Very good overall background on Natuna's environmental issues. ✗

A. SKOPP

OCT 31 1983

ESSO EASTERN INC.

Esso

P. O. BOX 1415 • HOUSTON, TEXAS 77001

G. R. GERVASI, MANAGER
NATUNA PROJECT DIVISION

NATURAL GAS DEPARTMENT

October 27, 1983

TO: R. G. Downing - Exxon Corp., N. Y.
S. W. Johnson - Exxon Corp., N. Y.
D. S. McCaffrey - Exxon Corp., N.Y.
A. M. Natkin/D. J. Schumacher - Exxon Corp., N.Y.
~~A.~~ Skopp, Exxon Engineering, Florham Park
M. S. Whittingham, Exxon Engineering, Florham Park
J. L. Woodward, Exxon Engineering, Florham Park
M. G. Bienstock, Exxon Engineering, Florham Park
K. W. Steinberg, Exxon Engineering, Florham Park
A. W. Maki, Research & Environment, East Millstone

Environmental Background Paper
Natuna Gas Project

FILE: 68-4-4

The attached background paper is being circulated to all attendees at the November 15 environmental meeting on the Natuna Project in an effort to get everyone up-to-date on the status of the project and, particularly, the involved environmental issues. The prime task of the meeting is to agree on a basis for the design of a study program which over the next 1-2 years will put Exxon in a position to reach a final decision on the environmental aspects of the project.

G. R. Gervasi

GRG:jdh

Attach.

cc: D. F. Gates
R. E. Simpson

3890N

BACKGROUND PAPER

ENVIRONMENTAL ISSUES

NATUNA GAS PROJECT

1. INTRODUCTION

1.1 Exxon is party to a Production Sharing Agreement (PSC) with Pertamina, the state oil company of Indonesia for exploitation of a large gas discovery located offshore in the Natuna Sea of Indonesia.

1.2 Exploratory drilling and geological/geophysical assessments have confirmed the existence of about 200 TCF of gas in place, with an average gas composition of 71.8% CO_2, 0.5 - 0.7% H_2S, 27.2% hydrocarbons (mostly methane) and the remainder N_2.

1.3 The earliest potential market for Natuna gas, yet identified, is a steam flood project in the Duri crude field of Central Sumatra in the early 1990's, which would be serviced by pipeline from Natuna Island. Potential exists for incremental pipeline sales to the power industry in Singapore during the same time frame, and long term, an opportunity may develop for additional sales to Sumatra or Java, but specific volumes/timing have not been defined.

The earliest markets for Natuna LNG are anticipated to be in Japan and/or perhaps South Korea or Taiwan in the early-to-mid 1990's. Demand in these countries is projected to grow modestly for the foreseeable future, and there is the potential in Japan for additional new volumes as replacement for LNG now supplied under contracts which will expire in the latter part of the 1990's and not be extended due to reserve limitations.

The present basis for the Natuna Project assumes sale of 500 MCFD of pipeline gas to Duri/Singapore beginning in mid-1991 and 760 MCFD of LNG to Japan starting in mid-1992. Over a nominal 20-year life the project would consume only about 30% of the estimated recoverable gas, making it highly likely that additional projects will eventually be developed to fully utilize the gas resource.

1.4 Exploitation will require removal and disposal of the CO_2 and H_2S prior to sale of the remaining gas (primarily methane) either by pipeline or as LNG.

1.5 Studies have shown that removal of the bulk of the CO_2/H_2S at the offshore production site is significantly lower in cost than bringing the raw gas ashore at Natuna Island (140 miles away) prior to removing the off gas.

The optimum process for removal of the off gas has been determined to be cryogenic treatment, in which the CO_2 and H_2S are removed concurrently as a single gaseous mixture. Separation of the CO_2 and H_2S would incur substantial additional costs but may be necessary depending upon the ultimate choice of disposal system.

1.6 The most direct and lowest cost means of disposal of the CO_2/H_2S is by incineration and discharge to the atmosphere. (Since the H_2S is toxic it must be incinerated to convert the H_2S to SO_x before being released to the atmosphere.) However, this raises environmental questions concerning the "greenhouse" effect of the CO_2 and acidic deposition (or "acid rain") of the SO_x.

1.7 Other disposal alternatives include injection of the off gas into the ocean, recovery and sale of the CO_2 and sulfur, and reinjection into the producing reservoir or a suitable nearby underground structure.

2. DISPOSAL BY INCINERATION AND ATMOSPHERIC EMISSION

2.1 Meeting the 1,260 MCFD of sales assumed in the Natuna Project requires production of 5.3 GCFD of raw gas and the removal and disposal of 75 MtY of CO_2 and 440-620 ktY of H_2S (equivalent to 830-1,160 ktY of SO_2 or 1,250-1,750 TD of sulfur).

If discharged to the atmosphere, the CO_2 volume would be about twice that emitted from what is believed to be the largest, industrial emission source of CO_2, Nanticoke's 4000 MW coal-fired power generation plant in Ontario, Canada. The volume of SO_x emitted would be about the same as that from the largest industrial source of SO_x, which is International Nickel's Sudbury smelter also in Ontario, Canada.

2.2 Assessments by a group of prominent scientists with expertise in the study of the greenhouse and acid rain phenomena, supplemented by state-of-the-art simulation model predictions of acid precipitation, have concluded that the CO_2/SO_x emissions from the Natuna Project would not produce any significant adverse effects on the environment.

These conclusions are felt to be representative of the current state of scientific knowledge and the majority view of credible experts; however, in view of the substantial scientific complexities involved in both the greenhouse and acid rain phenomena, the results probably will not be universally accepted as being fully conclusive from a scientific standpoint.

2.3 At present ~~that~~ there are no regulations applicable to the Natuna area which limit CO_2 or SO_x emissions. Although the outlook on future regulations is uncertain, given the industrialization aspirations of the Indonesian people, the remoteness of the Natuna location, and the high level of economic and socio-political importance which government officials attach to the Natuna Project, it is unlikely that restrictive emission controls would be imposed on the project by Indonesia, short of any international agreements which institute regulations on a worldwide basis.

2.4 Although emission regulations on CO_2/SO_x at Natuna are judged to be unlikely, there is uncertainty regarding Exxon's ultimate position on the acceptability of atmospheric discharge, particularly SO_x. There is a strong opinion within the Company that sulfur emission regulations will be imposed in the United States, Europe and possibly other areas without establishment of a sound scientific basis, and there is the further view that intense adverse public opinion could develop against industrial concerns that are perceived to be unresponsive to the acid rain issue, even if emissions are in a relatively isolated area of the world and are within existing laws applicable to that area.

Although a final position has not been taken by Exxon, there is sufficient concern to warrant thorough study and consideration of all available alternatives.

2.5 Preliminary assessments indicate that the incineration operation may produce an extensive and highly visable plume. The presence of a visable plume could provide a focal point for environmental criticism, and, therefore, would be a serious drawback for the atmospheric discharge alternative. Further studies are underway to define the opacity and areal extent of the plume but beyond this effort, no further new scientific studies of atmospheric discharge are judged to be warranted.

3. DISPOSAL BY SUB-SEA INJECTION

3.1 The lowest cost alternative to atmospheric disposal is injection into the ocean at the sea floor. Preliminary studies indicate a probable incremental investment of \$300-400 M (in 1983\$), with an overall effect on Esso's return of less than 1% DCF.

3.2 With this system the H_2S is oxidized and dispersed by ocean currents. While the CO_2 is absorbed, at least initially, there is uncertainty as to whether the CO_2 will react to form carbonates, which will deposit on the ocean floor, or otherwise be permanently absorbed, or will mix with the ocean surface and eventually be released to the atmosphere. The view among the majority of scientists appears to be the latter, but further study is needed to resolve this question.

3.3 Technical studies have indicated a good probability that the system is workable and safe. However, since there is no known operation of a similar nature, or certainly of a like magnitude, and much of the technology is new, further more definitive study and experimentation will be required before a suitable system can be designed with a high degree of confidence.

3.4 The environmental effects of CO_2/H_2S on marine life are not well known. Some evidence exists to indicate that any impacts will be minimal; however, studies are required to better define the effects at conditions expected to exist in the effluent plume.

3.5 Even should the preponderance of scientific data indicate that ocean disposal does not present any significant deleterious environmental effects, there is always some risk that disposal of industrial effluents in the ocean will develop into the same highly emotional and controversial issue as has happened with acid rain, and, accordingly, that ocean disposal might eventually be judged environmentally unacceptable regardless of scientific merits.

4. <u>DISPOSAL BY RECOVERY AND SALES</u>

4.1 One method of disposing of the CO_2 and H_2S is recovery and sale.

4.2 There is no obvious way of chemically treating CO_2 to make a more salable project and there is no present commercial market for CO_2 in the volumes available from the Natuna Project.

There is a likelihood use of CO_2 for enhanced crude recovery will grow in the future and eventually represent a sizeable market. However, there are no existing crude fields serviceable by pipeline from Natuna that are both susceptable to enhanced recovery by CO_2 and require significant volumes of CO_2. Thus, even assuming sufficient outlets could be found for CO_2 to enhance crude recovery projects in other parts of the world, the CO_2 would have to be supplied from Natuna by tankers in liquid form. Studies have shown that supplying CO_2 in this manner is extremely costly and clearly uncompetitive with alternative sources of CO_2 that could be made available locally, including recovery from fossil fuel combustion effluents. Hence, recovery and sale of CO_2 is not a feasible disposal alternative.

4.3 The conventional manner of disposing of H_2S where atmospheric emission is unacceptable is to convert the H_2S to sulfur, which is then sold.

Screening studies have shown that a market will probably be available to accommodate the sulfur recoverable from the Natuna Project, although the cost would be high because of the need to separate the small quantity of H_2S from the large volume of CO_2. Relative to atmospheric emission the incremental investment is roughly estimated to be \$1.3-1.4G (in 1983\$) which would reduce Exxon's return by about 2-3% DCF. Further study is planned to better define the costs related to this alternative, which could become an ultimate fallback for sulfur disposal if both atmospheric discharge and subsea injection are not acceptable.

5. DISPOSAL BY UNDERGROUND INJECTION

5.1 The only effective disposal route for both CO_2 and H_2S that eliminates discharge to the atmosphere or ocean is underground injection, either into the producing formation or a suitable nearby reservoir.

5.2 Preliminary geological examinations have failed to show any suitable formations for injecting gas anywhere in the vicinity with the exception of the producing reservoir, and reservoir modeling studies to date have indicated that reservoir injection does not appear to be practical.

Work conducted to date implies that even if a feasible reinjection operation is identified, the resultant cost is likely to be extremely high, both in terms of higher investment and operating costs and losses in ultimate hydrocarbon recovery. Further studies are needed to confirm reinjection is not a viable alternative.

6. FUTURE EFFORTS

6.1 Plans are to design and carry out an environmental study program over the next 1-2 years, with participation from all appropriate functions, to be in a position to reach a final decision on the environmental aspects of the project sometime in 1985.

$$CO_2 + H_2S \xrightarrow[air]{O_2} S\downarrow + CO_2 + H_2O$$

GRG:jdh
10/27/83

3836N

NATUNA

INPUT Component	%	Lb-mol/d	Lb/d	Lb CO2/d	Stoic Lb N2/d	Lb H2O/d	Lb SO2/d	Stoic Lb O2/d	HHV Btu/d	Btu/Ft3	% HHV
CO2	71.8	10467684	4.61E8	4.6058E8						0	0
CH4	26.46	3857589.5	6.17E7	1.6973E8	8.053E8	1.3887E8		2.469E8	1.4727E12	265.83666	93.355173
H2S	.54	78726.316	2.68E6		1.233E7	1417074	5038484	3778863	1.9058E10	3.4400842	1.2080714
C2H6	.44	64147.368	1.92E6	5644968	2.344E7	3463958		7184505	4.2922E10	7.7477053	2.7208
C3H8	.14	20410.526	898063	2694189	1.065E7	1469558		3265684	1.9439E10	3.5089305	1.2322485
iC4H10		0								0	0
nC4H10	.13	18952.632	1.1E6	3335663	1.286E7	1705737		3942147	2.3406E10	4.2249795	1.4837069
iC5H12		0								0	0
nC5H12		0								0	0
C6H14		0								0	0
N2	.49	71436.842	2E6		2000232					0	0
Subtotal	100	14578947	5.31E8	6.4199E8	8.666E8	1.4693E8	5038484	2.651E8	1.5776E12	284.75836	100
Air	99.998	47452669	1.37E9								
N2	78.084	37053683	1.04E9		1.729E8						
O2	20.946	9939634.7	3.18E8					5.301E7			
A	.934	443216.79	1.77E7								
CO2	.034	16134.23	709906	709906.1							
Total		62031616	1.9E9	6.427E8	1.04E9	1.4693E8	5038484	3.181E8	1.5776E12	284.75836	
Air/Fuel		3.2548762	2.5881								

OUTPUT Flue Gas	%	Lb-mol/d	Lb/d	Mt/a	Lb/MBtu	Global Mt/a '79	Global %	800 MW Mt/a	800 MW Lb/MBtu	8.9GW Mt/a	Nat/8.9GW	#mol/MBtu 800 MW	Mol % 800MW
CO2	23.531	14606745	6.43E8	129.2925	407.399	20643	.626326	5.93928	202.6053	52.917051	2.4433047	4.6046659	13.97
H2O	13.15	8162752.6	1.47E8	29.55808	93.1371			1.7885	61.010691	15.934953	1.8549214	3.3894829	10.28
N2	59.809	37125120	1.04E9	209.1188	658.931			19.756	673.93157	176.01944	1.1880437	24.068985	73.01
O2	2.6688	1656605.8	5.3E7	10.6644	33.6034			.82928	28.289039	7.3886147	1.4433554	.88403247	2.682
A	.71402	443216.79	1.77E7	3.566509	11.238						0		
SO2(Cont)	.12683	78726.316	5.04E6	1.013601	3.19384	226	.448496	.03504	1.1953115	.31219499	3.2466923	.01867674	.0567
SO2(NoCt)	.12683	78726.316	5.04E6	1.013601	3.19384			.206118	7.0312441	1.8364411	.55193768	.10986319	.3333
Total(Ct)	100	62073166	1.9E9	383.2139				28.3481		252.57225	1.5172445	32.965843	100
OUT-IN		41550	0	0	0	0	0	0					

801-END

PRINT COMPLETED AT 15:13:33 FOR USER: TBBX DIST: LA.317

END-801

	Illinois No. 6	Navajo Sub-Bituminous
PROXIMATE ANALYSIS		
WATER	13.0 %	16.5
COAL DAF	77.4 %	66.2
ASH	9.6 %	17.3
HHV	10,788 Btu/lb	8872 Btu/lb
Ultimate Analysis (DAF)		
C	77.0	76.76
H	5.8	5.71
N	1.3	1.37
S	5.0	0.95
O	10.9	15.21
Trace	—	0.04
HHV	13,940	13,400

$$2162 \times 10^3 \, \frac{\text{lb Navajo}}{h} \times \frac{.7676}{.77} \times \frac{.662}{.774} \times \frac{24\,h}{d} \times \frac{\text{U.S. ton}}{2000\ \text{lb}}$$

$$= 22.1 \times 10^3 \, \frac{\text{U.S. tons Illinois No. 6}}{\text{day}}$$

DAF

	Illinois № 6	Navajo.
C	77.00	76.76
H	5.8	5.71
N	1.3	1.37
S	5.0	0.95
O	10.9	15.21
TRACE	?	0.04
AHV	13,938	13,400

ROM COAL HHV 10788 8872 Btu/#

H_2O	13.0	16.5	356,525 #/hr
COAL DAF	77.4	66.2	1,431,696
ASH	9.6	17.3	374,016
			2,162,235 #/hr.

$\frac{13\#\ H_2O}{100\#\ \text{coal ROM}}$

1.4 # H
11.6 # O

$\frac{2\#\ H}{18\#\ H_2O} + \frac{16\#\ O}{18\#\ H_2O}$

NATUNA

INPUT Component	%	Lb-mol/d	Lb/d	Lb CO2/d	Stoic Lb N2/d	Lb H2O/d	Lb SO2/d	Stoic Lb O2/d	HHV Btu/d	Btu/Ft3	% HHV
CO2	71.8	10467684	4.61E8	4.6058E8						0	0
CH4	26.46	3857589.5	6.17E7	1.6973E8	8.053E8	1.3887E8		2.469E8	1.4727E12	265.83666	93.355173
H2S	.54	78726.316	2.68E6		1.233E7	1417074	5038484	3778863	1.9058E10	3.4400842	1.2080714
C2H6	.44	64147.368	1.92E6	5644968	2.344E7	3463958		7184505	4.2922E10	7.7477053	2.7208
C3H8	.14	20410.526	898063	2694189	1.065E7	1469558		3265684	1.9439E10	3.5089305	1.2322485
iC4H10		0								0	0
nC4H10	.13	18952.632	1.1E6	3335663	1.286E7	1705737		3942147	2.3406E10	4.2249795	1.4837069
iC5H12		0								0	0
nC5H12		0								0	0
C6H14		0								0	0
N2	.49	71436.842	2E6		2000232					0	0
Subtotal	100	14578947	5.31E8	6.4199E8	8.666E8	1.4693E8	5038484	2.651E8	1.5776E12	284.75836	100
Air	99.998	47452669	1.37E9								
N2	78.084	37053683	1.04E9		1.729E8						
O2	20.946	9939634.7	3.18E8					5.301E7			
A	.934	443216.79	1.77E7								
CO2	.034	16134.23	709906	709906.1							
Total		62031616	1.9E9	6.427E8	1.04E9	1.4693E8	5038484	3.181E8	1.5776E12	284.75836	
									1.7706E11 coal plant		
Air/Fuel		3.2548762	2.5881						8.9096743 RATIO		

OUTPUT Flue Gas				Mt/a	Lb/MBtu	Global Mt/a '79	Global %	800 MW Mt/a	800 MW Lb/MBtu	8.9GW Mt/a	Nat/8.9GW	#mol/MBtu 800 MW	Mol % 800MW
CO2	23.531	14606745	6.43E8	129.2925	407.399	20643	.626326	5.93928	202.6053	52.917051	2.4433047	4.6046659	13.97
H2O	13.15	8162752.6	1.47E8	29.55808	93.1371			1.7885	61.010691	15.934953	1.8549214	3.3894829	10.28
N2	59.809	37125120	1.04E9	209.1188	658.931			19.756	673.93157	176.01944	1.1880437	24.068985	73.01
O2	2.6688	1656605.8	5.3E7	10.6644	33.6034			.82928	28.289039	7.3886147	1.4433554	.88403247	2.682
A	.71402	443216.79	1.77E7	3.566509	11.238					0			
SO2(Cont)	.12683	78726.316	5.04E6	1.013601	3.19384	226	.448496	.03504	1.1953115	.31219499	3.2466923	.01867674	.0567
SO2(NoCt)	.12683	78726.316	5.04E6	1.013601	3.19384			.206118	7.0312441	1.8364411	.55193768	.10986319	.3333
Total(Ct)	100	62073166	1.9E9	383.2139				28.3481		252.57225	1.5172445	32.965843	100
OUT-IN		41550	0	0	0	0	0	0					

```
*********  *********      *               *********  *      **  ********
*********  *********     **               *********  **     **  *********
**    **   **           ***               **         ***    **  **     **
     **    ********    ****               **         ****   **  **     **
    **      ********  ** **    *******    ******     ** **  **  **     **
   **            **  **  **    *******    ******     **  ** **  **     **
  **             **  *********            **         **   ****  **     **
  **       **    **  *********            **         **    ***  **     **
  **       *********     **               *********  **     **  *********
  **        *******      **               *********  **      *  ********
```

PRINT COMPLETED AT 14:03:29 FOR USER: TBBX DIST: LA.317

```
*********  *      **  ********          *********  *********      *
*********  **     **  *********         *********  *********     **
**         ***    **  **     **         **    **   **           ***
**         ****   **  **     **              **    ********    ****
******     ** **  **  **     **  *******    **      ********  ** **
******     **  ** **  **     **  *******   **            **  **  **
**         **   ****  **     **           **             **  *********
**         **    ***  **     **           **       **    **  *********
*********  **     **  *********           **       *********     **
*********  **      *  ********            **        *******      **
```