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R. L. PRESTON
PROJECT EXECUTIVE

NATUNA PROJECT

February 3, 1981

Mr. G. A. Northington
Exxon Research & Engineering Co.
Florham Park, N.J.

ETR 81-1

$CO_2$ Emissions
Natuna Gas Project

FILE: 68-4-1-5

Dear Gene:

Sometime ago you passed to me a rough calculation you had made regarding the potential level of total emissions of $CO_2$ from producing Natuna Gas and subsequent burning of the LNG manufactured from the gas relative to what would be emitted if Natuna gas were not produced and coal was burned as a replacement for the LNG. Your calculation (attached) indicates that the total $CO_2$ emissions from producing Natuna gas and burning the LNG would be no higher than what would be emitted by burning an amount of coal equivalent in heating value to the LNG. This result is reflective of the fact that: (1) the $CO_2$ emitted per unit of heating value is higher for coal than for LNG because of the higher carbon content of coal (or conversely the lower hydrogen content), and (2) producing LNG at Natuna will result in the release of a significant amount of $CO_2$ because of the high $CO_2$ content of the raw gas.

I have made a brief, independent analysis of the relative release of $CO_2$. A copy of the calculation is attached. In the calculations, I have attempted to be somewhat more rigorous, firstly, in simulating the chemical, ash and moisture content and the heating value of coal likely to be burned in Japan (the properties used reflect a composite of some typical Australian coals) and, secondly, in reflecting, in a gross sense, the relative heat release from burning coal or LNG in a commercial boiler.

The calculations indicate that the total release of $CO_2$ from producing Natuna gas and burning of the LNG manufactured from the gas would be almost twice that emitted by burning an equivalent amount of coal. The $CO_2$ released from burning coal is calculated to be almost twice that from burning LNG (this result is consistent with the generalized data presented in Table 1 of S. Knisely's memorandum on "Controlling the $CO_2$ Concentration in the Atmosphere," issued by Exxon Engineering's Petroleum Department, dated October 16, 1979); but producing this volume of LNG at Natuna releases nearly 40% more $CO_2$ than is released from burning coal.

Based on these calculations, the $CO_2$ content of the raw gas at Natuna would have to be around 50% for the total $CO_2$ emissions to be equivalent.

It appears to me that there are two major reasons for the differing results of the two calculations. First, you assumed coal to be 100% carbon, but the heating value you used for coal (10,750 BTU/Lb) represents an "as-received" coal with some level of moisture and ash. The heating value of pure carbon is 14,100 BTU/Lb. This resulted in an overstatement of the amount of coal required, and thus the amount of $CO_2$ emitted, for a given level of heat release. Second, you used a $CO_2$ content of raw Natuna gas of 63%, whereas the nominal level we have been using for planning purposes is 71.8%. Adjusting your calculations for these two factors would bring the results of both calculations into close agreement.

Both of these calculations are, of course, very rough approximations. To get a more accurate evaluation one would need to determine more precisely the relative heat liberated by both fuels in a commercial boiler, which would, of course, involve a determination of relative stack temperatures, excess air, etc.; and the energy consumed in the producing (or mining), manufacturing, shipping and terminalling of each fuel. It is also likely that the relative release of $CO_2$ could vary significantly, depending on the specific coal considered. While the boiler efficiency would probably favor LNG, I would guess that coal would probably have the advantage in terms of the overall energy consumed in getting the fuels out of the ground and to the market. This would seem to be particularly true in the case of Natuna, where fuel requirements will be higher than in conventional LNG projects because of the need to either vent or reinject the $CO_2$ recovered from the raw gas. For example, including transportation and receiving losses, as well as fuel requirements for producing and liquefaction, around 1.6 times as much hydrocarbon will need to be produced as will finally be received at the boiler burner. While the enery requirements for coal mining, etc. are undoubtedly substantial also, I doubt they will be this high.

You may want to have one of your engineers look over these calculations to see if any additional light can be shed on this subject. However, I doubt that any extensive additional work is justified.

Very truly yours,

G. R. Gervasi

GRG:jdh/mkf
Attachments

cc: R. L. Preston
G. J. Lookabaugh

0405N

G A NORTHINGTON
CALCULATIONS

MR JOHN WOODWARD – What do you think of this

Steve Northington

## COAL BURNED IN JAPAN

$C + O_2 \rightarrow CO_2 + (12)(10,750\ BTU/\#)$

12# 44# 129.000 BTU

$\frac{1.000.000}{129.000} \times 12$ 93# COAL / $\frac{1,000,000}{129.000} \times 44$ GIVES 344# $CO_2$ AND 1,000.000 BTU

## METHANE BURNED IN JAPAN ($CO_2$ IN GAS VENTED OR [illegible])

$.372\,CH_4 + .744\,O_2 + .628\,CO_2 \rightarrow .372\,CO_2 + .628\,CO_2 + .744\,H_2O +$

.72 .72

$.372 \times 16 \times 21.500$

127,968 BTU

$.372\,CH_4 + .744\,O_2 + .628\,CO_2 \Rightarrow CO_2 + .744\,H_2O + 127,968$ BTU

$\frac{1,000,000}{127,968}$ .72

$\times 7.81$ $2.9\,CH_4 + 5.81\,O_2 + 4.9\,CO_2 \rightarrow 7.81\,CO_2 + 5.81\,H_2O + 1,000.000$ BTU

46.5# 343.8#

5.62

3.15

Conclusion

EXCLUDING ANY CO2 PRODUCED TO [illegible] [illegible] to separate the CO2 from the CH4 or natural

If the [illegible] were 37% CH4
63% CO2

The [illegible] CO2 emission from Natural Gas

is no more than the CO2 emitted from Coal

[illegible] produce the same energy in Japan.

KEEP IN MIND THAT IT TAKES ENERGY TO [illegible]

RAIL [illegible] & SEA SHIP the coal from the

WEST VIRGINIA HILLS TO JAPAN

## SUMMARY OF G.R. GERVASI CALCULATIONS

| | |
|---|---|
| $CO_2$ emitted from burning coal equivalent to 1MBTU heat release, Lbs | 253 |
| $CO_2$ emitted from burning LNG equivalent to 1M BTU heat release, Lbs. | 128 |
| $CO_2$ emitted in producing raw gas equivalent to that required to manufacture sufficient LNG for 1M BTU heat release, Lbs | 345 |
| Total $CO_2$ emitted for LNG case | 473 |

COAL BASIS

| | |
|---|---|
| MOISTURE | 8 % wt. |
| ASH | 12 " |
| CARBON | 82 wt (ash/moist. free) |
| HYDROGEN | 6 |
| OXYGEN | 8 |
| NITROGEN | 3 |
| SULFUR | 1 |
| | 100 |

LNG BASIS

| | |
|---|---|
| $C_1$ | 98.1 mol% |
| $C_2$ | 0.1 " |
| $N_2$ | 1.8 " |
| HHV | 23,135 BTU/LB |
| LLV | 20,850 BTU/LB |

Gas as produced:
71.8 % $CO_2$
27 % Hydrocarbon

SIMPLIFIED APPROACH

ASSUME
- SAME EXCESS AIR FOR BOTH FUELS
- " STACK TEMP. " " "

1. GROSS HEATING VALUE OF COAL

BY DULONG FORMULA

$$BTU/LB = 155.44C + 621(H - \tfrac{1}{8}O) + 40.5\,S$$

$$= 155.44 \times 82 + 621\left(6 - \frac{8}{8}\right) + 40.5 \times 1 = 13{,}060 \text{ moisture/ash free-basis}$$

as received basis $= 13{,}060 \times \frac{100-12-8}{100} = 10{,}448$ BTU/LB.

2. NET HEATING VALUE OF COAL

- ADJUST FOR $H_2$ COMB. – HHV · 61,070
  LLV 51,600
  9,470 BTU/LB $H_2$

$0.06 \times 0.8 \times 9470 = 454$ BTU/LB AS REC'D COAL = ADJ. TO COAL HHV

$\therefore$ LLV = 10,448 − 454 = 9994 BTU/LB

COAL COMBUSTION

$CH_{0.8}$:

$\% H_2 = \frac{0.8}{12.8} = 6\%$

$$2.5\,CH_{0.8} + 3O_2 \longrightarrow 2.5CO_2 + H_2O$$

| | | | | |
|---|---|---|---|---|
| 32 | 96 | 110 | 18 | #'s |

IF BURN 1# AS REC'D COAL LIBERATE 9555 BTU

TO GET $1\times10^6$ BTU'S MUST BURN $1\times10^6 \div 9555 =$ 104.7 #'s as rec'd coal

IF BURN 104.7 #'s AS REC'D COAL; BURN $104.7 \times 0.80 \times 0.88 = 73.7$ # OF $CH_{0.8}$

WHEN BURN 73.7 # $CH_{0.8}$ YIELD $\frac{73.7}{32} \times 110 =$ 253.3 #'s $CO_2$

N.G. COMBUSTION

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

| | | | | |
|---|---|---|---|---|
| 16 | 64 | 44 | 36 | #'s |

$$C_2H_6 + 3\tfrac{1}{2}O_2 \longrightarrow 2CO_2 + 3H_2O$$

| | | | | |
|---|---|---|---|---|
| 30 | 112 | 88 | 54 | #'s |

| | MOL FRACT | | | WT FRACT |
|---|---|---|---|---|
| $C_1$ | 0.9805 | × 16 = | 15.727 | 0.966 |
| $C_2$ | 0.0014 | × 30 = | 0.042 | 0.003 |
| $N_2$ | 0.0181 | × 28 = | 0.509 | 0.031 |
| | 1.0 | | 16.278 | |

IF BURN 1# NG LIBERATE 20,850 BTU (LHV)

TO GET $1\times10^6$ BTU MUST BURN $1\times10^6 \div 20{,}850 = 47.96$ # of NG

IF BURN 47.96 # of NG, BURN $47.96 \times 0.966 = 46.33$ #'s $CH_4$

& $47.96 \times 0.003$ 0.14 #'s $C_2H_6$

WHEN BURN:

46.33 # $CH_4$ YIELD $\frac{46.33}{16} \times 44 = 127.4$ # $CO_2$

0.14 # $C_2H_6$ YIELD $\frac{0.14}{30} \times 88 = 0.4$ # $CO_2$

Total 127.8 # $CO_2$

## $CO_2$ RELEASED IN PRODUCTION OF N.G.

ASSUME GAS COMP. = 71.8 % $CO_2$
27 % NG

TO PRODUCE 47.96 #'S OF N.G. OR $\frac{47.96}{16.278} = 2.95$ MOLS OF N.G.

REQUIRES PRODUCTION OF $\frac{2.95}{0.27} \times 0.718 = 7.84$ MOLS OF $CO_2$

OR 345 #'S OF $CO_2$

## TOTAL $CO_2$ EMITTED TO ATMOS

| | | |
|---|---|---|
| COAL COMBUSTION = | | 253.3 # $CO_2$ |
| N.G. COMBUSTION | 127.8 | |
| N.G. PRODUCTION | 345 | |
| TOTAL | | 472.8 # $CO_2$ |

FOR BREAKEVEN ONLY 253.3 - 127.8 = 125.5 #'S OR 2.85 MOLS $CO_2$ BE RELEASED DURING PRODUCTION

∴ REQ'D COMP AT B.E. : 2.85 MOLS $CO_2$ ; $\frac{2.85}{5.80} =$ 49 % $CO_2$
2.95 MOLS N.G.
5.80

• No ADJUSTMENT FOR C SINCE PRODUCES NO $H_2O$.

3. HEAT LOSSES SPECIFIC TO COAL

• MOISTURE IN COAL

| | |
|---|---|
| H@ 60°F vapor | 1088 |
| H@ 60°F liq. | 28 |
| ΔH | 1060 |

ADJUSTMENT TO COAL (LLV) =
1060 x 0.08 = 85 BTU/LB AS REC'D COAL

• ASH IN COAL
- ASSUME: – SP. HT CINDER = 0.25 BTU/LB-°F
– CINDER CONTAINS 20% COMBUSTIBLE
– CINDER LEAVES BOILER AT 1500°F

CINDER FORMED = $\frac{0.12}{1-0.2} = 0.15$ LB

COMBUSTIBLE LEFT IN CINDER: 0.15 x 0.2 = 0.03 LB

HT LOSS:

SENSIBLE HT = 0.15 x (1500-60) x 0.25 = 54 BTU/LB COAL

HT OF COMBUSTION: 0.03 x 9994 = 300

TOTAL 354

4. HEAT AVAILABLE FROM COAL

AS RECEIVED COAL: 9994-85-354 = 9555 BTU/LB

CH WT BASIS = $\frac{9555}{0.8 \times 0.88}$ = 13572 BTU/LB