

281  
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782

SOME USEFUL ENERGY

CONVERSION TABLES

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RECOMMENDED UNIT PREFIXES

As Adopted by the International Committee on Weights and Measures

| <u>MULTIPLES AND<br/>SUBMULTIPLES</u> | <u>PREFIXES</u> | <u>SYMBOLS</u> |
|---------------------------------------|-----------------|----------------|
| $10^{12}$                             | tera            | T              |
| $10^9$                                | giga            | G              |
| $10^6$                                | mega            | M              |
| $10^3$                                | kilo            | k              |
| $10^2$                                | hecto           | h              |
| 10                                    | deka            | da             |
| $10^{-1}$                             | deci            | d              |
| $10^{-2}$                             | centi           | c              |
| $10^{-3}$                             | milli           | m              |
| $10^{-6}$                             | micro           | u              |
| $10^{-9}$                             | nano            | n              |
| $10^{-12}$                            | pico            | p              |
| $10^{-15}$                            | femto           | f              |
| $10^{-18}$                            | atto            | a              |

SOURCE: National Bureau of Standards  
U. S. Department of Commerce

REPRESENTATIVE WEIGHTS OF PETROLEUM PRODUCTS

| <u>PRODUCT</u>          | <u>POUNDS<br/>PER BARREL</u> | <u>BARRELS PER<br/>SHORT TON</u> | <u>BARRELS PER<br/>METRIC TON</u> | <u>BARRELS PER<br/>LONG TON</u> |
|-------------------------|------------------------------|----------------------------------|-----------------------------------|---------------------------------|
| Asphalt                 | 361                          | 5.54                             | 6.11                              | 6.21                            |
| Coke                    | 401                          | 4.99                             | 5.50                              | 5.59                            |
| Crude Oil (Domestic)    | 295                          | 6.77                             | 7.46                              | 7.58                            |
| Crude Oil (Foreign)     | 315                          | 6.35                             | 7.00                              | 7.11                            |
| Distillate Fuel Oil     | 304                          | 6.58                             | 7.25                              | 7.37                            |
| Gasoline and Naphtha    | 259                          | 7.72                             | 8.51                              | 8.65                            |
| Kerosine                | 284                          | 7.05                             | 7.78                              | 7.90                            |
| Liquified Petroleum Gas | 190                          | 10.53                            | 11.60                             | 11.79                           |
| Lubricating Grease      | 300                          | 6.67                             | 7.35                              | 7.46                            |
| Lubricating Oil         | 315                          | 6.35                             | 7.00                              | 7.11                            |
| Petrolatum              | 300                          | 6.67                             | 7.35                              | 7.46                            |
| Residual Fuel Oil       | 331                          | 6.04                             | 6.66                              | 6.77                            |
| Road Oil                | 339                          | 5.90                             | 6.50                              | 6.61                            |
| Wax                     | 280                          | 7.13                             | 7.86                              | 7.99                            |

SOURCE: American Petroleum Institute.

FUEL CONVERSION FACTORS

| PRODUCT  | BTU        |
|--|------------|
| Bituminous coal and lignite                      |            |
| Production, average/short ton.....               | 24,050,000 |
| Consumption, average/short ton.....              | 23,750,000 |
| Electric generation/short ton.....               | 22,364,000 |
| Anthracite.....short ton.....                    | 25,400,000 |
| Petroleum products:                              |            |
| Natural gasoline.....barrel.....                 | 4,620,000  |
| Liquefied gases.....barrel.....                  | 4,011,000  |
| Jet fuel, naphtha-type.....barrel.....           | 5,355,000  |
| Jet fuel, kerosine-type.....barrel.....          | 5,670,000  |
| Gasoline (including aviation).....barrel.....    | 5,248,000  |
| Special naphtha.....barrel.....                  | 5,248,000  |
| Kerosine.....barrel.....                         | 5,670,000  |
| Distillate (including diesel).....barrel.....    | 5,825,000  |
| Residual fuel oil.....barrel.....                | 6,287,000  |
| Still gas.....barrel.....                        | 6,000,000  |
| Lubricants.....barrel.....                       | 6,065,000  |
| Waxes.....barrel.....                            | 5,537,000  |
| Petroleum coke.....barrel.....                   | 6,024,000  |
| Asphalt and road oil.....barrel.....             | 6,636,000  |
| Natural gas liquids                              |            |
| Natural gasoline and cycle                       |            |
| products.....gallon.....                         | 110,000    |
| LP-gases.....gallon.....                         | 95,500     |
| Ethane.....gallon.....                           | 73,390     |
| Natural gas, dry.....cubic foot.....             | 1,031      |
| Nuclear power <sup>1</sup> .....kilowatt-hour... | 10,660     |
| Hydropower <sup>1</sup> .....kilowatt-hour...    | 10,379     |

1. Outputs of nuclear and hydropower are converted to theoretical energy inputs calculated from national heat rates for fossil-fueled steam-electric plants.

SOURCE: Coal Age

## FUEL CONVERSION FACTS

| PRODUCT  | APPROXIMATE HEAT VALUE  |
|--|---|
| 1 ton of bituminous coal   | 25 Mcf of natural gas<br>189 gallons of gasoline<br>4.17 barrels of crude oil   |
| 1 MCF of natural gas   | 0.04 ton of coal<br>(80 lb of coal)<br>7.58 gallons of gasoline<br>0.17 barrel of crude oil<br>(7 gallons of crude oil) |
| 1 gallon of gasoline   | 0.005 ton of coal<br>(10.56 pounds of coal)<br>0.132 Mcf of natural gas<br>0.022 barrel of oil<br>0.917 gallon of oil   |
| 1 barrel of oil  | 1.24 ton of coal<br>(480 pounds of coal)<br>6 Mcf of natural gas<br>45.5 gallons of gasoline                            |
| 1 pound $U_3O_8$ in Conc.<br>(for electric power<br>from LWR reactors) | 8.9 tons of coal<br><br>37.1 barrels of crude oil   |

SOURCE: Coal Age

# Conversion Factors Used in the Oil Trade

Compiled by The Petroleum Economist. Full official conversion and other tables are contained in the volumes published jointly by the American Society for Testing Materials and the Institute of Petroleum, under the title "ASTM/IP Petroleum Measurement Tables".

## Linear and square measures

|                  |   |
|------------------|---|
| 1 inch           | =0.0254 metre   |
| 1 foot           | =0.333 yard<br>=12 inches<br>=0.305 m                     |
| 1 yard           | =3 feet<br>=36 inches<br>=0.914 m                         |
| 1 metre (m)      | =1.094 yards<br>=3.281 feet<br>=39.37 inches<br>=0.001 km |
| 1 kilometre (km) | =1 000 metres<br>=0.621 mile                              |
| 1 statute mile   | =1 760 yards<br>=1.609 km                                 |
| 1 nautical mile  | =6 080 feet<br>=1.15152 statute miles                     |
| 1 square foot    | =0.093 square metre                                       |
| 1 square yard    | =9 square feet<br>=0.836 square metre                     |
| 1 square metre   | =1.196 square yards<br>=10.764 square feet                |
| 1 acre           | =0.405 hectare<br>=4 840 square yards                     |
| 1 hectare (ha)   | =0.01 square km<br>=2.471 acres                           |
| 1 square km      | =0.386 square mile<br>=100 ha                             |
| 1 square mile    | =2.590 square km<br>=640 acres<br>=259 ha                 |

## Specific gravity: volume per ton

| Degrees<br>API | Spec.<br>gravity | Barrels per*<br>met. ton | long ton |
|----------------|------------------|--------------------------|----------|
| 25             | 0.904            | 6.98                     | 7.09     |
| 26             | 0.898            | 7.02                     | 7.13     |
| 27             | 0.893            | 7.06                     | 7.18     |
| 28             | 0.887            | 7.10                     | 7.22     |
| 29             | 0.882            | 7.15                     | 7.27     |
| 30             | 0.876            | 7.19                     | 7.31     |
| 31             | 0.871            | 7.24                     | 7.36     |
| 32             | 0.865            | 7.28                     | 7.40     |
| 33             | 0.860            | 7.33                     | 7.45     |
| 34             | 0.855            | 7.37                     | 7.49     |
| 35             | 0.850            | 7.42                     | 7.54     |
| 36             | 0.845            | 7.46                     | 7.58     |
| 37             | 0.840            | 7.51                     | 7.63     |
| 38             | 0.835            | 7.55                     | 7.67     |
| 39             | 0.830            | 7.60                     | 7.72     |
| 40             | 0.825            | 7.64                     | 7.76     |
| 41             | 0.820            | 7.69                     | 7.81     |
| 42             | 0.816            | 7.73                     | 7.85     |

\*Approx. figures 60°F

## Cubic measures

|                        |  |
|------------------------|--|
| 1 cubic inch           | =16.387 cubic centimetres  |
| 1 pint                 | =0.5683 litre  |
| 1 litre                | =1 000 cubic centimetres<br>=61.024 cubic inches<br>=1.7597 pints<br>=0.26417 American gallon<br>=0.21997 Imperial gallon<br>=0.035314 cubic foot  |
| 1 hectolitre           | =100 litres  |
| 1 American gallon      | =231 cubic inches<br>=3.7854 litres<br>=0.83268 Imperial gallon<br>=0.133681 cubic foot<br>=0.0238095 American barrel<br>=0.0037854 cubic metre    |
| 1 Imperial gallon      | =277.42 cubic inches<br>=4.5461 litres<br>=0.160544 cubic foot<br>=1.20094 American gallons<br>=0.028594 American barrel<br>=0.0045461 cubic metre |
| 1 cubic foot           | =28.317 litres<br>=7.4805 American gallons<br>=6.2288 Imperial gallons<br>=0.17811 American barrel<br>=0.028317 cubic metre                        |
| 1 American barrel      | =9 702 cubic inches<br>=158.99 litres<br>=42 American gallons<br>=34.9726 Imperial gallons<br>=5.6146 cubic feet<br>=0.15899 cubic metre           |
| 1 cubic metre          | =35.315 cubic feet<br>=1 000 litres<br>=264.17 American gallons<br>=219.97 Imperial gallons<br>=6.2898 American barrels                            |
| 1 kilolitre            | =1 000 litres<br>=6.2898 American barrels  |
| 1 gross ton (shipping) | =100 cubic feet or 2.83 cubic metres of permanently enclosed space   |

## Liquefied methane

|                            |   |
|----------------------------|---|
| 1 ton of liquefied methane | =approximately 16 barrels<br>=approximately 50 000 cubic feet (1 400 cubic metres) of natural gas, depending on methane content |
|----------------------------|---|

## Specific gravity ranges

|                    | Spec.<br>gravity | Barrels per<br>metric ton |
|--------------------|------------------|---------------------------|
| Crude oils         | 0.80-0.97        | 8.0-6.6                   |
| Aviation gasolines | 0.70-0.78        | 9.1-8.2                   |
| Motor gasolines    | 0.71-0.79        | 9.0-8.1                   |
| Kerosines          | 0.78-0.84        | 8.2-7.6                   |
| Gas oils           | 0.82-0.90        | 7.8-7.1                   |
| Diesel oils        | 0.82-0.92        | 7.8-6.9                   |
| Lubricating oils   | 0.85-0.95        | 7.5-6.7                   |
| Fuel oils          | 0.92-0.97        | 6.9-6.5                   |
| Asphaltic bitumens | 1.00-1.10        | 6.4-5.8                   |

## Weights

|                       |   |
|-----------------------|---|
| 1 oz                  | =28.35 grammes  |
| 1 lb                  | =0.453592 kilogramme<br>=0.009 cwt                        |
| 1 kg                  | =2.20462 lb<br>=0.01 quintal                              |
| 1 cwt                 | =112 lb<br>=50.802 kg                                     |
| 1 metric ton          | =0.98421 long ton*<br>=1.10231 short tons*<br>=2 204.6 lb |
| 1 English or long ton | =1.01605 metric tons*<br>=1.12 short tons*                |
| 1 short ton           | =0.892857 long ton*<br>=0.907185 metric ton*<br>=2 000 lb |

\*These conversions are based on the assumption that all weights are weights in air, which is the correct basis for computing bulk commercial quantities of petroleum.

## Power and heat units

|  |  |
|--|--|
| 1 hp (horsepower)                          | =550 foot pounds per second<br>=0.746 kilowatt<br>=1.014 PS (or Cheval Vapeur)                         |
| 1 PS (Pferdestaerke) or CV (Cheval Vapeur) | =542 foot pounds per second<br>=0.986 hp<br>=0.736 kW  |
| 1 kW (kilowatt)                            | =1 000 watts<br>=1.340 hp<br>=1.359 PS or CV<br>=737 foot pounds per second                            |
| 1 foot pound per second                    | =0.00136 kilowatt<br>=0.00182 hp<br>=0.00184 PS or CV  |
| 1 therm                                    | =100 000 Btu (British thermal units)<br>=25 200 kilocalories<br>=25.2 thermies<br>=29.3 kilowatt hours |
| 1 000 kilocalories (large calories)        | =3 968 Btu<br>=1.163 kilowatt hours<br>=1 thermie  |
| 1 kilowatt hour                            | =3 411 Btu<br>=1.340 hp hours<br>=859.6 kilocalories   |

## Calorific value of fuels

|                    | Rough gross values in Btu per lb |
|--------------------|----------------------------------|
| Crude oils         | 18 300-19 500                    |
| Gasolines          | 20 500                           |
| Kerosines          | 19 800                           |
| Benzole            | 18 100                           |
| Ethyl alcohol      | 11 600                           |
| Gas oils           | 19 200                           |
| Fuel oils (Bunker) | 18 300                           |
| Coal (Bituminous)  | 10 200-14 600                    |
| LNG                | 22 300                           |

## NATURAL GAS CONVERSION TABLE

| <u>UNIT OF MEASURE</u>         | <u>BTU EQUIVALENCE</u> |
|--------------------------------|------------------------|
| 1 Cubic Foot                   | 1,000 Btu              |
| 1 Therm = 100 Cubic Feet       | 100,000 Btu            |
| 1 Mcf = 1,000 Cubic Feet       | 1,000,000 Btu          |
| 1 M Therm = 100,000 Cubic Feet | 100,000,000 Btu        |
| 1 Mmcf = 1,000,000 Cubic Feet  | 1,000,000,000 Btu      |

SOURCE: American Gas Association, Gas Facts.

FUEL CONVERSION FACTORS  
HEAT VALUES OF MISCELLANEOUS FUELS

| SOLID               | BTU/lb.<br>as fired |
|---------------------|---------------------|
| Coal                | 7000-14000          |
| Bagasse             | 3600-6500           |
| Bark                | 4500-5200           |
| General wood wastes | 4500-6500           |
| Sawdust, shavings   | 4500-7500           |
| Coffee grounds      | 4900-6500           |
| Nut hulls           | 7700                |
| Rice hulls          | 5225-6500           |
| Corn cobs           | 8000-8300           |
| Municipal refuse    | 4500-6500           |
| Industrial refuse   | 6600-7300           |

FUEL CONVERSION FACTORS  
HEAT VALUES OF WOOD FUELS

| TYPE          | BTU/lb. | TYPE                 | BTU/lb. |
|---------------|---------|----------------------|---------|
| Ash, white    | 7669    | Pine, white          | 8044    |
| Beech         | 7679    | Walnut, black        | 7690    |
| Beech, yellow | 7677    | Non-resinous         |         |
| Chestnut      | 7667    | seasoned             | 6300    |
| Cottonwood    | 7698    | Charcoal             |         |
| Elm, white    | 7683    | Willow               | 13,530  |
| Hickory       | 7691    | <u>Woodwaste</u>     |         |
| Maple, sugar  | 7677    | California redwood   | 4570    |
| Maple, red    | 7690    | Western hemlock      | 3630    |
| Oak, red      | 7691    | Douglas fir          | 5800    |
| Oak, white    | 7683    | Sawdust (green)      |         |
| Pine, yellow  | 8025    | Douglas fir          | 4910    |
|               |         | Briquettes (sawdust) |         |
|               |         | Douglas fir          | 8130    |
|               |         | Tan bark             | 2600    |

MISCELLANEOUS CONVERSION FACTORS

1 Quad =  $10^{15}$  BTU = 10,000,000,000,000,000 BTU

1 BTU (British Thermal Unit) = the amount of heat required to raise  
1 pound water 1 degree Fahrenheit.

1 kwh electricity = 3.142 BTU

2 trillion BTU per year = 1000 barrel per day crude oil

FUEL COST COMPARISONS  
PER MILLION BTU

|                     |                      |
|---------------------|----------------------|
| Bituminous coal     | 13,000 BTU/lb        |
| Natural gas (dry)   | 1031 BTU/cu ft       |
| Crude oil           | 5,800,000 BTU/barrel |
| Distillate fuel oil | 5,825,000 " "        |
| Residual fuel oil   | 6,287,000 " "        |
| L-P gases           | 95,500 BTU/gallon    |
| Ethane              | 73,390 " "           |

1 barrel = 42 gallons

Bituminous Coal:

|                          |      |       |       |       |       |       |
|--------------------------|------|-------|-------|-------|-------|-------|
| Dollars per ton          | 6.50 | 13.00 | 19.50 | 26.00 | 32.50 | 39.00 |
| Cost/million BTU (cents) | 25   | 50    | 75    | 100   | 125   | 150   |

Natural gas dry:

|                          |    |    |    |    |     |     |     |     |
|--------------------------|----|----|----|----|-----|-----|-----|-----|
| Cents per 1000 cu. ft.   | 20 | 40 | 60 | 80 | 100 | 120 | 140 | 160 |
| Cost/million BTU (cents) | 21 | 41 | 62 | 82 | 103 | 124 | 144 | 165 |

Distillate fuel oil:

|                          |      |       |       |       |
|--------------------------|------|-------|-------|-------|
| Cents per gallon         | 20   | 24    | 28    | 32    |
| Dollars per barrel       | 8.40 | 10.08 | 11.76 | 13.44 |
| Cost/million BTU (cents) | 144  | 175   | 202   | 231   |

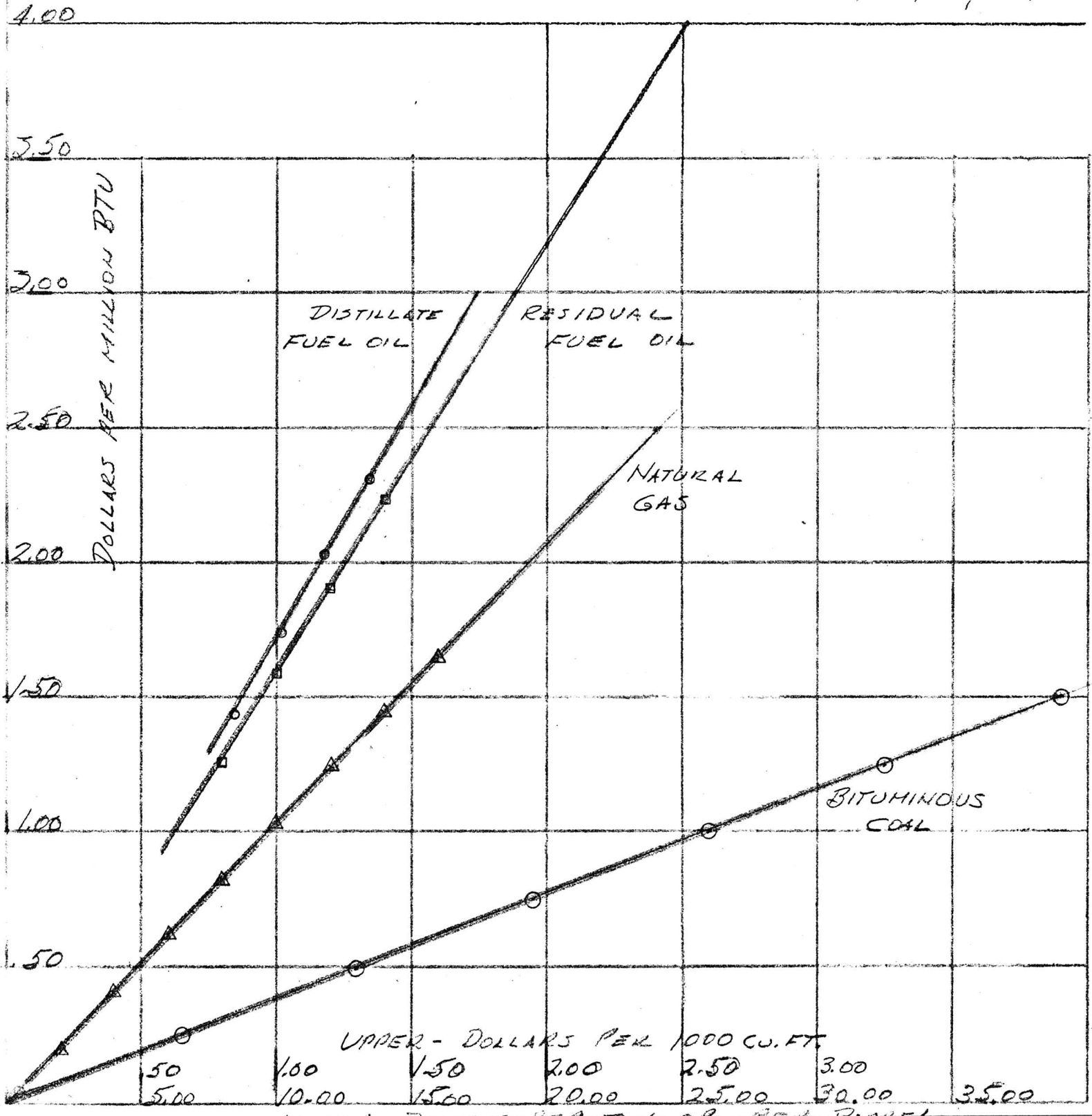
Residual fuel oil:

|                          |      |       |       |       |
|--------------------------|------|-------|-------|-------|
| Cents per gallon         | 19   | 24    | 29    | 33    |
| Dollars per barrel       | 8.00 | 10.00 | 12.00 | 14.00 |
| Cost/million BTU (cents) | 127  | 159   | 191   | 223   |

1 ton coal = 26,000,000 BTU per ton  
 1 ton coal = 25,200 CF natural gas  
 1 ton coal = 4.47 Bbls distillate oil  
 1 ton coal = 4.14 Bbls residual oil

BTU CONTENTS

COAL 13,000/LB.  
 NATURAL GAS (DRY) 1031/CO.FT.  
 DISTILLATE 5,725,000/BB1  
 RESIDUAL 6,287,000/BB1



\$/10<sup>6</sup> Btu

Elec  
¢/kwh

Fuel Oil  
¢/gal

Propane  
¢/gal

Gasoline  
¢/gal

Wood  
\$/cord

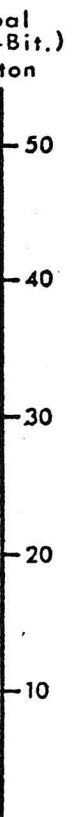
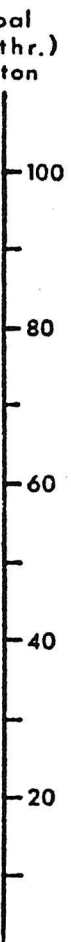
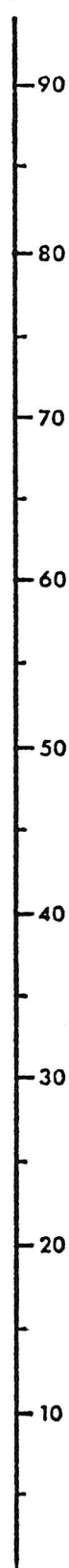
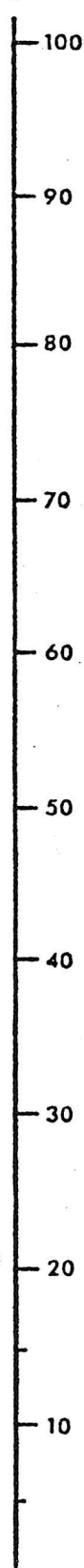
Nat Gas  
\$/Mcf

Coal  
(Anthr.)  
\$/ton

Coal  
(Sub-Bit.)  
\$/ton

U<sub>3</sub>O<sub>8</sub>  
\$/lb

FUEL COST COMPARATOR  
Center for Energy Studies, KSU  
Energy Fact Sheet No. 2  
December 1973



# How to compare costs of gas and alternate fuels

## Growing shortage of natural gas prompts consideration of practical replacements, including coal, heavy fuel oil, middle distillates and LPG

CONVERSION from natural gas to other fuels has progressed from possibility to reality for many companies and will become necessary for many others in months and years ahead.

Fuels considered practical replacements for gas include coal, heavy fuel oils, middle distillates (such as kerosine-type turbo fuel and burner fuel oils) and liquefied petroleum gas (LPG).

To compare relative costs of fuels, the quoted prices normally are converted to the price per million British thermal units (Btu). With HHV being the higher (gross) heating value of the fuel, the following equations may be used:

### Coal

$$\text{Cents/million Btu} = \frac{\text{dollars/ton} \times 100 \times 10^6}{\text{lb./ton} \times \text{HHV}}$$

### Heavy fuel oils

$$\text{Cents/million Btu} = \frac{\text{dollars/barrel} \times 100 \times 10^6}{\text{gallons/barrel} \times \text{HHV}}$$

### Middle distillates and LPG

$$\text{Cents/million Btu} = \frac{\text{cents/gallon} \times 10^6}{\text{HHV}}$$

### Natural gas

$$\text{Cents/million Btu} = \frac{\text{cents/Mcf} \times 10^6}{\text{HHV} \times 1,000}$$

The approximate heat contents (HHV) of the fuels are as follows:

### Coal

|                |                |
|----------------|----------------|
| Anthracite     | 13,900 Btu/lb. |
| Bituminous     | 14,000 Btu/lb. |
| Sub-bituminous | 12,600 Btu/lb. |
| Lignite        | 11,000 Btu/lb. |

### Heavy fuel oils and middle distillates

|                       |                  |
|-----------------------|------------------|
| Kerosine              | 134,000 Btu/gal. |
| No. 2 burner fuel oil | 140,000 Btu/gal. |

|                                      |                  |
|--------------------------------------|------------------|
| No. 4 heavy fuel oil                 | 144,000 Btu/gal. |
| No. 5 heavy fuel oil                 | 150,000 Btu/gal. |
| No. 6 heavy fuel oil,<br>2.7% sulfur | 152,000 Btu/gal. |
| No. 6 heavy fuel oil,<br>0.3% sulfur | 143,800 Btu/gal. |

### Gas

|                   |                   |
|-------------------|-------------------|
| Natural           | 1,000 Btu/cu. ft. |
| Liquefied butane  | 103,300 Btu/gal.  |
| Liquefied propane | 91,600 Btu/gal.   |

## Typical characteristics of fuel oils

|                         | Kerosine | No. 2 burner fuel |
|-------------------------|----------|-------------------|
| Gravity, °API           | 41.4     | 36.3              |
| Pounds per gallon       | 6.814    | 7.022             |
| Flash point, °F         | 133      | 165               |
| Btu/gal.                | 134,000  | 140,000           |
| Viscosity, SSU at 100°F | 31.5     | 35.0              |
| Pour point, °F          | -30      | 0                 |
| Sulfur, wt. %           | 0.04     | 0.18              |
| Carbon residue, wt. %   | 0.01     | 0.05              |
| BS&W, %                 | —        | 1.30 <sup>2</sup> |

<sup>1</sup>Saybolt Furol Viscosity at 122°F.  
<sup>2</sup>mg/100 ml

### LPG

|                               |      |
|-------------------------------|------|
| Vapor pressure, psig at 100°F | 188  |
| Distillation, 95% point, °F   | -40  |
| Residue, vol. %               | 0.05 |
| Oil-ring test                 | none |

**Thermal efficiency.** A direct comparison of the Btu content of the four fuels is misleading because coal and fuel oil burn more efficiently than natural gas and LPG. Gas has a higher hydrogen content than coal and fuel oil and, therefore, more water is produced when gas is burned. The water vapor produced during combustion is vaporized, absorbing heat from the burning fuel, and this heat is lost up the chimney without producing useful energy.

The exact differences in combustion efficiencies of the fuels vary somewhat depending on the size and type of combustion equipment. The following formula may be used to calculate a representative comparison of the heat available from \$1 worth of each of the fuels, based on their percent efficiencies in standard-size boilers (220,000 pounds of steam/hour) designed for their use:

Heat from \$1 worth of fuel

$$(\text{million Btu}) = \frac{E \times 10^6}{\text{Cents/million Btu}}$$

where:

- E = percent efficiency = 89.5 for coal
- = 88.5 for oil
- = 84.2 for gas

**Combustion equipment.** Furnaces that are coal-fired require, among other things, large combustion chambers, wide tube spacing and provisions for ash removal. For this reason, conversion of a gas-fired furnace to coal is

not practical unless the furnace was originally designed for coal and was later converted to gas. If coal were readily available and attractive from a price consideration, however, the investment in new coal-fired furnaces might be worth considering.

**Heavy fuel oils:** Although a furnace is most efficient on the fuel for which it was designed, a gas furnace can, in some cases, be converted to burn heavy fuel oils. Conversion would primarily require installation or modification of fuel oil heaters, combustion equipment, air blowers, air pre-heaters, control equipment and chimney.

**Middle distillates:** When considered as alternate fuels for natural gas-fired equipment, the conversion considerations for middle distillates would be similar to those discussed previously for heavy fuel oils, except that such a conversion probably would be more practical and somewhat less expensive. Middle distillates, in addition to serving as furnace and process fuels, can be burned in diesel engines and industrial gas turbines for power generation. This would be an advantage where an alternate to natural gas was being considered as a standby fuel or as a replacement for natural gas.

**LPG:** Conversion from natural gas to LPG would require the least alterations to existing combustion equipment and, compared to the other alternate fuels, would be minor in nature.

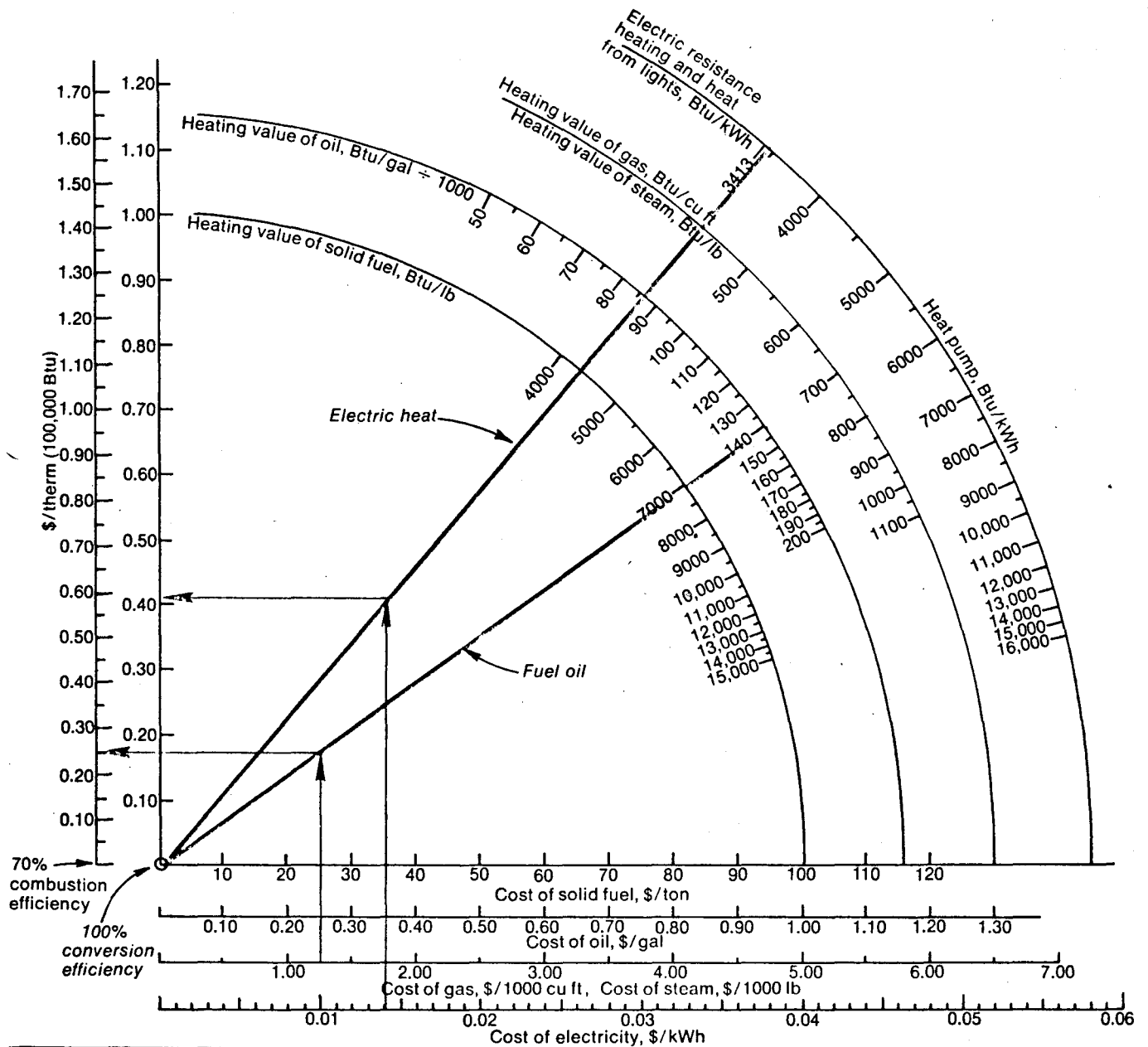
(Excerpted from a booklet, "Conversion from Natural Gas to Other Fuels," prepared and copyrighted by Exxon Co., U.S.A.)

| No. 4 fuel oil | No. 4 fuel oil 1% sulfur | No. 4 fuel oil 0.4% sulfur | No. 5 fuel oil | No. 5 fuel oil 1% sulfur | No. 6 fuel oil 2.7% sulfur | No. 6 fuel oil 1% sulfur | No. 6 fuel oil 0.5% sulfur | No. 6 fuel oil 0.3% sulfur |
|----------------|--------------------------|----------------------------|----------------|--------------------------|----------------------------|--------------------------|----------------------------|----------------------------|
| 23.3           | 26.1                     | 27.3                       | 22.0           | 24.1                     | 14.1                       | 22.9                     | 24.8                       | 26.0                       |
| 7.612          | 7.476                    | 7.420                      | 7.676          | 7.573                    | 8.082                      | 7.632                    | 7.539                      | 7.481                      |
| 170            | 194                      | 189                        | 180            | 193                      | 176                        | 200+                     | 200+                       | 200+                       |
| 144,000        | 143,800                  | 143,000                    | 150,000        | 144,500                  | 152,000                    | 145,500                  | 144,000                    | 143,800                    |
| 96             | 78                       | 91                         | 180            | 160                      | 160 <sup>1</sup>           | 278                      | 235                        | 164                        |
| -10            | -20                      | +15                        | 0              | 0                        | +25                        | +55                      | +55                        | +55                        |
| 1.62           | 0.93                     | 0.37                       | 1.43           | 0.91                     | 2.71                       | 0.96                     | 0.44                       | 0.28                       |
| 2.9            | 1.9                      | 1.8                        | 3.5            | 3.9                      | 12.4                       | 7.0                      | 5.4                        | 4.8                        |
| 0.10           | 0.10                     | 0.10                       | 0.20           | 0.20                     | 0.40                       | 0.40                     | 0.30                       | 0.30                       |

Sulfur, volatile, g/100 cu. ft. vapor..... 4  
 Water content..... dry

Dew point, °F.....-30  
 Specific gravity, 60/60 °F.....0.501

# Comparing process energy costs



| Typical heating values        |               |
|-------------------------------|---------------|
| <b>Fuel oil, Btu/gal</b>      |               |
| No. 1                         | 137,400       |
| No. 2                         | 139,600       |
| No. 4                         | 145,100       |
| No. 5                         | 148,800       |
| No. 6                         | 152,400       |
| <b>Propane, Btu/gal</b>       |               |
|                               | 91,500        |
| <b>Natural gas, Btu/cu ft</b> |               |
|                               | 1035          |
| <b>Coal, Btu/lb</b>           |               |
| Bituminous                    | 11,500-14,000 |
| Subbituminous                 | 8300-11,500   |
| Lignite                       | 6300-8300     |
| <b>Steam, Btu/lb</b>          |               |
|                               | 1012          |
| <b>Electricity, Btu/kWh</b>   |               |
| Resistance heating            | 3413          |
| Heat pumps                    | up to 13,000  |

**Example:** There are two ways to heat a manufacturing plant at night: Leave all the lights on, or operate a 70%-efficient No. 2-oil-fired boiler to provide heat for radiators. If electricity, excluding demand charges, costs 1.4¢/kWh and oil is 25¢/gal, approximately how much can be saved by using the latter approach?

**Solution:** Draw a line from the index to 140,000 Btu/gal on the second circular scale. (The average heating value of No. 2 fuel is presented in the table.) Next, locate 25¢/gal on the appropriate horizontal scale and draw a vertical line to intersect the "fuel oil" line. From this point, draw a horizontal line to intersect with the extreme-left vertical scale. Result: Oil heat for this case costs 25.5¢/therm.

To find the cost of heat from lights, draw a line from the index to 3413 Btu/kWh on the last circular scale. Then draw a vertical line from \$0.014/kWh on the bottom abscissa and intersect the "electric heat" line. Finally, draw a horizontal line from this point to the closest ordinate scale and find 41¢/therm. (Note that this figure assumes all electric heat goes to the building and none is exhausted.) Hence, oil heat saves about 15½¢/therm.

# Facts & Factors on Metrication\*

About 90% of the world's population operates on the metric system. Canada and the United States are the last major holdouts. England has completed half of its ten year program to convert to the metric system. Japan is completing its change and Australia has begun a ten year program towards conversion. On January 19, 1971 the ASTM Board of Directors adopted the metric practice resolution to work toward simplification of units of measurement using the International System of units, or SI.

The International System of Measurement (SI) is the currently recommended form of the metric system. But, since measurement of concrete in centimeters and stress and pressure in kilograms — force per unit area is common in many "metric" nations, these units may be used in ACI publications even if they do not conform strictly to SI.

A ready-mix truck will deliver 8 cu yds of concrete having a 4" slump today. In the near future the same order will be for 6.00m<sup>3</sup> with a 102 mm slump!

A building of 400,000 sq ft of floor space will be referred to as having an area of 37,160 m<sup>2</sup>.

And the 3000 psi concrete strength that is popular today will be 21 newtons per square millimeter (N/mm<sup>2</sup>), or 210 kilograms/square centimeter (kgf/cm<sup>2</sup>).

The standard 4'x8' plywood form material will become a 1 by 2.5 meter unit. This is really 39<sup>3</sup>/<sub>8</sub> inches by 88 inches.

The following tables will be of assistance in conversions:

## CONCRETE STRENGTH

| Non-SI Metric Equivalent<br>(kilogram/square centimeter) | American Measurement<br>(pounds/square inch) | SI Metric Equivalent<br>(newtons/square millimeter) |
|--|--|---|
| 140 kgf/cm <sup>2</sup>                                  | 2,000 psi                                    | 14 N/mm <sup>2</sup>                                |
| 175 kgf/cm <sup>2</sup>                                  | 2,500 psi                                    | 17 N/mm <sup>2</sup>                                |
| 210 kgf/cm <sup>2</sup>                                  | 3,000 psi                                    | 21 N/mm <sup>2</sup>                                |
| 245 kgf/cm <sup>2</sup>                                  | 3,500 psi                                    | 24 N/mm <sup>2</sup>                                |
| 280 kgf/cm <sup>2</sup>                                  | 4,000 psi                                    | 28 N/mm <sup>2</sup>                                |
| 315 kgf/cm <sup>2</sup>                                  | 4,500 psi                                    | 31 N/mm <sup>2</sup>                                |
| 350 kgf/cm <sup>2</sup>                                  | 5,000 psi                                    | 35 N/mm <sup>2</sup>                                |
| 420 kgf/cm <sup>2</sup>                                  | 6,000 psi                                    | 41 N/mm <sup>2</sup>                                |
| 490 kgf/cm <sup>2</sup>                                  | 7,000 psi                                    | 48 N/mm <sup>2</sup>                                |
| 560 kgf/cm <sup>2</sup>                                  | 8,000 psi                                    | 55 N/mm <sup>2</sup>                                |

| To convert from | to              | multiply by |
|-----------------|-----------------|-------------|
| <b>LENGTH</b>   |                 |             |
| foot            | meter (m)       | 0.3048E†    |
| inch            | centimeter (cm) | 2.54E       |
| yard            | meter (m)       | 0.9144E     |
| mile (statute)  | kilometer (km)  | 1.609       |

|             |                                      |        |
|-------------|--------------------------------------|--------|
| <b>AREA</b> |                                      |        |
| square foot | square meter (m <sup>2</sup> )       | 0.0929 |
| square inch | square centimeter (cm <sup>2</sup> ) | 6.451  |
| square yard | square meter (m <sup>2</sup> )       | 0.8361 |

|                          |                                     |          |
|--------------------------|-------------------------------------|----------|
| <b>VOLUME (capacity)</b> |                                     |          |
| cubic foot               | cubic meter (m <sup>3</sup> )       | 0.02832  |
| gallon (U.S. liquid)‡    | cubic meter (m <sup>3</sup> )§      | 0.003785 |
| gallon (Can. liquid)‡    | cubic meter (m <sup>3</sup> )§      | 0.004546 |
| ounce (U.S. liquid)      | cubic centimeter (cm <sup>3</sup> ) | 29.57    |

|                |                      |        |
|----------------|----------------------|--------|
| <b>FORCE</b>   |                      |        |
| kilogram-force | newton(N)            | 9.807  |
| kip            | kilogram-force (kgf) | 453.6  |
| kip            | newton (N)           | 4448   |
| pound-force    | kilogram-force(kgf)  | 0.4536 |
| pound-force    | newton (N)           | 4.448  |

|  |   |         |
|--|---|---------|
| <b>PRESSURE OR STRESS (Force per Area)</b> |   |         |
| kilogram-force/square meter                | newton/square meter (N/m <sup>2</sup> )                 | 9.807   |
| kip/square inch (ksi)                      | kilogram-force/square centimeter (kgf/cm <sup>2</sup> ) | 70.31   |
| pound-force/square foot                    | kilogram-force/square meter (kgf/m <sup>2</sup> )       | 4.882   |
| pound-force/square foot                    | newton/square meter (N/m <sup>2</sup> )                 | 47.88   |
| pound-force/square inch psi                | kilogram-force/square centimeter (kgf/cm <sup>2</sup> ) | 0.07031 |
| pound-force/square inch psi                | newton/square meter (N/m <sup>2</sup> )                 | 6895    |

|                                 |                              |         |
|---------------------------------|------------------------------|---------|
| <b>BENDING MOMENT OR TORQUE</b> |                              |         |
| inch-pound-force                | meter-kilogram-force (m-kgf) | 0.01152 |
| inch-pound-force                | newton-meter (Nm)            | 0.1130  |
| foot-pound-force                | meter-kilogram-force (m-kgf) | 0.1383  |
| foot-pound-force                | newton-meter (Nm)            | 1.356   |
| meter-kilogram-force            | newton-meter (Nm)            | 9.807   |

|                       |               |        |
|-----------------------|---------------|--------|
| <b>MASS</b>           |               |        |
| ounce-mass (avdp)     | gram (g)      | 28.35  |
| pound-mass (avdp)     | kilogram (kg) | 0.4536 |
| ton (metric)          | kilogram (kg) | 1000E  |
| ton (short, 2000 lbm) | kilogram (kg) | 907.2  |

|                           |   |        |
|---------------------------|---|--------|
| <b>MASS PER VOLUME</b>    |   |        |
| pound-mass/cubic foot     | kilogram/cubic meter (kg/m <sup>3</sup> ) | 16.02  |
| pound-mass/cubic yard     | kilogram/cubic meter (kg/m <sup>3</sup> ) | 0.5933 |
| pound-mass/gallon (U.S.)† | kilogram/cubic meter (kg/m <sup>3</sup> ) | 119.8  |
| pound-mass/gallon (Can.)‡ | kilogram/cubic meter (kg/m <sup>3</sup> ) | 99.78  |

|                      |                 |                    |
|----------------------|-----------------|--------------------|
| <b>TEMPERATURE**</b> |                 |                    |
| deg Celsius (C)      | kelvin (K)      | tK=(tC+273.15)     |
| deg Fahrenheit (F)   | kelvin (K)      | tK=(tF+459.67)/1.8 |
| deg Fahrenheit (F)   | deg Celsius (C) | tC=(tF-32)/1.8     |

Symbols of metric units are given in parentheses.

†E indicates that the factor given is exact.

‡One U.S. gallon equals 0.8327 Canadian gallon.

§One liter (cubic decimeter) equals 0.001 m<sup>3</sup> or 1000 cm<sup>3</sup>.

\*\*These factors convert one temperature reading to another and include the necessary scale corrections. To convert a difference in temperature from Fahrenheit degrees to Celsius or kelvin degrees, divide by 1.8 only, i.e., a change from 70 to 88 F represents a change of 18 F deg or 18/1.8=10 C deg. To convert deg C to deg F, tF=1.8 to +32.

\*Reprinted from Engineering Data, New York Concrete Construction Institute Inc., 110 East 42nd St., New York City, N.Y.

## METRICATION

Feet x 0.3048 = Meters

Miles x 1.6093 = Kilometers

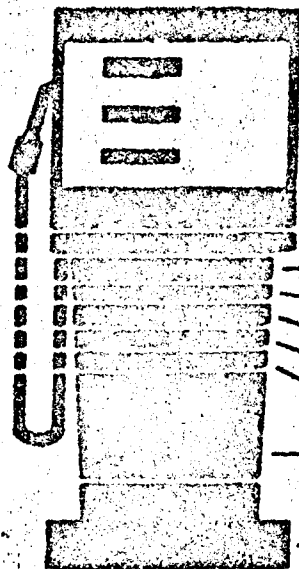
Cubic feet x 0.0283 = Cubic meters

Cubic yards x 0.7646 = Cubic meters

Short tons x 0.9072 = Metric tons

Horsepower (U.S.) x 1.01387 = Metric horsepower

## WHERE YOUR GAS MONEY GOES



- 23.5c CRUDE OIL COST
- 2.0c TRANSPORTATION OF CRUDE
- 2.5c REFINERY OPERATIONS
- 1.5c TRANSPORT OF GAS TO TERMINAL & STORAGE
- 2.5c TRANSPORT OF GAS TO SERVICE STATION
- 2.0c MARKETING COSTS
- 2.0c PROFITS
- 12.0c EXCISE TAXES
- 10.7c SERVICE STATION COST & DEALER PROFIT

Source: A.P.I.

58.7c SERVICE STATION PRICE TO CONSUMER

\* Average cost of crude to American refiners

AP

This chart gives the breakdown on a gallon of gas costing 58.7 cents, the average U.S. price for regular in July, 1975.

## JSGS and USBM Standardize Mineral-Resource Terminology

New definitions for mineral-resource terms have been announced jointly by the U.S. Geological Survey and the U.S. Bureau of Mines. The classification system adopted is based on the extent of geologic knowledge about mineral deposits, including fuels, and the economic feasibility of their recovery. The chart that accompanies this article was supplied by these agencies to help demonstrate relationships between the terms.

The Oklahoma Geological Survey has not yet adopted the new classification system but is evaluating its applicability to Oklahoma terminology. Terms of the new system are defined below. Please note that "measured," "indicated," and "inferred" are applicable for both the reserve and the identified-subeconomic components.

**Resource**—A concentration of naturally occurring solid, liquid, or gaseous materials in or on the earth's crust in such form that economic extraction of a commodity is currently or potentially feasible.

**Identified resources**—Specific bodies of mineral-bearing material whose location, quality, and quantity are known from geologic evidence supported by engineering measurements with respect to the demonstrated category.

**Undiscovered resources**—Unspecified bodies of mineral-bearing material surmised to exist on the basis of broad geologic knowledge and theory.

**Reserve**—That portion of the identified resource from which a usable mineral and energy commodity can be economically and legally extracted at the time of determination. The term *ore* is also used for reserves of some minerals.

**Measured**—Material for which estimates of the quality and quantity have been computed, within a margin of error of less than 20 percent, from analyses and measurements from closely spaced and geologically well-known sample sites.

**Indicated**—Material for which estimates of the quality and quantity have been computed partly from sample analyses and measurements and partly from reasonable geologic projections.

**Demonstrated**—A collective term for the sum of materials in both measured and indicated resources.

**Inferred**—Material in unexplored but identified deposits for which estimates of the quality and size are based on geologic evidence and projection.

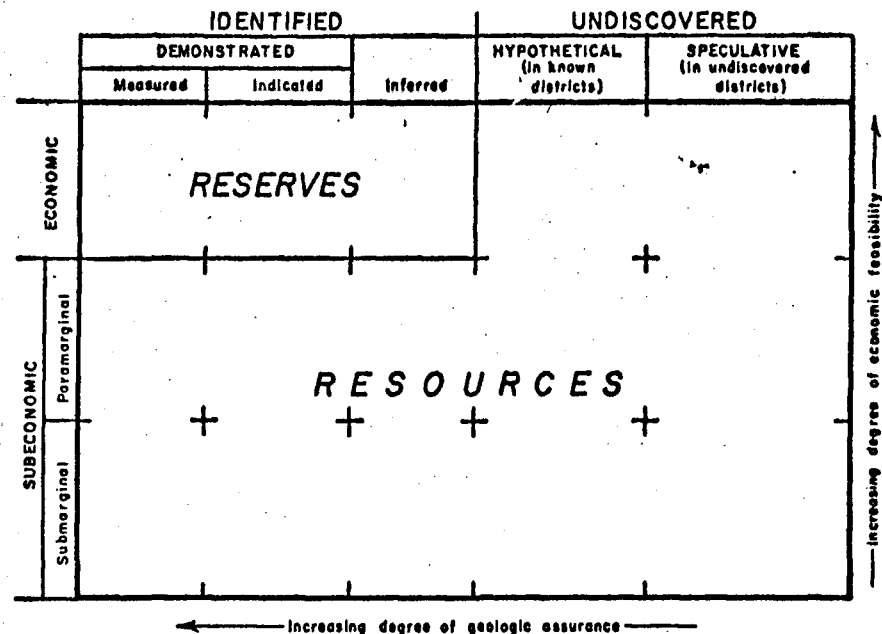
**Identified-Subeconomic resources**—Known deposits not now minable economically.

**Paramarginal**—The portion of subeconomic resources that (a) borders on being economically producible or (b) is not commercially available solely because of legal or political circumstances.

**Submarginal**—The portion of subeconomic resources which would require a substantially higher price (more than 1.5 times the price at the time of determination) or a major cost-reducing advance in technology.

**Hypothetical resources**—Undiscovered materials that may reasonably be expected to exist in a known mining district under known geologic conditions. Exploration that

## TOTAL RESOURCES



confirms their existence and reveals quantity and quality will permit their reclassification as a reserve or identified-subeconomic resource.

**Speculative resources**—Undiscovered materials that may occur either in known types of deposits in a favorable geologic setting where no discoveries have been made, or in as yet unknown types of deposits that remain to be recognized. Exploration that confirms their existence and reveals quantity and quality will permit their reclassification as reserves or identified-subeconomic resources.

# SOIL—SEPARATE SIZE LIMITS OF CE,USBR; ASTM; AASHO; USDA; INTERNATIONAL; WENTWORTH; AND KRUMBEIN METHODS.

| PARTICLE SIZE — IN.                            |                       |      |      |      |      |           |                |                |             |             | .0029            | .0041            | .0059    | .0098       | .0165         | .0331         | .0469         | .0787         |         |     |     |     |      |      |      |     |        |      |      |      |      |      |      |      |      |
|--|-----------------------|------|------|------|------|-----------|----------------|----------------|-------------|-------------|------------------|------------------|----------|-------------|---------------|---------------|---------------|---------------|---------|-----|-----|-----|------|------|------|-----|--------|------|------|------|------|------|------|------|------|
| PARTICLE SIZE — MM.                            | .001                  | .002 | .005 | .01  | .02  | .05       | .1             | .2             | .5          | 1.0         | 2.0              | 5.0              | 10.0     | 20.0        | 50.0          | 100           | 200           | 300           |         |     |     |     |      |      |      |     |        |      |      |      |      |      |      |      |      |
| ARMY CORPS OF ENGINEERS, BUREAU OF RECLAMATION | FINES (CLAY AND SILT) |      |      |      |      |           |                | FINE SAND      |             |             | MEDIUM SAND      |                  |          | COARSE SAND | FINE GRAVEL   |               |               | COARSE GRAVEL |         |     |     |     |      |      |      |     |        |      |      |      |      |      |      |      |      |
| AMERICAN SOCIETY FOR TESTING MATERIALS         | CLAY                  |      | SILT |      |      |           |                | FINE SAND      |             |             | COARSE SAND      |                  |          | GRAVEL      |               |               |               |               |         |     |     |     |      |      |      |     |        |      |      |      |      |      |      |      |      |
| AMERICAN ASSOC. OF STATE HIGHWAY OFFICIALS     | CLAY                  |      | SILT |      |      |           |                | FINE SAND      |             |             | COARSE SAND      |                  |          | FINE GRAVEL |               | MEDIUM GRAVEL | COARSE GRAVEL |               |         |     |     |     |      |      |      |     |        |      |      |      |      |      |      |      |      |
| U.S. DEPARTMENT OF AGRICULTURE                 | CLAY                  | SILT |      |      |      |           | VERY FINE SAND | FINE SAND      | MEDIUM SAND | COARSE SAND | VERY COARSE SAND | FINE GRAVEL      |          |             | COARSE GRAVEL |               |               |               |         |     |     |     |      |      |      |     |        |      |      |      |      |      |      |      |      |
| INTERNATIONAL                                  | CLAY                  | SILT |      |      |      | FINE SAND |                |                |             | COARSE SAND |                  |                  |          | GRAVEL      |               |               |               |               |         |     |     |     |      |      |      |     |        |      |      |      |      |      |      |      |      |
| WENTWORTH                                      | CLAY                  |      | SILT |      |      |           |                | VERY FINE SAND | FINE SAND   | MEDIUM SAND | COARSE SAND      | VERY COARSE SAND | GRANULES | PEBBLES     |               |               |               |               | COBBLES |     |     |     |      |      |      |     |        |      |      |      |      |      |      |      |      |
| KRUMBEIN PHI SCALE                             | 10.0                  | 9.0  | 8.0  | 7.0  | 6.0  | 5.0       | 4.0            | 3.0            | 2.0         | 1.0         | 0.0              | -1.0             | -2.0     | -3.0        | -4.0          | -5.0          | -6.0          |               |         |     |     |     |      |      |      |     |        |      |      |      |      |      |      |      |      |
| U.S. STANDARD SIEVE SIZES                      |                       |      |      |      |      |           |                |                |             |             | 400              | 325              | 270      | 200         | 140           | 100           | 60            | 40            | 20      | 16  | 10  | 4   | 3/8" | 1/2" | 3/4" | 1"  | 1 1/2" | 2"   | 3"   |      |      |      |      |      |      |
| PARTICLE SIZE — MM.                            | .001                  | .002 | .003 | .004 | .005 | .006      | .007           | .008           | .009        | .010        | .02              | .03              | .04      | .05         | .06           | .07           | .08           | .09           | .10     | 2.0 | 3.0 | 4.0 | 5.0  | 6.0  | 7.0  | 8.0 | 9.0    | 10.0 | 20.0 | 30.0 | 40.0 | 50.0 | 60.0 | 70.0 | 80.0 |