING PROPANE AND BUTANE. BOTH ARE PARAFFIN-BASED COMBUSTIBLE GASES USED AROUND THE WORLD. MANY OF THE CHARACTERISTICS BETWEEN THE TWO GASES VARY, BUT THE MOST IMPORTANT DIFFERENCES ARE AS FOLLOWS:

- SPECIFIC GRAVTY
- HEATING VALUE
- PERCENT AIR IN AIR-GAS MIXTURE NEEDED TO ACHIEVE COMPLETE COMBUSTION
- LIMITS OF FLAMMABILITY
- INITIAL BOILING POINT
- LIQUIFIED PETROLEUM IS ALWAYS DELIVERED UNDER CONSIDERABLE PRESSURE SO THAT THE FUEL IS MAINTAINED IN THE LIQUIFIED FORM UNTIL READY FOR USE. WHEN THE PRESSURE IS REMOVED, THE FUEL VAPORIZES.

# LIQUIFIED PETROLEUM



## AVERAGE PROPERTIES OF COMMERCIAL LPG

| | Propane | Butane |
|---|---|---|
| Vapor Pressure, psig | | |
| 70 deg F | 124 | 31 |
| 90 deg F | 167 | 49 |
| 100 deg F | 192 | 59 |
| 105 deg F | 206 | 65 |
| 130 deg F | 286 | 97 |
| Specific Gravity of Liquid | 0.509 | 0.582 |
| Initial Boiling Point ( 14.7 psia ),F | -51 | 15 |
| Weight/gal liquid @ 60 deg F, lbs | 4.24 | 4.84 |
| Dew Point @14.7 psia, F | -46 | 24 |
| Specific Heat of Gas, C(p) | 0.404 | 0.382 |
| Specific Gravity (air = 1 ) | 1.52 | 2.01 |
| Ignition Temperature, F | 920-1020 | 900-1000 |
| Max. Flame Temp, F | 3595 | 3615 |
| Max. Rate of Flame Velocity | | |
| Cm /sec | 84.9 | 87.1 |
| In/ sec | 33.4 | 34.3 |
| Limits of Flammability, %gas-air | | |
| Lower Limit | 2.40 | 1.90 |
| Higher Limit | 9.60 | 8.60 |
| Required for Complete Comb (%) | | |
| cu ft O(2)/cu ft gas | 4.90 | 6.30 |
| cu ft air / cu ft gas | 23.40 | 30.00 |
| lbs O(2)/lb gas | 3.60 | 3.54 |
| lbs air / lb gas | 15.58 | 15.30 |
| Products of Complete Comb | | |
| cu ft CO(2) / cu ft gas | 3.00 | 3.90 |
| cu ft H(2)O / cu ft gas | 3.80 | 4.60 |
| cu ft N(2) / cu ft gas | 18.50 | 23.70 |
| Ultimate CO by Vol. | 13.90 | 14.10 |
| Total Heating Values after Vap | | |
| Btu/cu ft | 2522 | 3261 |
| Btu/ lb | 21560 | 21180 |
| Btu/gal | 91500 | 102591 |

# MANUFACTURED GAS



MANUFACTURED GAS IS JUST THAT—A GASEOUS FUEL THAT RESULTS FROM PROCESSES DESIGNED TO DISTILL OR PROVIDE, AS A BY-PRODUCT, A COMBUSTIBLE FUEL. THE NEXT SLIDE WILL SHOW THE INITIAL SOURCE FOR SEVERAL GAS TYPES, THE HEATING VALUE AND SPECIFIC GRAVITY RESULTING FROM THE PROCESS. IT IS IMPORTANT TO NOTE THAT MANUFACTURED GAS, RELATIVE TO NATURAL, PROPANE AND BUTANE GASSES, HAS A CONSIDERABLY LOWER HEATING VALUE AND LOWER SPECIFIC GRAVITY. ORIFICE SIZE DETERMINATIONS AND FLOW THROUGH A BURNER ARE DETERMINED BY HEATING VALUE AND SPECIFIC GRAVITY, THEREFORE, THESE VALUES BECOME VERY IMPORTANT RELATIVE TO INDIVIDUAL BURNER PERFORMANCE.

# MANUFACTURED GAS



## MANUFACTURED GASES –TYPICAL ANALYSIS

| GAS TYPE | SOURCE | SPECIFIC GRAVITY | GROSS HEATING VALUE |
|---|---|---|---|
| Acetylene | Calcium carbide & water | 0.91 | 1499 |
| Blast Furnace | By-product, pig iron | 1.04 | 81 |
| Blue | Coke | 0.54 | 300 |
| Blue | Bituminous Coal | 0.55 | 335 |
| Blue | Coke,steam, oxygen | 0.75 | 262 |
| Butane | Natural gas | 2.07 | 3371 |
| Butane | Refinery gas | 2.03 | 3310 |
| Carbureted Water | Low gravity back run | 0.54 | 536 |
| Carbureted Water | High Btu | 0.69 | 850 |
| Coal | Continuous vertical retort | 0.47 | 358 |
| Coal | Horizontal retort | 0.42 | 532 |
| Coal | Inclined retort | 0.47 | 542 |
| Coke Oven | By-product | 0.36 | 567 |
| Coke Oven | By-product | 0.40 | 580 |
| Coke Oven | 9 Hr. charging | 0.31 | 502 |
| Refinery Oil | Blain down blast | 0.45 | 586 |
| Refinery Oil | Coke-fire | 0.66 | 970 |
| Refinery Oil | Twin generator | 0.80 | 1000 |

**MANUFACTURED GAS TYPICALLY HAS A LOWER HEATING VALUE THAN NATURAL GAS AND CERTAINLY LOWER THAN LP GAS.**

# GAS FACTS – NATURAL GAS



SPECIFIC GRAVITY = 0.56

HEATING VALUE = 1,000 BTU/$FT^3$ (APPROXIMATELY )

FLAME TEMPERATURE = 3416° F

FLAME SPEED PROPAGATION = 26.00 INCHES / SECOND

LIMITS OF FLAMMABILITY = 5.00 TO 15 %

IGNITION TEMPERATURE = 1202° F

AIR REQUIRED FOR COMPLETE COMBUSTION = 9.6$FT^3$ /$FT^3$ GAS

# GAS FACTS – LP



## PROPANE GAS

SPECIFIC GRAVITY = 1.55

HEATING VALUE = 2588 BTU/$FT^3$

FLAME TEMPERATURE = 3497° F

FLAME SPEED PROPAGATION = 32.00 INCHES / SECOND

LIMITS OF FLAMMABILITY = 2.57 TO 9.5 %

IGNITION TEMPERATURE = 932° F

AIR REQUIRED FOR COMPLETE COMBUSTION = 26.3 $FT^3$ /$FT^3$ GAS

# GAS FACTS – LP



## BUTANE GAS

SPECIFIC GRAVITY = 2.00

HEATING VALUE = 3184 $BTU/FT^3$

FLAME TEMPERATURE = 3443° F

FLAME SPEED PROPAGATION = 33.00 INCHES / SECOND

LIMITS OF FLAMMABILITY = 1.86 TO 8 .41 %

IGNITION TEMPERATURE = 896° F

AIR REQUIRED FOR COMPLETE COMBUSTION = 31.1 $FT^3$ /$FT^3$ GAS

# ALTITUDE CONSIDERATIONS FOR GASEOUS FUELS

BURNER INPUTS ARE DEFINITELY AFFECTED BY ALTITUDE. AS THE ALTITUDE INCREASES, THE ATMOSPHERIC PRESSURE DECREASES AND THE AMOUNT OF PRIMARY AND SECONDARY AIR AVAILABLE FOR MIXING IS LESSENED. FOR PROPER COMBUSTION, THIS NECESSITATES RECALCULATION OF THE ORIFICE SIZE NEEDED. GENERALLY, BURNER INPUTS ARE DECREASED AS THE ALTITUDE INCREASES. THIS IS GOVERNED BY THE "FUEL GAS CODES" AND BY THE AMERICAN NATIONAL STANDARDS INSTITUTE. THE TABLE THAT FOLLOWS WILL INDICATE THE POSSIBLE EFFECTS ON COMBUSTION PROCESSES.

# ALTITUDE CONSIDERATIONS



## ALTITUDE:

Altitude is actually not a problem but leads to several problems. As the altitude increases, the atmospheric pressure decreases and the availability of primary air decreases. Generally, there are no corrections for input at altitudes less than 2,000 feet above sea level. As per the National Fuel Gas Code ( ANSI Z223.1/ NFPA 54 ) "above 2,000 feet, the appliance must be derated 4% for every 1,000 feet above sea level". Also, pressure switches and other components do not react the same at higher elevations.

| Effect of Elevation on Normal Barometric Pressure | | |
|---|---|---|
| Elevation (Feet) | Decrease in pressure per foot of added elevaton in inches of mercury | Normal barometric pressure a start of zone of elevations in inches of mercury |
| Sea level to 1,000 | 0.00112 | 29.92 |
| 1,000 to 2,000 | 0.00108 | 29.82 |
| 2,000 to 3,000 | 0.00104 | 27.78 |
| 3,000 to 4,000 | 0.00100 | 26.77 |
| 4,000 to 5,000 | 0.00096 | 25.81 |
| 5,000 to 6,000 | 0.00920 | 24.87 |

# CHARACTERISTICS OF GASEOUS FUELS MOST USED IN USA



| GAS | IGNITION TEMPERATURES (°F) | FLAME TEMPERATURES (°F) | FLAME SPEED INCHES/SEC | FLAMMAILITY LIMITS (HIGHER %) | %AIR $FT^3/FT^3$GAS | HEATING VALUE $BTU/FT^3$ |
|---|---|---|---|---|---|---|
| NATUTRAL | 1202 | 3416 | 26 | 15 | 9.6 | 1022 |
| PROPANE | 920--1020 | 3497 | 33.4 | 9.5 | 23.9 | 2522 |
| BUTANE | 900--1000 | 3443 | 34.3 | 8.44 | 31.1 | 3261 |

LOWER LIMIT OF FLAMMABILITY = 5.00%
UPPER LIMIT OF FLAMMABILITY = 15.00%

**The limits of flammability are always given as the percentage of gas in the gas-air mixture. The values above are for natural gas and show a range of values ignition through which ignition may occur. As you can see, the lower limit is 5% and the upper limit is 15%. There is a considerable differences in flammability limits for the three gases.**

# GASEOUS MIXTURES



IT IS NOT UNCOMMON TO FIND COMBUSTIBLE GASEOUS FUELS THAT DO NOT FIT NEATLY INTO THE NATURAL, LP ( PROPANE AND BUTANE ) OR MANUFACTURED CATEGORIES. IN DEALING WITH VENDORS IN SOUTH AMERICA, THE CARIBBEAN, THE MIDDLE-EAST AND ASIA, I HAVE FOUND A REMARKABLE VARIETY OF COMBUSTIBLE MIXTURES THAT EXHIBIT SIGNIFICANT DIFFERENCES IN SPECIFIC GRAVITY AND HEATING VALUES RELATIVE TO THE “GAS FACTS” GIVEN EARLIER.

IT IS VERY IMPORTANT TO KNOW AS MUCH ABOUT THE COMBUSTIBLE MIXTURE AS POSSIBLE BUT CERTAINLY THE HEATING VALUE AND THE SPECIFIC GRAVITY. THE SIMPLE EXCEL CHART FOLLOWING THIS SLIDE WILL GIVE A QUICK METHOD FOR DETERMINING THOSE TWO VALUES.

THE REAL PROBLEM LIES IN GETTING THE VENDOR OR BOTTLER TO DECLARE THE CONSTITUENTS IN THE MIXTURE. THIS MAY TAKE SOME PERSUASION AND TIME. GE ALWAYS REQUIRED A LETTER OF DECLARATION FROM THE PRIMARY SUPPLIER.

# PHYSICAL PROPERTIES OF PARAFFIN SUBSTANCES



**Before we look at the excel spreadsheet, let's examine several characteristics for several members of the paraffin family. These are given below.**

| Substance | lb/lb of Comb Req O(2)/AIR | Ignition Temp (F) | Limits of Flammability % gas in air LOWER/UPPER | Flame Temp (F) |
|---|---|---|---|---|
| Methane | 4.049/17.195 | 1301 | 5.00/15.00 | 3484 |
| Ethane | 3.688/15.899 | 968-1166 | 3.00/12.50 | 3540 |
| Propane | 3.537/15.246 | 871 | 2.10/10.10 | 3573 |
| n-Butane | 3.476/14.984 | 761 | 1.86/8.41 | 3583 |
| iso-Butane | 3.476/14.984 | 864 | 1.80/8.44 | 3583 |
| n-Pentane | 3.554/15.323 | 588 | 1.40/7.80 | N/A |
| iso-Pentane | 3.554/15.323 | 788 | 1.32/N/A | N/A |
| Neopentane | 3.554/15.323 | 842 | N/A/N/A | N/A |
| n-Hexane | 3.535/15.238 | 478 | 1.25/6.90 | N/A |
| Neohexane | 3.535/15.238 | 797 | N/A/N/A | N/A |
| n-Heptane | N/A | 433 | 1.00/6.00 | N/A |
| Triptane | N/A | N/A | N/A/N/A | N/A |
| n-Octane | N/A | 428 | 0.95/3.20 | N/A |
| iso-Octane | N/A | N/A | N/A/N/A | N/A |

# CALCULATION FOR TOTAL HEATING VALUE AND SPECIFIC GRAVITY OF GASEOUS MIXTURES

| GAS | MIXTURE % | HEATING VALUE Btu/Ft^3 | CONTRIBUTION TO FINAL MIX Btu/Ft^3 | SP.GR | CONTRIBUTION TO FINAL MIX SP.GR |
|---|---|---|---|---|---|
| METHANE | 0.70 | 1012 | 708.4 | 0.554 | 0.3878 |
| ETHANE | 0.10 | 1786 | 178.6 | 1.038 | 0.1038 |
| PROPANE | 0.10 | 2563 | 256.3 | 1.552 | 0.1552 |
| NITROGEN | 0.10 | 0 | 0 | 0.967 | 0.0967 |
| TOTAL MIXTURE | | | 1143.3 | | 0.7435 |

Table for Computing Total Heating Value and Total Specific Gravity

1. The individual constituents for the gaseous “mix” must be known along with their heating values and specific gravities.
2. Using an Excel spreadsheet, construct the table as show in the example above.
3. Multiply the contents of columns two and three and put the results in column four.
4. Multiply the contents of columns two and five and put the results in column six.
5. Add the values in column four to get the TOTAL HEATING VALUE.
6. Add the values in column six to get the TOTAL SPECIFIC GRAVITY.

# INTERCHANGEABILITY OF GASES



Two gases may be regarded as interchangeable if their flame characteristics are satisfactory after substitution of one gas for another. A flame which does not lift, yellow tip, produce carbon ( sooting ), produce carbon monoxide in excess percentages or flash back, is considered satisfactory in this frame of reference. One way to look at interchangeability is to check for similarities of flow through an orifice. Interchangeability is very important due to the need to substitute one gas for another during periods of increased demand. ( This is not to be confused with "peak shaving". )

There are several mathematical models used to evaluate the interchangeability of gases. These are as follows:

**AGA Interchangeability Indexes:**

- " C " Factor—Research involving 250 different gas mixtures.
- Lifting, Flashback and Yellow Tipping—How gases over 800 Btu/Ft$^3$ could supplement or be substituted for natural or high-Btu gases, where I(L) = lifting index, I(F) = flashback index and I(Y) = yellow tipping index.

# INTERCHANGEABILITY OF GASES (CONTINUED)



**Other Indexes:**

- Knoy Formulas
- Weaver Indexes
- Bureau of Mines Interchangeability Studies
- Wobbe Index-- The Wobbe Index is the main indicator of interchangeability of fuel gases, such as natural gas, LPG, manufactured gas, etc. This index is not used that frequently in the United States or Canada but is used over the remainder of the world and provides a great comparison of fuel gas characteristics. It basically compares the heat input factor of a burner at constant pressure. The Wobbe Index is defined by the following equation.

$$\text{Wobbe Index} = HV / \sqrt{Sp.Gr.}$$

where HV = heating value and Sp Gr = the specific gravity of the gaseous fuel. The table below will indicate the Wobbe Index of several gases.

# WOBBE INDEX OF VARIOUS GASES



| WOBBE INDEX | | | | |
|---|---|---|---|---|
| GAS | UPPER INDEX | LOWER INDEX | UPPER INDEX | LOWER INDEX |
| | kCAL/m^3 | kCAL/m^3 | Btu/Ft^3 | Btu/Ft^3 |
| Hydrogen | 11,528 | 9,715 | 1295.7472 | 1091.966 |
| Methane | 12,735 | 11,452 | 1431.414 | 1287.2048 |
| Ethane | 16,298 | 14,931 | 1831.8952 | 1678.2444 |
| Ethylene | 15,253 | 14,344 | 1714.4372 | 1612.2656 |
| Natural gas | 12,837 | 11,597 | 1442.8788 | 1303.5028 |
| Propane | 19,376 | 17,817 | 2177.8624 | 2002.6308 |
| Propylene | 18,413 | 17,180 | 2069.6212 | 1931.032 |
| n-butane | 22,066 | 20,336 | 2480.2184 | 2285.7664 |
| Iso-butane | 21,980 | 20,247 | 2470.552 | 2275.7628 |
| Butylene-1 | 21,142 | 19,728 | 2376.3608 | 2217.4272 |
| LPG | 20,755 | 19,106 | 2332.862 | 2147.5144 |
| Acetylene | 14,655 | 14,141 | 1647.222 | 1589.4484 |
| Carbon monoxide | 3,060 | 3,060 | 343.944 | 343.944 |

# BURNER CHARACTERISTICS

# BURNER CHARACTERISTICS



THE COMPONENT THAT DETERMINES INPUT AND FLOW RATE FOR ANY BURNER IS THE BURNER ORIFICE. IT IS INTEGRAL TO THE OPERATION OF THE BURNER ITSELF. THERE ARE BASICALY TWO ORIFICE TYPES; 1.) FIXED AND 2.) ADJUSTABILE. TRADITIONALLY, FIXED ORIFICES ARE USED FOR PRODUCTS SUCH AS RANGES, WATER HEATERS AND HOME HEATING SYSTEMS. BURNERS THAT WILL BURN ONE TYPE OF GAS; I.E. NATURAL, PROPANE, BUTANE, MANUFACTURED, ETC AND NEVER EXPERIENCE THE NEED FOR CHANGE-OVER TO ANOTHER TYPE OF GAS CAN USE A FIXED ORIFICE. ANY TIME THE NEED TO CHANGE FROM ONE TYPE OF GAS TO ANOTHER OCCURS, THE BURNER ORIFICE MUST BE RESIZED AND THE GAS REGULATOR MUST BE CHANGED OR MODIFIED TO ADDRESS THE DELIVERY PRESSURE. THE NEXT TWO SLIDES WILL SHOW THESE TWO ORIFICE TYPES.

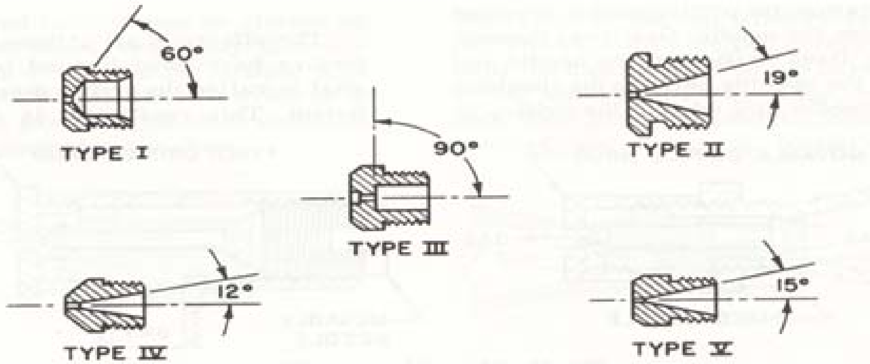
THE FORMULA FOR CALCULATING THE FLOW RATE IN $FT.^3$ PER HOUR IS GIVEN IN THE NEXT SLIDE. ALL OF THE INPUT TABLES USE THIS CALCULATION FOR THEIR TABULATIONS.

# BURNER ORIFICES



$q = 1658.5\ KA \sqrt{H/d}$ where

q = gas discharge in $Ft^3$ / hr
K = coefficient of discharge ( This is dependent upon orifice design and is given in the following table.)
A = area of orifice in $in^2$
H = gas pressure in W.C.
d = specific gravity of gas

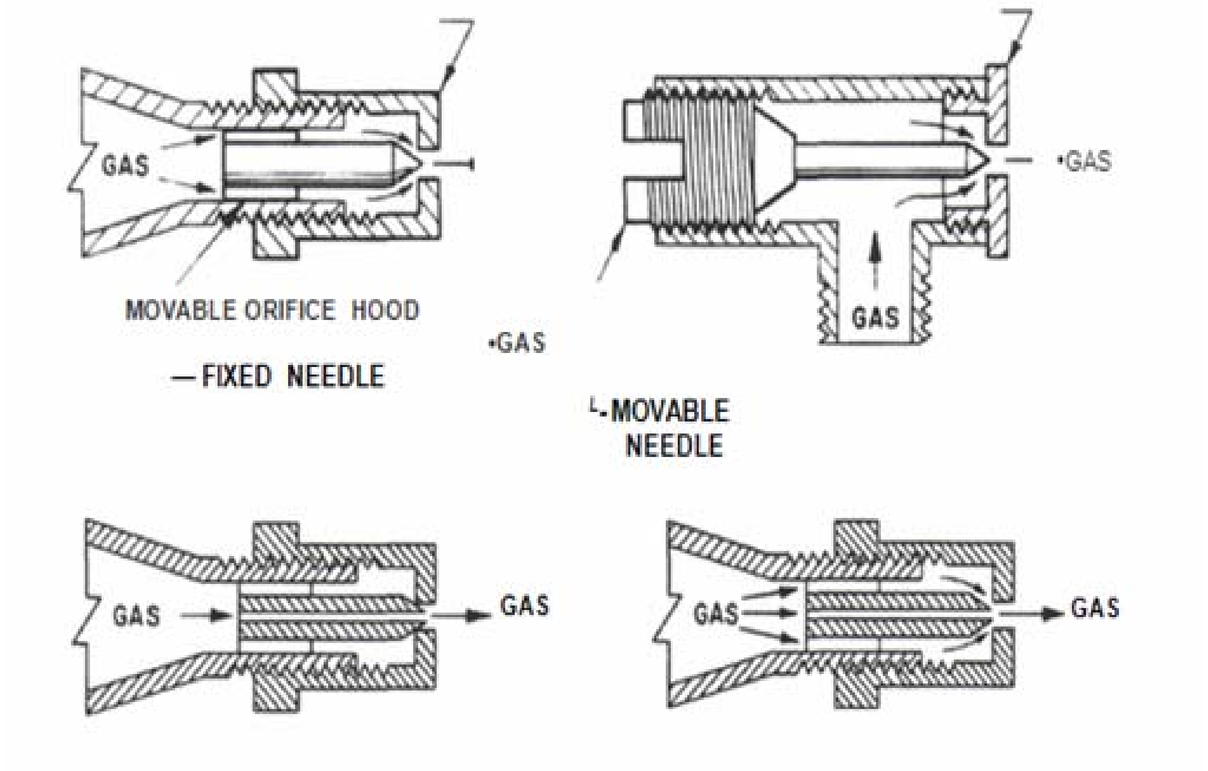



| ORIFICE TYPE | ORIFICE DISCHARGE COEFFICIENT |
|---|---|
| I | 0.80 |
| II | 0.82 |
| III | 0.65 |
| IV | 0.83 |
| V | 0.83 |

**Each orifice type has a specific "K" factor. Please note that for approach angles up to 60 degrees, the "K" factor is roughly 0.80.**

# BURNER ORIFICES (CONTINUED)






ADJUSTABLE ORIFICES

**These orifices are typically found in oven cavities where the change from natural to propane gas can occur.**

# GOOD COMBUSTION



GOOD COMBUSTION IS NOT AN ACCIDENT.  CAREFUL PLANNING, GOOD BURNER DESIGN AND GOOD SYSTEM DESIGN ALL CONTRIBUTE TO SATISFACTORY PERFORMANCE AND INSURE LONG LIFE WITH NO REAL ISSUES.  THE NEXT SEVERAL SLIDES WILL GIVE EXAMPLES OF GOOD COMBUSTION AND REALLY BAD COMBUSTION.  YOU WILL BE ABLE TO SEE FOR YOURSELF THE EFFECTS OF A GOOD SYSTEM DESIGN.  THE TEXT ACCOMPANYING THE PICTURES WILL DEFINE “GOOD” AND “BAD”.

# GOOD COMBUSTION



**IDEAL BURNER CHARACTERISTICS:**

1. Blue flame with possibly some yellow tips when using propane or butane as the fuel. **( NOTE: These burners are firing natural gas with a heating value of approximately 1075 Btu/Ft³ )**
2. Distinct individual flame pattern. You can count the number of ports by counting the number of individual flames emanating from those ports.
3. No blowing or lifting of flames; i.e., separation of the flame from the burner port.
4. No lazy flames. ( This is an indication of too little primary or secondary air. )
5. No flash-back of burner flames.
6. No offensive noise during ignition, operation or extinction.
7. No offensive odors emanating from the combustion process.
8. Flame heights are uniform around the burner periphery. **( NOTE: In looking at the simmer burners below ( smaller burners ), you will notice that the flame heights are not equal. This is by design and involves the configuration of the burner grates mounted above the burners themselves. )**

# BURNERS FIRING IMPROPERLY



1. Yellow flames—even for propane or butane—this would be a terrible flame pattern.
2. Flame heights very irregular.
3. No distinct flame patterns.
4. Indications that there are considerable issues with pressure or pressure drop through the system.
5. Lazy flames indicating issues with primary air.
6. Evidence of sooting ( carboning ) that will produce excessive CO.

# ISSUES



The following issues and considerations are very important to gas burners and burner systems. Proper burner design and application can alleviate many of the problems that can occur.

1. TIME TO LIGHT—The time it takes for the burner to ignite leaving no uncombusted gas-air mixture in the burner head or port area. Generally, the time-to-light maximum is four (4) seconds.

2. FLAME CARRYOVER—The time it takes for ALL burner ports to ignite. It is very critical that they all do ignite and no raw gas be left in the combustion chamber.

3. BLOWING OFF OR LIFTING OF BURNER FLAMES—Flames igniting but lifting from the individual ports. This occurs when the velocity of the gas-air mixture is greater than the velocity of the flame front for the gas being combusted.

4. LAZY FLAME—A flame that is “seeking” primary air; consequently, moving about the burner head in a random manner. This condition may produce excessive carbon monoxide.

# ISSUES CONTINUED



5.) FLASHBACK—Burner flashback occurs when the velocity of the gas-air mixture issuing from the burner ports is less than the velocity of the gas flame front for the gas in use. This causes the flame to "flash back" to the burner orifice.

6.) PRESSURE LOSS IN GAS DELIVERY SYSTEM—The Enemy. Pressure loss will reduce the amount or primary air entrained into the burner and can create a lack of air necessary for complete combustion.

7.) ALIGNMENT OF BURNER ORIFICE WITH BURNER VENTURE- The centerline of the burner orifice, relative to the centerline of the burner venture, should be collinear. It has been proven that an angle much greater than 3 degrees can be very detrimental for production of a homogenous mixture of gas and primary air.

8.) YELLOW TIPPING—Yellow tipping is a sign of incomplete combustion and that primary and / or secondary air is not adequate. LP gasses may exhibit some yellow tipping but an inordinate amount is not at all good.

# PRIMARY AIR VS LIFTING



THE NEXT TWO SLIDES ARE INSERTED TO MERELY SHOW RELATIONSHIPS DO EXIST THAT CAN AND DO DETERMINE THE OPERATION OF A BURNER. WE WILL INDICATE AND LIST THOSE RELATIONSHIPS WITH SLIDES 38, 39, AND 40.

# PRIMARY AIR VS LIFTING



| Percent Primary Air at Lifting Btu/Sq. In Port Area | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Port Size | Natural | | | Butane | | | Manufactured | | |
| | 15,000 | 20,000 | 25,000 | 15,000 | 20,000 | 25,000 | 15,000 | 20,000 | 25,000 |
| 50 | 57 | 52 | 48 | | | | | | |
| 46 | 65 | 58 | 53 | 59 | 49 | 44 | 106 | 104 | 102 |
| 36 | 71 | 64 | 55 | 68 | 59 | 52 | 114 | 109 | 106 |
| 30 | 72 | 65 | 58 | | | | | | |
| 75 | 67 | 60 | 74 | 65 | 57 | 118 | 112 | 108 | |
| 0.25 | 96 | 87 | 78 | 82 | 73 | 64 | 133 | 125 | 119 |

**This chart shows that the smaller the port size the greater the tendency for flames to lift from burner ports. As port size is increased a higher percentage of primary air may be accommodated before lifting occurs. It also shows that butane has a slightly greater tendency to lift from ports than natural gas. On manufactured gas, the lifting limits are so high they are seldom reached on commercial burners.**

# LIFTING LIMITS VS PORT SIZE



| | MFG Gas | | | | Natural Gas | | | | Butane Gas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % Primary Air at Yellow-Tip Limit | | | Rate Below Which Yellow-Tips Disappears No Primary Air Btu/Hr-Sq.In | % Primary Air at Yellow-Tip Limit | | | Rate Below Which Yellow-Tips Disappears No Primary Air Btu/Hr-Sq.In | % Primary Air at Yellow-Tip Limit | | | Rate Below Which Yellow-Tips Disappears No Primary Air Btu/Hr-Sq.In |
| Port Size | 15M | 20M | 25M | | 15M | 20M | 25M | | 15M | 20M | 25M | |
| 0.250 | 19 | 20 | 21 | | 38 | 39 | 39 | | 58 | 58 | 58 | |
| 26DMS | 6 | 9 | 11 | 6500 | 24 | 26 | 28 | | 48 | 50 | 52 | |
| 36DMS | 2 | 5 | 7 | 12500 | 19 | 21 | 22 | | 38 | 42 | 45 | |
| 46DMS | | | | 28000 | 11 | 13 | 15 | | | 32 | 38 | |
| 60DMS | | | | 95000 | | | | 46500 | | | | |

**This table shows that as the port size is increased, a greater percentage of primary air is required to preclude yellow tips.**

# CRITICAL BURNER RELATIONSHIPS



1. AIR SHUTTER DESIGN
2. THROAT TO PORT AREA RATIO
3. DISTANCE OF GAS ORIFICE TO BURNER THROAT
4. ANGLE OF DIVERGENCE FOR VENTURE TUBE DOWNSTREAM OF THROAT
5. LENGTH OF MIXING TUBE
6. PORT SIZE
7. PORT DEPTH
8. NUMBER OF PORTS, CONSEQUENTLY PORT LOADING
9. PORT SPACING & NUMBER OF PORT ROWS

# IGNITION SYSTEMS

# IGNITION TYPES



THE FOLLOWING IGNITION SYSTEMS ARE ON THE MARKET TODAY. BY FAR, THE MOST PROMINENT THREE ARE THE STANDING PILOT, SPARK IGNITION AND HOT SURFACE IGNITION SYSTEMS. THE PIEZOELECTRIC SYSTEM IS USED PRIMARILY IN GAS GRILL COOKING PRODUCTS. THERE ARE MILLIONS OF GAS GRILLS PRODUCED EACH YEAR SO THE PIEZOELECTRIC DEVICE IS DISCUSSED EVEN THOUGH IT IS VERY SPECIFIC TO THAT PRODUCT AND HAS ITS VERY OWN DESIGN CRITERIA.

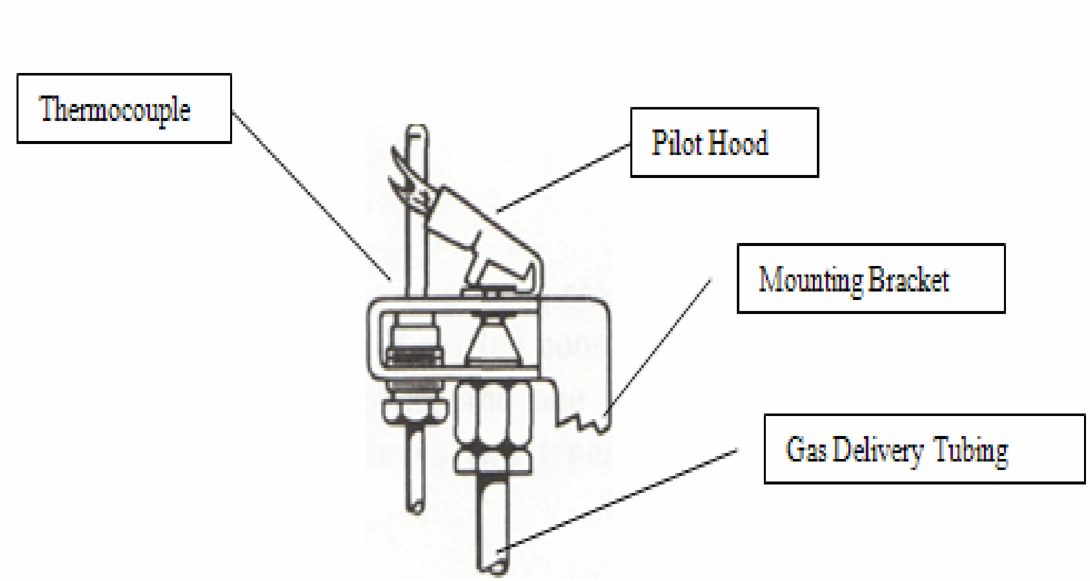
IT IS AMAZING TO ME THAT THE MATCH-LIGHT SYSTEM IS STILL AROUND. IN MANY PARTS OF THE WORLD TODAY, IT IS THE IGNITION SYSTEM OF CHOICE. MANY PARTS OF SOUTH AMERICA AND ASIA STILL REQUIRE A MATCH TO FIRE UP THE “COOKER”. WE WILL NOT BE DISCUSSING THAT SYSTEM SINCE THERE IS NOT MUCH TO DISCUSS.

ANOTHER SYSTEM THAT IS DEFINITELY IN USE, BUT FOR AIRCRAFT ENGINES, IS THE MAGNETO DEVICE. HERE AGAIN, WE WILL LEAVE THAT DISCUSSION FOR ANOTHER TIME AND ANOTHER PLACE.

1. **STANDING PILOT**
2. **SPARK IGNITION**
3. **HOT SURFACE**
4. **HYBRID SYSTEMS**
5. **FLAME FAILURE DEVICES (FFD)**
6. **PIEZOELECTRIC**
7. **MAGNETO IGNITION SYSTEMS**
8. **RE-IGNITION DEVICES**
9. **MATCH LIGHT**

# STANDING PILOT IGNITION SYSTEM

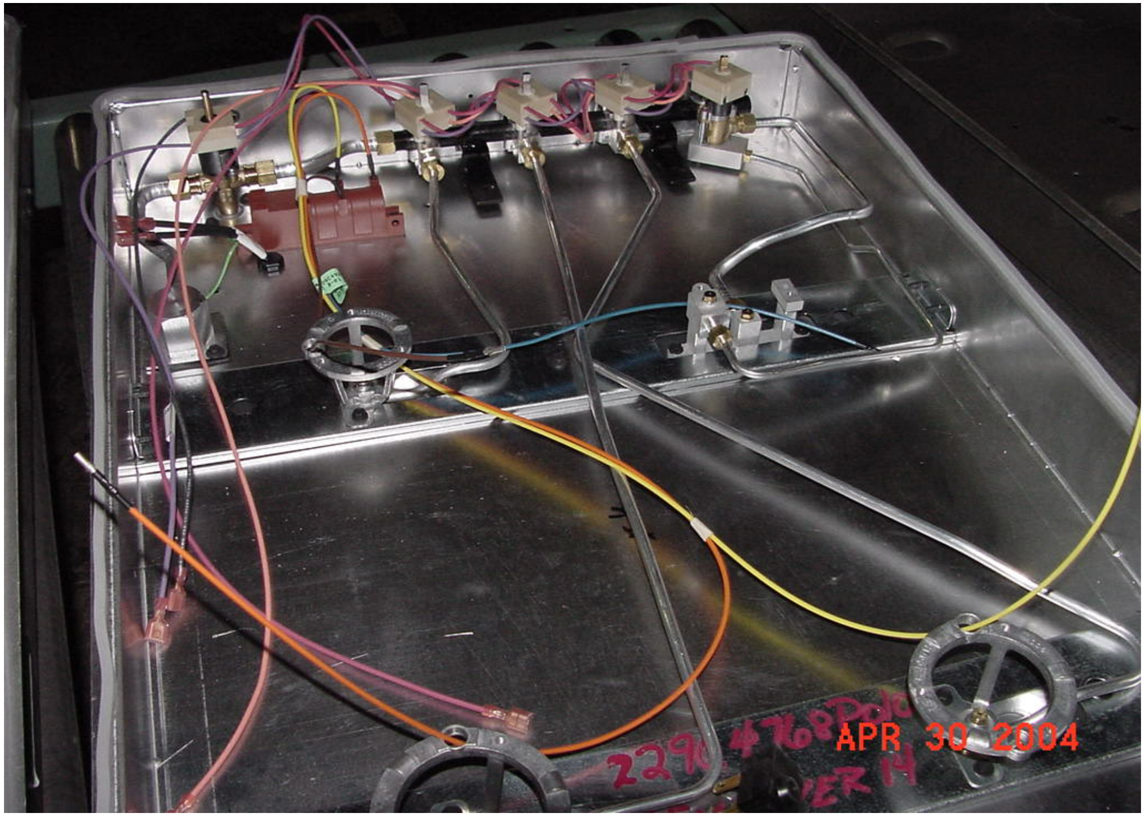





THE STANDING PILOT SYSTEM HAS BEEN AROUND FOR YEARS BUT IS SLOWLY BEING REPLACED BY SPARK IGNITION OR HOT SURFACE IGNITION SYSTEMS. THE THERMOCOUPLE AND GAS TUBING ARE CONNECTED TO A CONTROL VALVE THAT ALLOWS GAS TO FLOW WHEN THE SOLENOID IN THE GAS VALVE IS “MADE” OR ENERGIZED. AN OPEN FLAME IMPINGING UPON THE THERMOCOUPLE GENERATES A MILLI-VOLTAGE; THEREBY, ACTUATING A SOLENOID. THE SOLENOID, GENERALLY BEING NORMALLY CLOSED, WILL CYCLE OPEN, DRIVING A SMALL GAS VALVE THAT ALLOWS GAS TO FLOW TO THE PILOT BURNER. IT IS A VERY STRAIGHTFORWARD SYSTEM AND HAS A PROVEN TECHNOLOGY.

# SPARK IGNITION SYSTEM



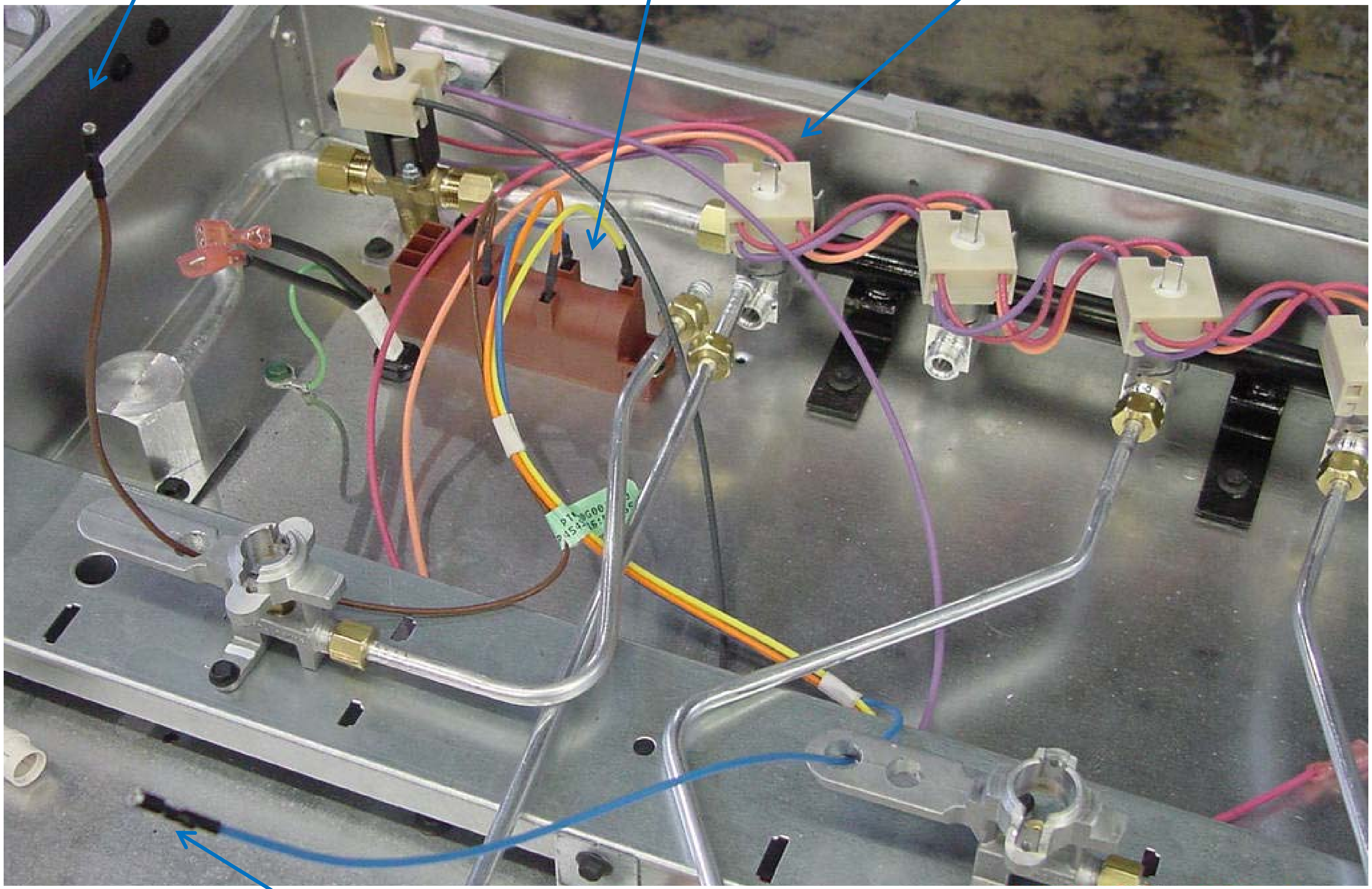



**TYPICAL SPARK IGNITION COMPONENTS**

1. SPARK MODULE
2. SPARK ELECTRODES
3. IGNITION SWITCHES ( VALVE SWITCHES )
4. IGNITION WIRING
5. IGNITION WIRING TERMINATIONS
6. GAS TUBING AND FITTINGS

# SPARK IGNITION COMPONENTS





# SPARK ELECTRODE PLACEMENT

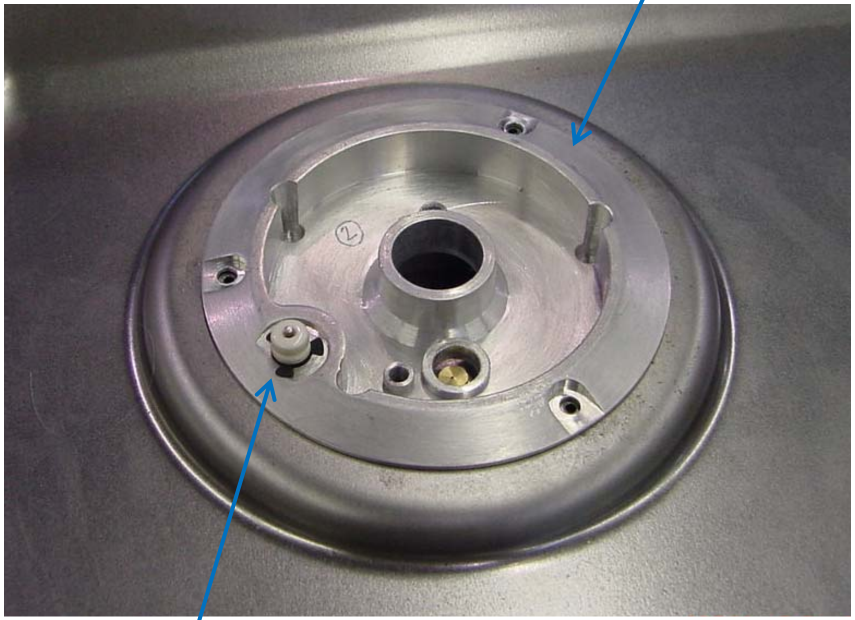


SPARK ELECTRODE PLACEMENT CAN BE VERY CRITICAL TO THE SUCCESSFUL OPERATION OF A GAS BURNER. TO A GREAT DEGREE, THE PLACEMENT IS ACCOMPLISHED BY TRIAL AND ERROR. YOU DO NEED TO BE AWARE OF OUTSIDE COMPONENTS THAT MAY HINDER THE OPERATION OF THE ELECTRODE. PARTS SUCH AS BURNER GRATES, ADJOINING BURNER ELEMENTS, KNOBS, ETC CAN GREATLY AFFECT THE IGNITION PROCESS. IN THE FOLLOWING SLIDES, THE ELECTRODES HAVE BEEN STRATEGICALLY PLACED TO AVOID THE ISSUES JUST MENTIONED.

# SPARK ELECTRODE PLACEMENT



BURNER BASE



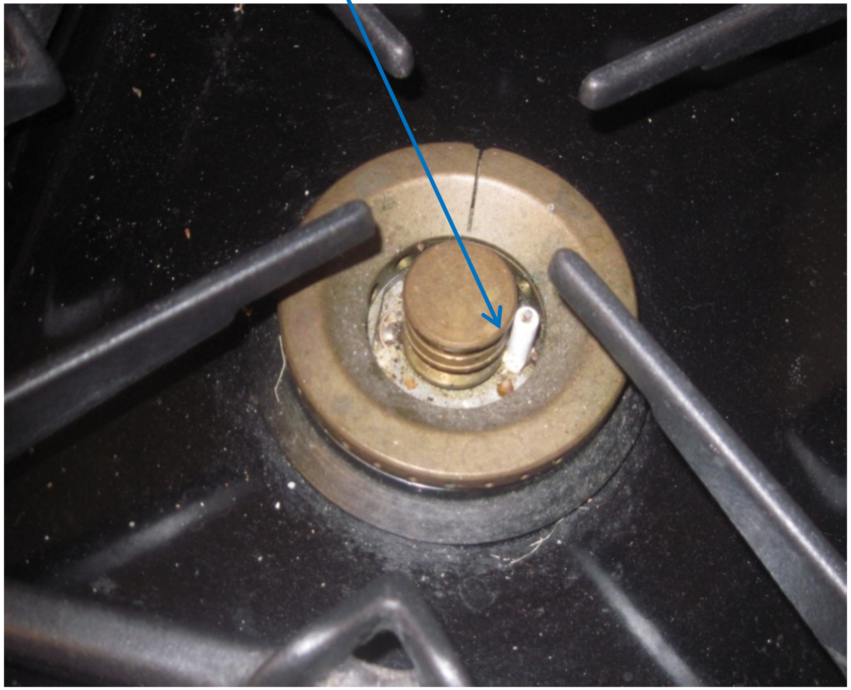
DEFENDI BURNER

ELECTRODE

4:00 O'CLOCK POSITION

8:00 O'CLOCK POSITION

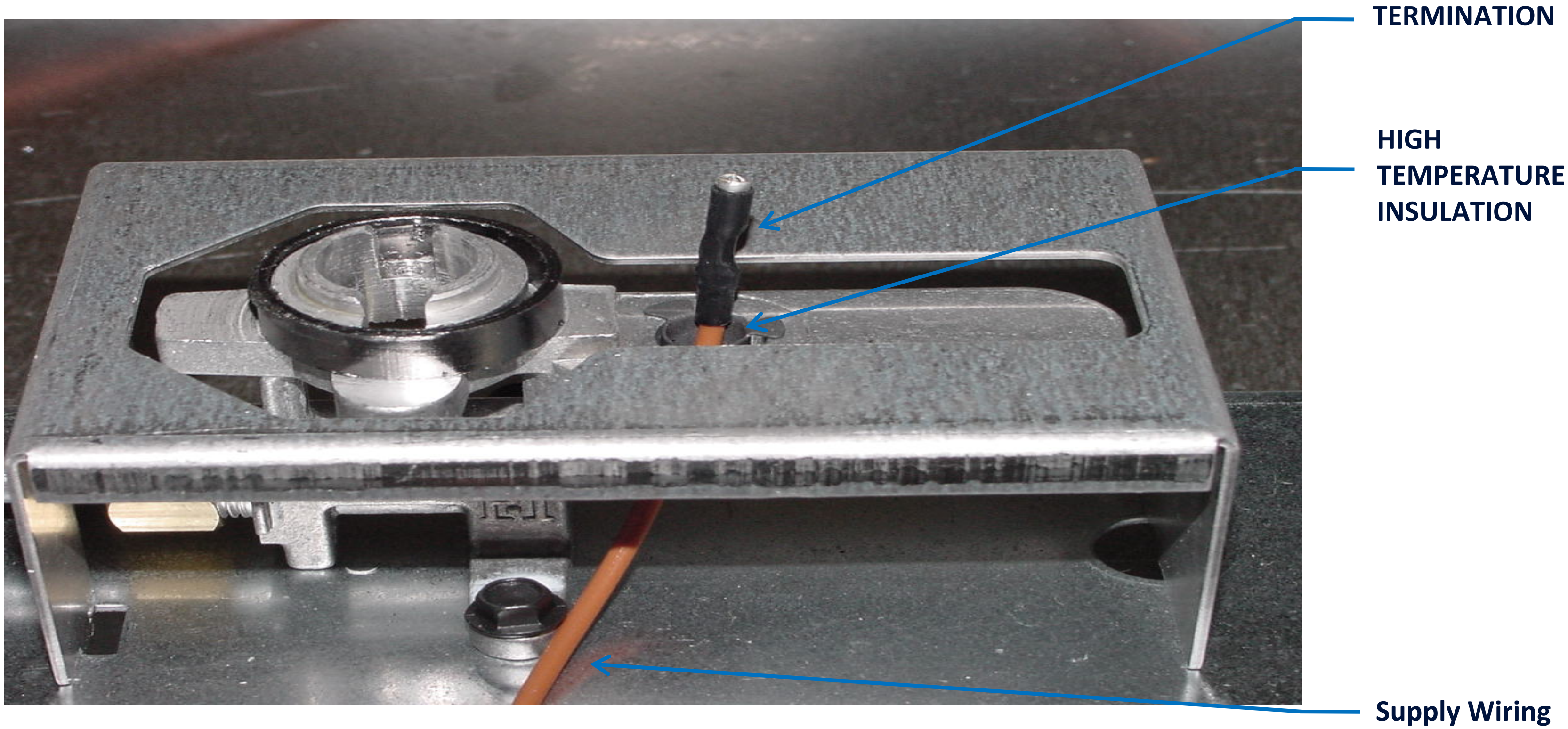
ELECTRODE



ISPHORDING BURNER

# ELECTRODE TERMINATIONS & INSULATION






The materials used for ignition wires, wire insulation and terminations are critical to operation of a spark ignition system. It is imperative that the selection and specification of these elements be adequate relative to the conditions that may be found when the burner and burner system is in use. Flame temperature, burner duration and the fuel used for combustion must be taken into consideration.

# HOT SURFACE IGNITION

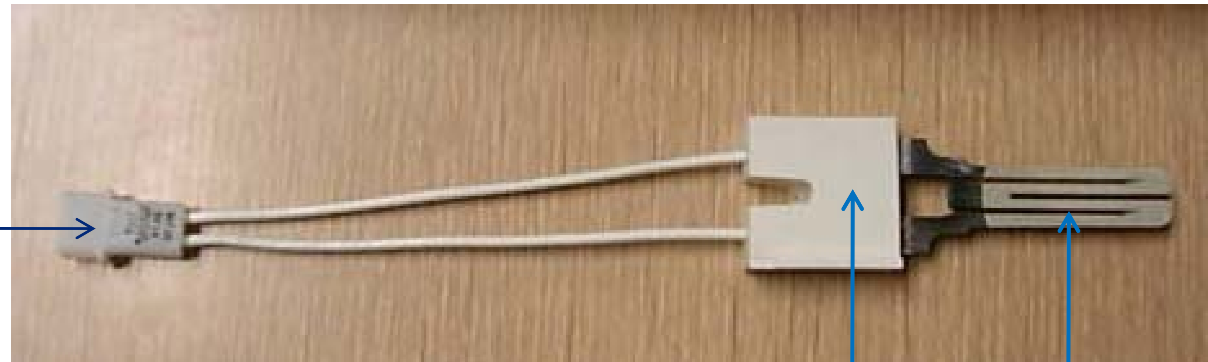


Hot surface ignition is one of the newer methods used to ignite a gas-fired burner. The technology has matured over the years to the point where successful operation and long life expectancy are definitely within reach.

# HOT SURFACE IGNITION ELECTRODE TYPES AND NOMENCLATURE

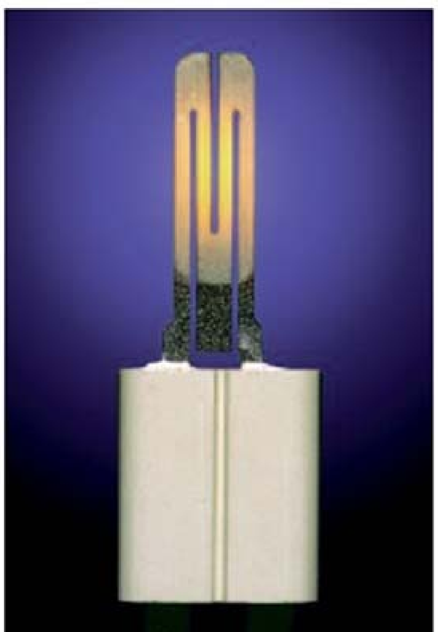


TERMINATION



IGNITION SURFACE

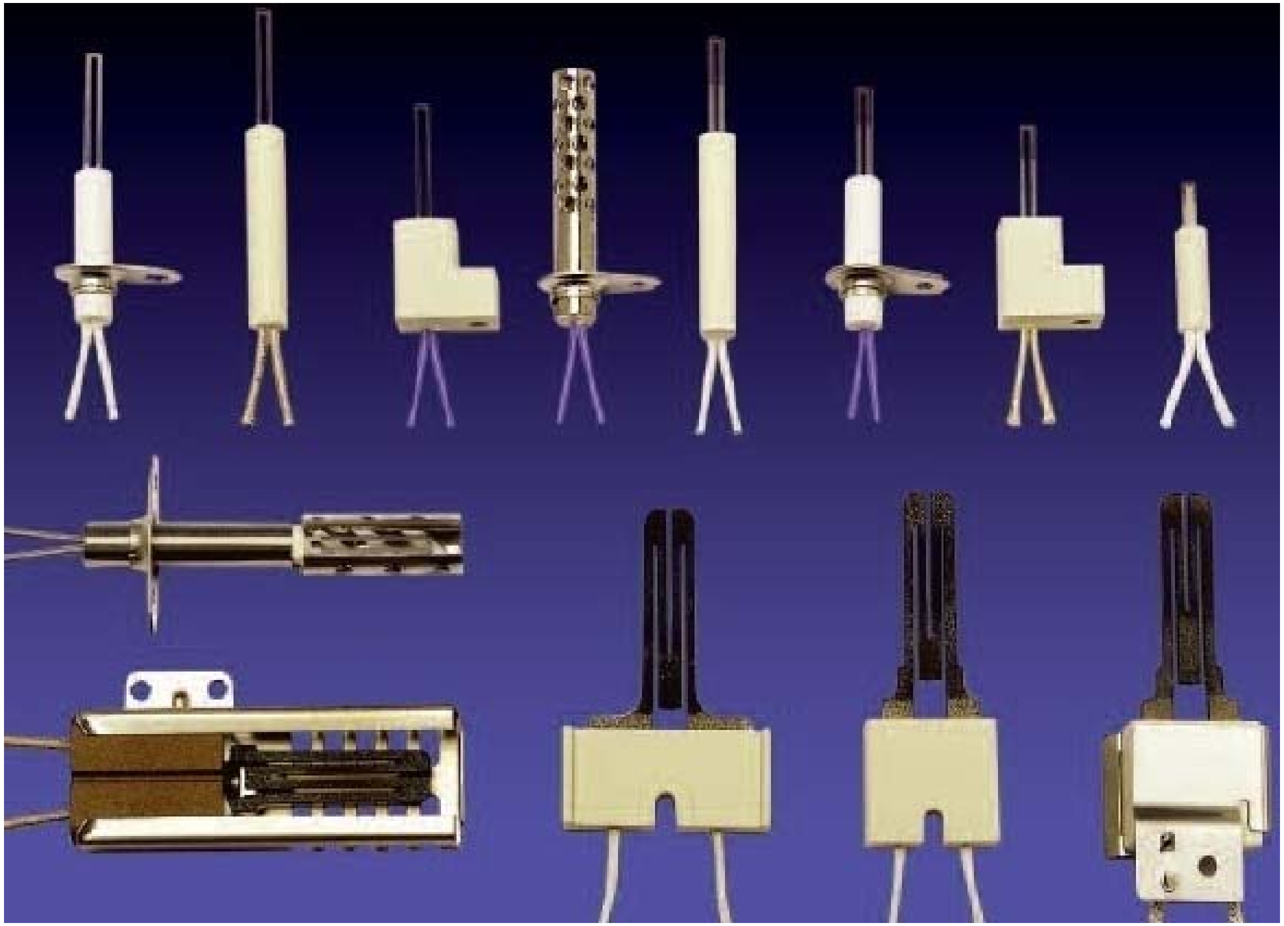
CERAMIC BLOCK



MEANS OF ATTACHMENT

# HOT SURFACE IGNITION





This JPEG will show the great variety of configurations possible today. All designs are custom and specified to the electrode vendor by the end user. One of the great things about hot surface ignition is the many possibilities for the design engineer.

# HOT SURFACE IGNITION



The list given below will show the very minimum requirements for selection of a hot surface igniter. The following slide will indicate the important questions to ask when reviewing the equipment available relative to any application.

## MINIMUM REQUIREMENTS

1. MATERIALS AND APPLICATION REQUIREMENTS CRITICAL
2. VERY HIGH TEMPERATURES EXPERIENCED IN CONTINUOUS FLAME
3. MATERIAL MUST HAVE VERY RAPID HEAT-UP TIME. ( UNDER 4 SECONDS FOR APPLIANCES.)
4. ACCEPTABLE SERVICE LIFE
5. MATERIAL SHOULD BE AS ROBUST AS POSSIBLE TO WITHSTAND SHIPMENTS
6. VOLTAGE COMPATIBLE-12V, 24V, 120V and 208-240V SYSTEMS AVAILABLE
7. NO ELECTRICAL NOISE
8. HOT SURFACE RE-IGNITION SYSTEM—SENSES FLAME AND TURNS ON CONTROL ONLY WHEN IGNITION IS REQUIRED

# HOT SURFACE IGNITION



## QUESTIONS TO ASK

1. TIME TO TEMPERATURE
2. ROOM TEMPERATURE RESISTANCE
3. TEMPERATURE RANGE—MINIMUM AND MAXIMUM
4. STEADY STATE CURRENT
5. IGNITER MATERIAL
6. MATERIAL OF HOLDER ( CERAMIC BLOCK )—STEATITE OR CORDIERITE IS GENERALLY USED
7. WHAT TERMINATIONS ARE AVAILABLE
8. CONTROL SYSTEM COMPATABILITY
9. AGENCY APPROVAL
10. LEAD WIRE LENGTH AND INSULATING CAPABILITIES

# FLAME FAILURE DEVICES



**Flame Safety Devices**

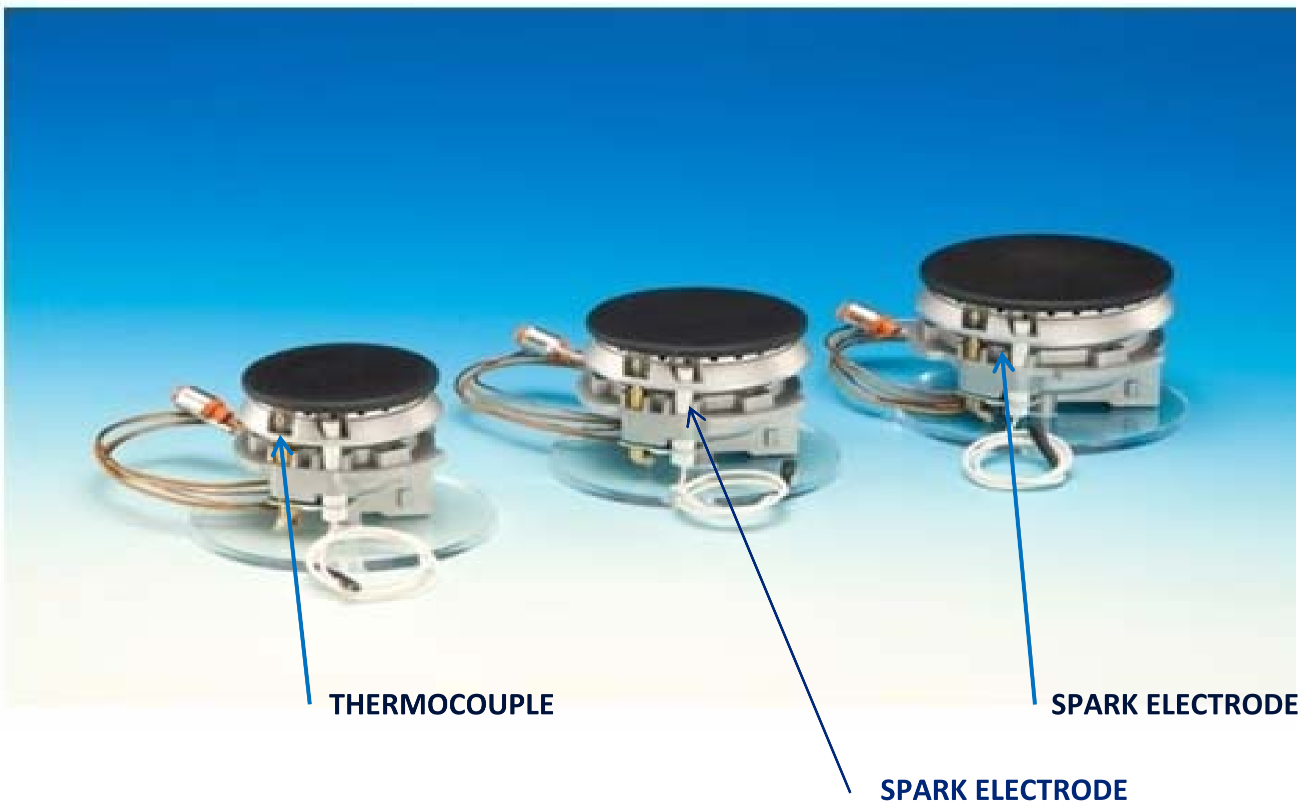
*Flame safety devices* (or flame failure devices) work by stopping the gas supply to the cooktop if the flame goes out.

The flame safety device works by utilising a thermocouple heated by the burner flame. The thermocouple generates a small electrical current which is connected to a small electromagnetic valve in the gas supply line. When the the thermocouple is hot, the valve continues to stay open. When the flame is extuinguished (by a draught or gust of air) the thermocouple goes cold and the electrical current no longer passes through it. The valve is then turned off automatically because the electromagnet has had its electrical current shut off.

# FLAME FAILURE DEVICES

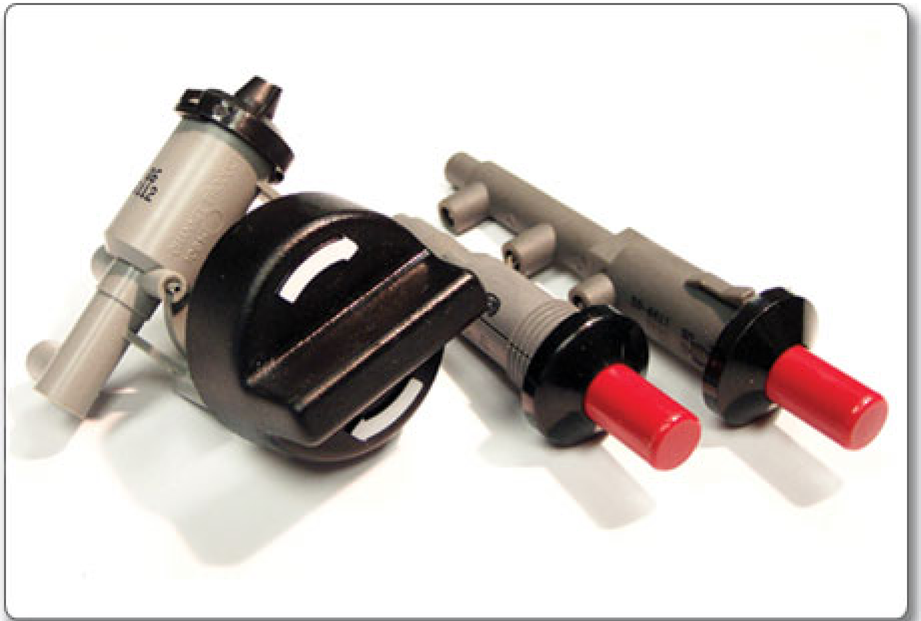


This slide shows the relative placement of the sensing thermocouple compared to the spark electrode. The thermocouple must be in the flame front in order to be the receptor of heat necessary to generate adequate millivoltage for driving the system. The actual operation is very similar to a standing pilot system.



# PIEZOELECTRIC IGNITERS

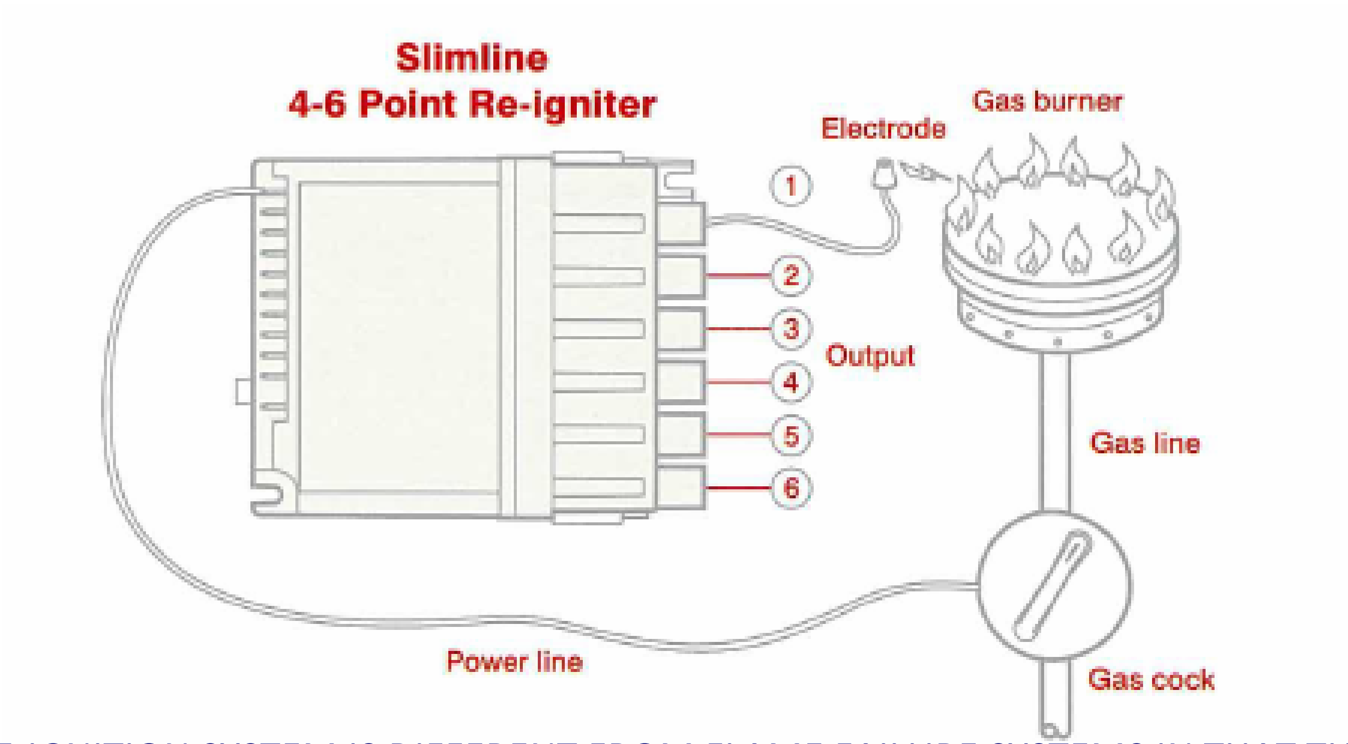




A piezoelectric ignition system is one in which a spring loaded hammer impacts a quartz or PZT crystal. When the crystal is deformed, a voltage is created. This voltage is great enough to "jump a gap" thereby creating a spark and igniting a combustible gaseous mixture. One popular use is providing the ignition source for a barbeque grill. Millions of piezo systems are sold each year for gas grills. Their means of operation makes them unsuitable for other types of installations.

# RE-IGNITION SYSTEMS






A RE-IGNITION SYSTEM IS DIFFERENT FROM FLAME FAILURE SYSTEMS IN THAT THERE IS AN EFFORT TO RE-LIGHT THE BURNER FLAME WITH ANY FLAME OUTAGE. AN FFD MERELY CLOSES THE FLOW OF GAS TO THE BURNER AFTER A LOSS OF FLAME WITHOUT TRYING FOR RE-IGNITION. RE-IGNITION SYSTEMS CONTINUOUSLY MONITOR THE PRESENCE OF THE BURNER FLAME AND ACT ACCORDINGLY IF THERE IS FLAME OUTAGE. THESE SYSTEMS HAVE GAINED GREAT ACCEPTANCE WHEN FLAME OUTAGE WOULD PRODUCE A SIGNIFICANT PROBLEM TO SYSTEM OPERATION AND CONSUMER LIABILITY.

# REIGNITION VALVE SWITCH



The assembly of components to the left shows a combination valve , selection knob and a reignition valve switch. There are several configurations that will vary depending upon the manufacturer but the basic system is represented here. It is imperative that there be a good tight fit between the valve switch and the valve—very critical.

**Flame Detection**

•Flame detection utilizes the superior flame rectification principal, primarily due to its ability to tolerate leakage currents to earth. These leakage currents are significantly larger than the flame current itself. The circuit passes a current through the electrode flame and burner to the “electrical” earth. The power to provide the current flow is derived from the main line voltage. Any significant leakage currents to earth that render the flame detection inoperative will result in continuous sparking of the electrode to the burner cap or burner body.

•The module detects a flame under all flame conditions provided the electrode is positioned such that the detected flame current exceeds the minimum specified flame current.

•The response time of the circuit for detection and loss of flame is dependent primarily on the magnitude of the flame and will meet the requirements as detailed within the technical specification.

•It is recommended that the burner design and the positioning of the electrode be configured so as to achieve a flame current greater than the specified minimum to increase the circuit’s response time. RESPONSE TIME IS CRITICAL TO THE PROPER FUNCTIONING OF THE BURNER SYSTEM. On a burner with poor flame stability, this will allow an increased time between loss of flame and re-establishment of flame signal before the spark is generated.

# IGNITION SYSTEM TROUBLE-SHOOTING

# TROUBLE-SHOOTING IGNITION SYSTEMS



We are going to take a look at the following five systems to discover what problems can and do occur and the steps necessary to fix any issues. We will limit our discussion to only these five since they are by far the most prevalent ignition systems used in the world today.

1. **STANDING PILOT**
2. **SPARK IGNITION**
3. **HOT SURFACE IGNITION**
4. **FLAME FAILURE DEVICES (FFD)**
5. **RE-IGNITION SYSTEMS**

# SPARK IGNITION COMPONENTS



SPARK IGNITION SYSTEMS GENERALLY REQUIRE THE FOLLOWING COMPONENTS: 1.) SPARK ELECTRODES, 2.) SPARK MODULES 3.) ASSOCIATED WIRING AND 4.) IGNITION SWITCHES, ONE PER GAS VALVE. AS MENTIONED EARLIER, THE SPARK MODULE PRODUCES A DC VOLTAGE UPWARDS TO 15,000 VOLTS BUT WITH VERY VERY SMALL AMPERAGE TO PRECLUDE ANY SHOCK POTENTIAL. THE EXACT AMPERAGE WILL VARY DEPENDING UPON THE SYSTEM SPECIFIED AND USED. THE SPARK WILL “JUMP” THE GAP BETWEEN THE ELECTRODE AND A TARGET, USUALLY LOCATED ON THE BURNER CAP OR EVEN THE BURNER HEAD.

THE NEXT SLIDE WILL SHOW THOSE PROBLEMS THAT CAN EXIST WITH A SPARK IGNITION SYSTEM.

# TROUBLE-SHOOTING SPARK IGNITION SYSTEMS



1. **GROUNDING .** A spark ignition system MUST be adequately grounded to provide continuity in the circuit in order to produce a spark from the electrode to the burner surface. Some companies require their engineers to provide a "ground map" showing the methods used for grounding electrical components and demonstrating continuity between electrical components. Grounding ( or the lack thereof ) constitutes one of the greatest problems in a spark ignition system.

2. **POWER --** I'm saying the obvious, but if you do not get ignition and there is no spark when an individual ignition switch is rotated, check to make sure you have power to the system and the spark module. Most residential systems operate on 120 VAC. That voltage should be available to the ignition module. All ignition modules have upper and lower specification limits so there is a range of voltages in which successful operation may be had. Check to make sure the voltage supplied is within this specified range AND test for acceptable ignition in your reliability lab. KNOW YOUR SYSTEM.

3. **ELECTRODE SPACING--** Even though significant voltages are generated, the spark gap must not be too distant from the burner surface. This spacing must be maintained during assembly, transit and use to preclude movement that might result in delayed ignition or no ignition. This is a must.

4. **BURNER CAP OR TARGET--** If a burner cap is used for the spark "target", that cap must be designed in a fashion to preclude difficulties with assembly or re-assembly after cleaning or removal. Ideally, the target should be held in a fixed position and keyed or pined so that rotation or separation is not possible relative to adjacent burner parts. The point here is to maintain the desired spark gap so that no rotation of burner parts can widen that gap and delay or eliminate ignition.

# TROUBLE-SHOOTING SPARK IGNITION SYSTEMS CONTINUED

5. **IMPROPER WIRE TERMINATIONS**--All terminations MUST be very tight so as to preclude high-resistance areas. This necessitates properly specifying the terminations relative to size, material and compatibility with mating components. Also, it is very important to insure that the electrical termination between the wiring and the electrode “cold” pin or spade be accomplished in a fashion to prevent inadvertant sparking at the termination. A high resistance at that termination can result in the spark occurring below the electrode and not at the electrode tip.

6. **TERMINATION CRIMP HEIGHTS**--When an electrical termination is used to connect one component to another, it is very important to specify the crimp height of that termination. This is to preclude a loose fit between the two components.

7. **CRACKED ELECTRODE CERAMIC**--The methods used to fabricate electrodes have improved significantly but cracks do occur in the body of the ceramic. These cracks can produce voltage “leaks” that cause sparking at points below the electrode tip. Not good! The only “fix” is replacement of the electrode.

8. **IMPROPER SPECIFICATION FOR WIRE INSULATION** --Insulation for the wiring carrying the DC voltage must be specified to handle the environment; i.e. temperature, abrasion, chemicals, etc, seen by the burner system and the individual burner components. Insulation that breaks or wears can create premature sparking to adjacent grounded metal resulting in a spark that will not “jump the gap”. It is always recommended that life testing be accomplished on a burner system using a spark ignition source to determine the exact failure mode and the meantime between failure. This will give some indication as to how long the ignition system might last in the field under normal and abnormal conditions. At GE, we always tested a spark ignition to six million “sparks”. That was the target number for the spark module and the associated electrodes. Please note also that testing occurred at normal, reduced and elevated voltages. The USL and LSL values were verified.

# TROUBLE-SHOOTING SPARK IGNITION SYSTEMS CONTINUED

**9.“DAISY-CHAIN” VS DIRECT WIRING--**The design engineer will have to determine if a “daisy-chain” pattern or direct wiring is most desirable when multiple burners are in use. The “daisy-chain” approach connects the electrodes from burner to burner so that when one burner fires, they all fire. The direct approach allows for firing one burner at a time. Multiple “pin-outs” are available on the spark module to direct the voltage to the burner needing to be ignited. The cost associated with the daisy-chain configuration is definitely less but has some drawbacks.

**10. VALVE SWITCHES WITH CAM IN WRONG POSITION--**Every valve switch will have a cam arrangement so that the various valve positions may be accomplished; i.e. light, high, low, simmer, etc etc. It is imperative that the proper orientation of the valve cam be had relative to the valve body and the control knob so that the proper setting may be had.

**11. VALVE SWITCHES NOT SEATED PROPERLY IN SWITCH BODY**—Sometimes the valve switches do not seat properly relative to the valve body itself. It is uncommon for them to loosen during transit and unpacking. This can definitely produce a much less than desirable situation in which the proper operation is not possible. All of the valve switches must fit tightly onto the valve body and produce the desired effect when the control knob is turned to the desired position or the system put into operation.

# TROUBLE-SHOOTING PIEZOELECTRIC SYSTEMS



**A PIEZOELECTRIC DEVICE IS ,IN ESSENCE, A SPARK IGNITION SYSTEM. AS SEEN BY THE PREVIOUS SLIDE, IT OPERATES IN VERY DIFFERENT FASHION BUT DOES DEPEND UPON A GENERATED VOLTAGE TO "JUMP THE GAP" AND PROVIDE NECESSARY HEAT TO LIGHT THE GAS BURNER. THE FOLLOWING ISSUES MAY OCCUR WHEN TROUBLE-SHOOTING A PIEZO SYSTEM:**

**1.SPARK GAP TO LARGE OR TOO NARROW--** There will be a specified gap recommendation for the piezo system. Check for the proper gap when no spark is generated.

**2.BROKEN ELECTRODE--** If and when this occurs, you are going to need a new igniter. Attempts to repair the electrode will be fruitless and very frustrating.

**3.ELECTRICAL WIRING FROM BODY OF CRYSTAL TO ELECTRICAL BROKEN--** Repair may be possible here but continuity must be restored for the device to work properly.

**4.IMPROPERLY GROUNDED--**There may be a problem with the spark jumping to an adjacent metal part instead of across the electrode. This could be due to a cracked piezo body. Generally, this can be seen if present but necessitate removing the device for examination.

**5.WORN INTERNAL SPRING--**A piezo device depends upon a significant impact to the crystal. If this impact is not substantial enough, there will not be generated the proper voltage to drive the spark. This could be a worn spring. Replacement then becomes necessary.

# TROUBLE-SHOOTING HOT SURFACE IGNITION SYSTEMS



1. **ELECTRICAL CONNECTIONS--** Just as with a spark ignition system, a hot surface igniter MUST have electrical continuity and the connections must be operational and provide the proper voltage. One of the most prevalent problems is a high resistance connection. When this occurs, there can be a significant voltage drop across the terminations restricting amperage necessary to drive the igniter to the desired temperature. If the connections look proper, disconnect the hot surface igniter and measure the voltage coming from the controller. A good reading is 115 to 120 VAC. If there is no voltage coming to the device, the problem lies "upstream" of the igniter component.

2. **VISIBLE ABNORMAL AREAS ON SURFACE--**Check the igniter to see if there are any imperfections or visible "spots" on the surface of the igniter. This may indicate a high resistance area and an actual break in the material itself. The material used in the actual element is very fragile and can be damaged fairly easily. Usually the material used is Silicon Carbide or in newer systems Silicon Nitride. Both are somewhat brittle and any sharp impact can break or damage the component.

3. **OILS AND /OR DIRT--**If there is an issue with ignition examine the igniter for oils, dirt and even debris on the igniter body. It is not uncommon for oils to be present that inhibit the device from reaching the desired temperature. You would think that they would eventually burn off but sometimes undue agony can result in the meantime.

# TROUBLE-SHOOTING HOT SURFACE IGNITION SYSTEMS CONTINUED

4. **"GAP" BETWEEN IGNITER AND BURNER IGNITION PORT(S)**—As with spark ignition systems, the gap between the hot surface igniter and the "target" is critical for proper ignition times and ignition itself. This gap must be maintained during the life of the product. When replacement becomes necessary, it is imperative that the gap be maintained after installation of the new component.

5. **RESISTANCE**--You will need a multimeter to check the resistance of the hot surface igniter. A hot surface igniter uses resistance just like a light bulb to glow in order to ignite the gas. It typically has a life span of 2 to 3 years depending on the usage and the conditions of the appliance. Set the multimeter so it can properly measure a resistance from 10 to 200 ohms. Disconnect the hot surface igniter from the control system and measure the resistance. A good hot surface igniter will have a resistance of 40 to 90 ohms. Greater than 90 ohms indicates a failing or failed device. (NOTE: The actual resistance will be specified by the manufacturer. Find out what is acceptable.)

6. **CRACKS IN "HOLDING" CERAMIC**—The hot surface electrode can be very delicate and if cracked, will not produce a surface temperature that can ignite the gas-air mixture coming from the burner ports. Check the igniter to see if there are any imperfections or visible "spots" on the surface of the igniter. This may indicate a high resistance area and an actual break in the material itself. The material used in the actual element is very fragile and can be damaged fairly easily. Usually the material used is Silicon Carbide or in newer systems Silicon Nitride. Both are somewhat brittle and any sharp impact can break or damage the component.

# TROUBLE-SHOOTING STANDING PILOT SYSTEMS



1. **GAS LEAKAGE**--All fittings must be tight and produce no leaks at the tubing / pilot interface or the tubing / control interface. "Soap up" the fittings and look for bubbles or use a gas detector (sniffer) when trying to find any leakage if the flame size is not adequate or hitting the thermocouple improperly.

2. **FERRELL**--Sometimes ferrells (if required ) are inadvertently omitted or damaged during assembly of the pilot tubing to the pilot body. There must be a good, tight fit so the Ferrell is snug against the pilot orifice body to preclude leakage. This is a must.

3. **PILOT HOODS**--The centerline of the pilot hood must be coaxial with the centerline of the pilot orifice to insure uniformity of the pilot flame and good flame distribution within the pilot hood itself.

4. **LINT AND DEBRIS**--In some installations; i.e. water heaters, furnaces etc. there is a possibility of lint forming within or around the pilot orifice. This can be very disruptive and should be removed for proper and timely ignition.

5. SPACING—The space or gap between the thermocouple and the pilot hood must be specified and held during transit, installation and operation of the equipment. Also, the pilot flame must hit the thermocouple properly and engulf the device if there is to be developed the proper millivoltage needed to drive the solenoid.

# TROUBLE-SHOOTING STANDING PILOT SYSTEMS CONTINUED

6. **THERMOCOUPLE--**Placement of the thermocouple relative to the burner flame must be maintained as per specifications from the manufacturer of the pilot assembly. The thermocouple is generally held in place by a wire clip. This clip must be installed to insure no movement and proper spacing relative to the pilot flame. If there are difficulties in lighting, examine the thermocouple for breaks and "nicks". It may be necessary to increase the input of the pilot burner flame to compensate for any spacing issues with the thermocouple. One other caution, sharp bends may create internal damage to the thermocouple and reduce its ability to transmit the necessary millivoltage to the control. Most domestic systems using a thermocouple generate around 30 MV. The controls to drive the system generally require 14 to 18 MV. The "final word" must lie with the manufacturer of the control system. They can indicate the upper and lower specification limit or the conditions of acceptability for the millivoltage required. These conditions need to be tested to insure no issues with ignition.

7. **INTERFACE BETWEEN THERMOCOUPLE AND CONTROL--**There must be a proper fit between the thermocouple and the control device. The T'couple must be "seated" properly with the threads not crossed so that electrical continuity does exist and milliamps can be generated when the pilot flame hits the T'couple bulb. Again, it is important to know the upper specification limit (USL) and the lower specification limit (LSL) for the milliamperage generated by the equipment you are using. Make sure you use the thermocouple specified by the manufacturer of the control.

8. **SOOTING--**If there is an issue with carbon monoxide and sooting does occur, it is imperative that the pilot orifice be examined and cleaned if necessary. The reason for burner sooting must be discovered and the system put back in operation with CO levels being less than 800 PPM. (NOTE: The PPM levels may vary depending upon the equipment and the standard the equipment is tested against. Please consult ANSI or the appropriate standard for the exact requirements. )

# TROUBLESHOOING FLAME FAILURE DEVICES



1. **SOLENOID VIABILITY--A solenoid is an integral part of the circuitry for a flame failure device. The proper millivoltage must be generated by the flame before the solenoid can be pulled in to open the gas passage. The very same principles are used for a FFD as compared to a standing pilot.**

2. **THERMOCOUPLE IMPROPERLY SPACED-- As with a standing pilot or spark ignition device, the thermocouple must be spaced properly relative to the burner cap, burner head or target located on the cap. There must be NO movement that would increase or decrease this gap. VERY IMPORTANT!!!**

3. **ELECTRICAL TERMINATIONS AND WIRING—Avoid high resistance electrical connections. These can significantly drop the ability of the FFD to carry current thereby reducing the millivoltage required to pull in the solenoid.**

4. **GAS PASSAGEWAYS—The gas passageways must be kept free of line and debris and any gas connections must be leak-free. It is very important that the connections be "soaped up" and tested for leaks prior to putting the system into operation.**

5. **PRESSURE DROP IN SYSTEM—Again, pressure drop is the ENEMY. You will always have pressure drops across valves, fittings, etc but those can be compensated for by design.**

# TROUBLE-SHOOTING FLAME FAILURE DEVICED CONTINUED

6. **LOW SUPPLY VOLTAGE TO SPARK MODULE--**As you recall, the spark module is nothing more than a step-up transformer. It receives a supply voltage; i.e. 120 VAC, 60Hz, and increases that voltage to approximately 15,000 volts DC. A low supply voltage can affect the output voltage,consequently providing a much lower than needed charge to "jump the gap". The input voltage can be checked with a volt meter and it is definitely recommended that this be accomplished prior to putting the equipment into service.

7. **THERMOCOUPLE SEATED IMPROPERLY--**It is important that the thermocouple be seated proper into the body of the control otherwise there could develop a high-resistance point that would significantly diminish the millivoltage generated. Also, look for cross-threading of the thermocouple threads into the control if there is an issue with millivoltage.

# TROUBLE-SHOOTING RE-IGNITION SYSTEMS



1. **VALVE SWITCHES SEATED IMPROPERLY**--The valve switches MUST be seated properly, as well as being tight, relative to the gas valve. A loose switch will not function properly and could fire inadvertently in random positions when the valve knob is turned. It is not uncommon at all to have valves fire in an incorrect position and when this happens, suspect looseness of the switch on the valve.

2. **LOW SUPPLY VOLTAGE TO SPARK MODULE**--Same situation as with the flame failure system. Low supply voltage can create a situation in which inadequate amperage is generated and ignition will not occur. It is very important to test your product for normal, reduced and increased supply voltage to make sure there are no issues with ignition when either of the three conditions occur.

3. **HIGH RESISTANCE ELECTRICAL CONNECTIONS**--High resistance connections can reduce the voltage created and needed for ignition. If you suspect this issue test for this issue.

4. **ELECTRODE OR HOT SURFACE SPACING IMPROPER**—Again, that can create an issue that will disallow timely ignition or no ignition at all. Make sure there is a specification and that specification is adhered to.

**I WOULD LIKE TO THANK THE ASGE FOR MY INVITATION AND HOPE THE PRESENTATION WAS BENEFICIAL TO YOU ALL.**