ORKUSTOFNUN
NATIONAL ENERGY AUTHORITY
HYDRO ENERGY DIVISION

LUMMUS

THE LUMMUS COMPANY LIMITED
P. O. Box 64, 100 Fetter Lane
London EC4P 4BA

REFINERY FEASIBILITY STUDY ICELAND

OS81013/VOD05
Reykjavík, July 1981

ORKUSTOFNUN
NATIONAL ENERGY AUTHORITY
HYDRO ENERGY DIVISION
GRENSÁSVEGUR 9,
108 REYKJAVÍK ICELAND

LUMMUS

THE LUMMUS COMPANY LIMITED
P. O. Box 64, 100 Fetter Lane
London EC4P 4BA

REFINERY FEASIBILITY STUDY ICELAND

OS81013/VOD05
Reykjavík, July 1981

Published with
the permission of
the Lummus Company Ltd.

ORKUSTOFNUN

Dags. 1981 04 27 | Tilv. vor JB/sg
Dags. | Tilv. yðar

Iðnaðarráðuneytið
Arnarhvoli
101 Reykjavík

Olíuhreinsunarstöð á Íslandi

Að beiðni hins háa ráðuneytis hefur Orkustofnun haft með höndum könnun á möguleikum þess að vinna hér á landi olíuvörur þær, sem nú eru fluttar fullunnar til landsins. Stofnunin samdi við ráðgjafafyrirtækið The Lummus Company Ltd. í London um að vinna þetta verk fyrir hana. Hjálagt fylgir eintak af skýrslu Lummus.

Athugun sú, sem skýrslan fjallar um, tekur til olíuhreinsunarstöðvar sem annar fyrirsjáanlegri eftirspurn íslendinga eftir olíuvörum, sem er talið að muni nema 562 þúsund tonnum á ári að meðtöldum 15 þúsund tonnum af malbiki. (Núverandi notkun malbiks er um 10 000 tonn/ári, en hún er talin munu vaxa mjög nú á næstunni). Til framleiðslunnar þarf um 600 þús. tonn af hráolíu, en stöðin er hönnuð fyrir 675 þús. tonn miðað við 330 rekstrardaga. Almennt eru olíuhreinsistöðvar hannaðar með nokkrum slaka, þannig að árleg afköst slíkrar stöðvar gætu numið um 750 þús. tonnum af hráolíu ef hagkvæmur markaður finnst fyrir einstakar afurðir. Hagkvæmnisathugun miðast þó eingöngu við innlendan markað.

Athugunin náði til mismunandi gerða af hráolíu, og voru borin saman ferns konar hráefni:

1. Létt hraolía frá Norðursjónum (Ninien/Ekofisk 70/30%).
2. Meðalþung hráolía frá Saudi-Arabíu (Light Arabian).
3. Meðalþung hráolía frá Sovétríkjunum (Romashkinskaja).
4. Þung hráolía, eða svartolía.

Auk þess voru athugaðar blöndur af þessum hráolíum.

Meginniðurstöður athugunarinnar má draga saman þannig:

1. Tæknilega er mögulegt að byggja olíuhreinsistöð, sem breytir léttari eða meðalþungri hráolíu í þær olíuafurðir sem íslendingar þarfnast, án útflutnings á olíuvörum.

2. Heildarstofnkostnaður slíkrar stöðvar er áætlaður 127 milljónir dollara eða 831 milljónir króna miðað við verðlag í Bretlandi, en 115 milljónir dollara miðað við verðlag í suðurríkjum Bandaríkjanna. Sjálf hreinsunarstöðin er áætluð að kosta $ 55 milljónir dollara, tankar og byggingar 52 milljónir dollara, olíuafgreiðsla og höfn 20 milljónir. Þessar og aðrar verðtölur í brefi þessu miðast við verðlag í janúar 1981.

3. Árlegt söluverðmæti afurða er mun meira en heildarstofnkostnaður olíuhreinsistöðvarinnar. Vegna þess hve veltan er mikil miðað við stofnkostnað og árlegan reksturskostnað þá nægir að virðisaukinn sé 15% af árlegri veltu til að stöðin skili 12% raunvöxtum af fjárfestingu (sjá töflu I). Stöðin veltir stofnkostnaði sínum á rúmum 8 mánuðum. Olíuhreinsunarstöð er að þessu leyti verulega frábrugðin t.d. vatnsaflsvirkjunum. Sem dæmi má nefna að það myndi taka Blönduvirkjun um 5,5 ár að velta stofnkostnaði sínum þó að hún seldi alla orku sína á núverandi heildsölugjaldskrá Landsvirkjunar til notanda með 5000 stunda nýtingartíma. Í reynd yrði veltutíminn væntanlega lengri en það.

4. Miðað við verðlag á olíuvörum á Rotterdammarkaði í janúar 1981, sem er mjög lágt miðað við það verð sem skráð er á hráolíu á sama tíma, (sjá mynd I) kemur í ljós að ef hráolía fengist frá Saudi-Arabíu á skráðu útflutningsverði þar ($ 32 á tunnu), skilar olíuhreinsistöðin raunvöxtum, sem nema 12,6% miðað við 20 ára afskriftatíma og 11,0% miðað við 15 ára afskriftartíma.

5. Við tiltölulega litla hækkun á hráolíuverði, að óbreyttu afurðaverði, minnkar arðurinn ört, og er 8,1% miðað við 20 ára afskriftartíma ef notuð er olía frá Sovétríkjunum, sem áætlað er að kosti $ 34,20 á tunnu. Tap er á stöðinni ef keypt er olía úr Norðursjó, miðað við verðlag í dag.

6. Eins og getið er í 4. lið er verðlag á Rotterdammarkaði mjög lágt í janúar 1981, og má sem dæmi taka skráð verð á gasolíu $ 302,00, sem er mun lægra en það verð sem samið var um við BNOC sumarið 1980, en það var um $ 330.00. Frá þeim tíma hefur hráolía hækkað um 10% og líklegt að BNOC telji að "eðlilegt" verð á gasolíu sé nú nær $ 350 á tonn. Til þess að kanna áhrif afurðaverðs á hagkvæmni olíuhreinsunarstöðvar eru því í töflu 1 sýnd áhrif af 10% hækkun afurðaverðs án hækkunar á hráolíu. Kemur þá í ljós að hagnaður af stöðinni vex mjög mikið og þá er stöðin einnig arðbær þótt keypt sé hráolía úr Norðursjó.

7. Af framansögðu má ljóst vera að olíuhreinsistöð á Íslandi er mjög ódýr trygging gegn sveiflum á Rotterdammarkaði, þar eð álagning hennar nemur aðeins 15% af söluverðmæti þegar hún skilar nægjanlegum arði. Ein sveifla í framtíðinni á hlutfallinu milli verðs á olíuvörum á Rotterdammarkaði og á hráolíu, af sömu stærð og mynd I sýnir nægir til að greiða að fullu stofnkostnað hreinsunarstöðvarinnar meðan hún stendur yfir, vegna hins stutta veltutíma hennar.

8. Á mynd I er sýnt hvernig verð á gasolíu hefur þróast á Rotterdammarkaði og útflutningsverð hráolíu frá Saudi-Arabíu á sama tíma. Einnig er sýnt hvernig hlutfallið á milli þessara verða hefur þróast, og kemur í ljós að verðlag á Rotterdammarkaði í janúar 1981 er það hagstæðasta sem þekkst hefur frá ársbyrjun 1977 miðað við verð á hráolíu frá Saudi-Arabíu, en jafnframt það óhagstæðasta fyrir rekstur olíuhreinsunarstöðvar.

9. Lummus komst að þeirri niðurstöðu að ekki sé hægt að byggja olíuhreinsunarstöð, sem hentar samsetningu íslenska markaðarins og notar mjög þunga hráolíu né heldur svartolíu. Þannig stöð myndi aðeins anna hluta af íslenska markaðinum, eða að öðrum kosti vera það stór að flytja þyrfti út sumar afurðirnar. Rekstraráætlanir sem byggja á verulegum útflutningi eru óöruggar og að ósk Orkustofnunar miða Lummus áætlanir sínar við að útflutningur sé enginn.

10. Í skýrslunni er reiknað með að öll gufa sé framleidd úr olíu og gasi. Í heild er notuð orka sem samsvarar 83 GWh til gufuframleiðslu. Ef hægt er að selja olíuna og gasið sem notað er til gufuframleiðslu á sama verði og svartolíu, þá er hagkvæmt að nota rafmagn á 20 mills/kWh, til gufuframleiðslunnar. Raforka til rekstrar nemur um 30 GWh á ári.

    Í skýrslunni er talað um að nota propan (kosangas) til vetnisframleiðslu, þar eð ekki er gert ráð fyrir markaði fyrir allt propanið innanlands. Ef hins vegar reynist unnt að selja propanið fyrir $ 300,00 á tonn innanlands eða utan þá er hagkvæmara að nota rafmagn á 17,5 mills/kWh til vetnisframleiðslunnar. Til þess þarf 61 GWh árlega.

Það er mat Orkustofnunar að niðurstöður þessarar könnunar, þær sem að framan voru raktar, gefi tilefni til að það verði kannað nánar, hvort rétt sé að koma á fót olíuhreinsunarstöð hérlendis. Ljóst er af framansögðu að miklu getur skipt fyrir afkomu stöðvarinnar hvaðan hráolía yrði keypt til hennar, en það tengist aftur spurningunni um það, hvaða vægi sé rétt að gefa verðinu á olíunni annars vegar og öryggi í aðföngum hins vegar þegar mörkuð er stefna í olíukaupamálum. Almennir viðskiptahagsmunir hljóta og að tengjast þeirri stefnumörkun.

Að þessu athuguðu vill Orkustofnun leyfa sér að leggja til við hið háa ráðuneyti, að framhald þessa máls verði það, að ráðuneytið hafi forgöngu um myndun starfshóps með fulltrúum þess, Viðskiptaráðuneytis, Orkustofnunar og olíufélaga er falið verði að gera á málinu nánari úttekt er m.a. taki mið af viðhorfum í olíukaupum til landsins á næstu árum, og skili um það álitsgerð til ráðuneytanna beggja.

Allra virðingarfyllst,

Jakob Björnsson

Jakob Björnsson

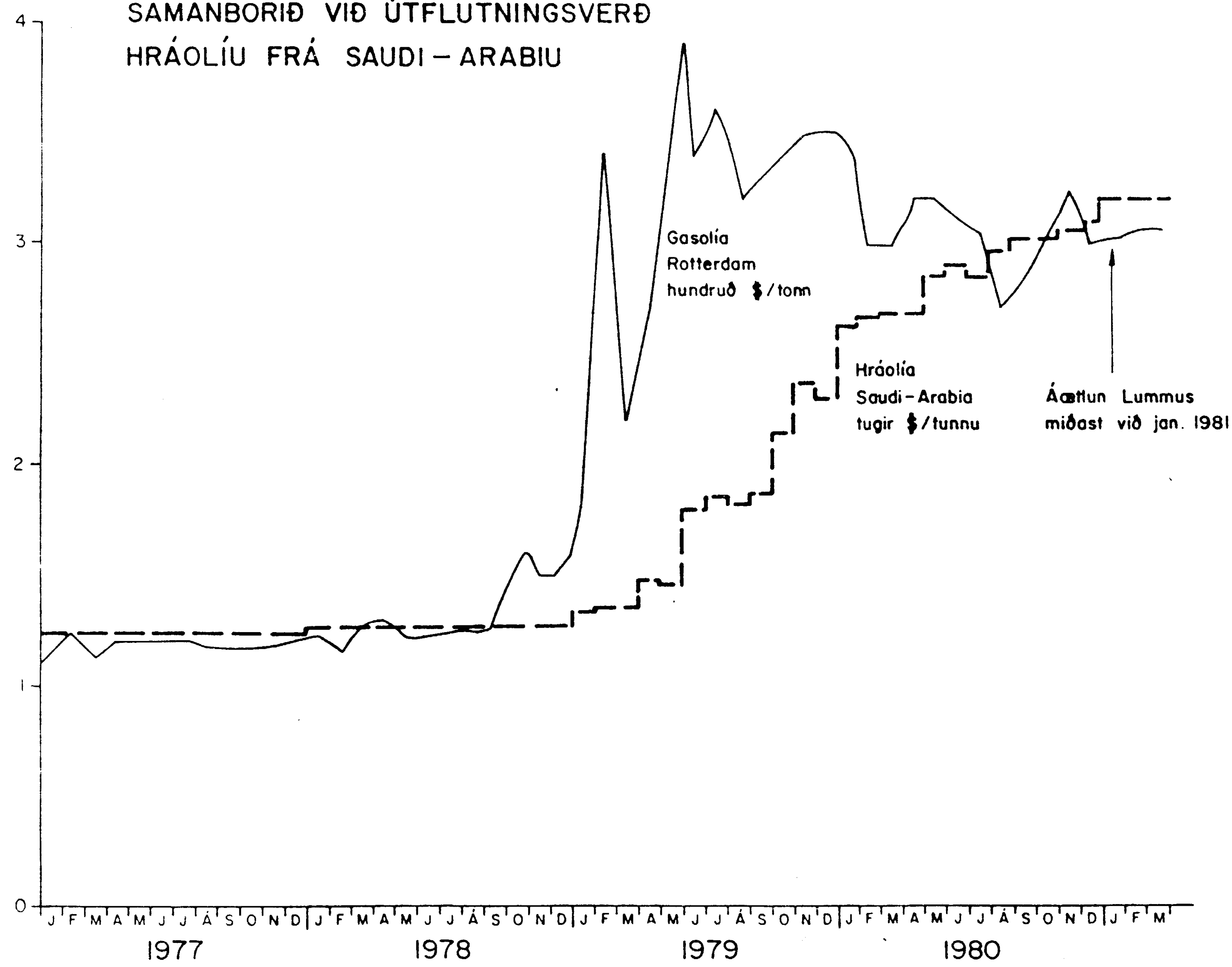
TAFLA 1

Yfirleit yfir hagkvæmni olíuhreinsunarstöðvar, miðað við verðlag í janúar 1981. Kostnaður er talinn í þúsundum dollara á ári.

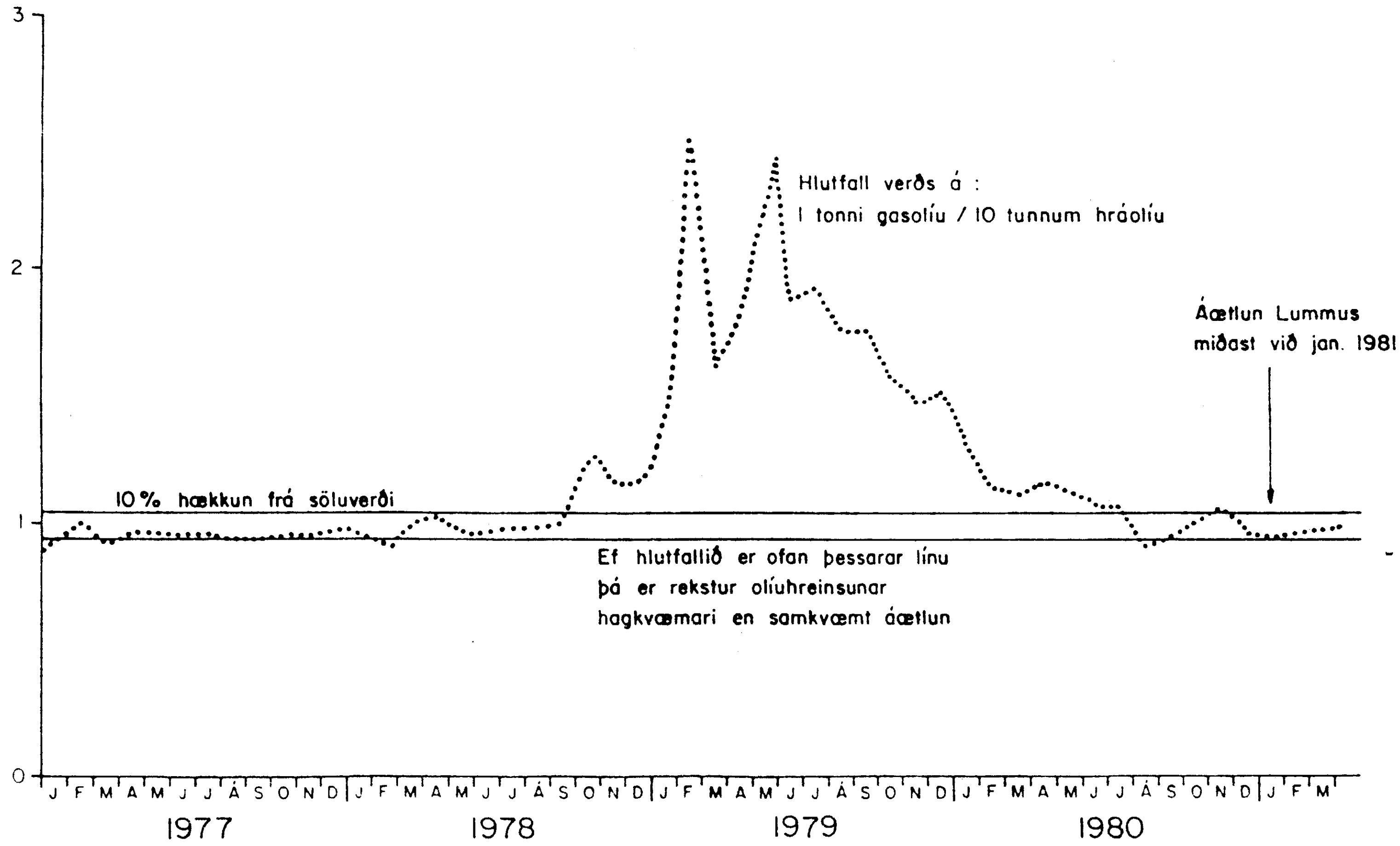
Uppruni hráolíu	Norðursjór	Saudi-Arabia	Sovétríkin	Norðursj.-Saudi Blanda 1	Norðursj.-Saudi Blanda 2
Söluverð afurða	185.286	182.745	183.127	182.295	185.221
Kaupverð hráolíu	179.898	153.624	158.662	162.083	166.293
Virðisauki	5.388	29.121	24.465	20.212	18.928
Virðisauki % af veltu	2,9%	15,9%	13,4%	11,1%	10,2%
Rekstrarliðir:					
Hvatar og íblöndunarefni	248	248	248	248	248
Rafmagn	554	554	554	554	554
Laun vaktavinnumanna	2.800	2.800	2.800	2.800	2.800
Stjórnun og skrifstofuhald	4.200	4.200	4.200	4.200	4.200
Viðhald olíuhreinsitækja *	2.200	2.200	2.200	2.200	2.200
Viðhald tanka, húsa, bryggju *	1.440	1.440	1.440	1.440	1.440
Rekstrarkostnaður alls	11.442	11.442	11.442	11.442	11.442
Rekstrarafgangur án afskrifta og vaxta	÷ 6.054	17.679	13.023	8.770	7.486
Endurheimtutími stofnkostnaðar	-	7,2 ár	9,8 ár	14,5 ár	17,0 ár
Raunvextir m.v. 20 ára afskrift	-	12,6%	8,1%	2,9%	1,6%
Raunvextir m.v. 15 ára afskrift	-	11,0%	6,0%	0,5%	-
Rekstrarafgangur með 10% hækkun afurða	12.475	35.953	31.336	27.000	26.000
Endurheimtutími stofnkostnaðar	10,2 ár	3,5 ár	4,1 ár	4,7 ár	4,9 ár
Raunvextir m.v. 20 ára afskrift	7,5%	28,1%	24,3%	20,8%	20,0%
Raunvextir m.v. 15 ára afskrift	5,3%	27,5%	23,5%	19,8%	19,0%

* Miðað við heildarstofnkostnað $ 127.000

VERÐLAG GASOLÍU Á ROTTERDAMMARKAÐI SAMANBORIÐ VIÐ ÚTFLUTNINGSVERÐ HRÁOLÍU FRÁ SAUDI – ARABIU



VERÐLAG GASOLÍU Á ROTTERDAMMARKAÐI
SAMANBORIÐ VIÐ ÚTFLUTNINGSVERÐ
HRÁOLÍU FRÁ SAUDI-ARABIU



LETTER TO THE MINISTRY OF INDUSTRY (Translation)

OIL REFINING IN ICELAND

At the request of the Ministry of Industry Orkustofnun (National Energy Authority) has studied the possibility of producing locally the oil products, that are now imported. The NEA engaged Lummus Ltd, London, to produce a feasibility study of an oil refinery in Iceland.

The study covers a refinery, capable of supplying our expected future needs for oil products, which are estimated at 562.000 tonnes annually including 15.000 tonnes of bitumen. The refinery uses annually about 600.000 tonnes of crude, but its design capacity is 15.000 bpsd, which is equivalent to 675.000 tonnes in 330 days of operation. Generally a refinary is designed with some margin of overcapacity, and the refinery should be able to process 750.000 tonnes annually if a favourable market is found for the excess products. The feasibility study though is limited to the local market.

The study covers different qualities of crude, including:

1. Light crude, North Sea.
2. Middle crude, Light Arabian.
3. Middle crude, U.S.S.R.
4. Heavy crude, bunker C.

Different mixtures of these were also considered.

The main results of the study can be summarised as follows:

1. Technically it is possible to build a refinery, which converts light and middle crude into the products used in Iceland without any export of products.
2. The total installed cost of the refinery is estimated at $127 million, U.K. prices, and $115 million, based on U.S. Gulf coast prices. The U.K. price is divided into: Process plants $55 million, offsites facilities $52 million and product loading and jetties $20 million. All prices refer to January 1981.
3. The yearly product value is considerably greater than the total installed

cost (TIC) of the refinery. As the product value is so great compared to the TIC a gross margin (before interest and depreciation) of 15% of the product value is sufficient to make a discounted return of 12% on capital (see table I). The refinery turns over the TIC in 8 months, in this respect it is very different from a hydro-power station, which takes five or more years to turn over the capital cost.

4. Based on Rotterdam Spot Market prices in January 1981, which is historically low compared to crude prices (see fig. 1), the refinery of Arabian Light at $32.00 per barrel gives a discounted 12,6 % i.r.o.r. over 20 years and 11% over 15 years.

5. A relatively small increase in crude prices, product prices remaining constant, reduces the return drastically to 8,1% over 20 years, when refining $34,20 per barrel crude from U.S.S.R The refining of North Sea gives a negative return.

6. The Rotterdam Spot market is historically low in January 1981 compared to crude prices. The price of gas oil for example is $302 per tonne, which is considerably lower than the price of about $330, negotiated with BNOC in the summer of 1980. Since then the price of crude has increased by 10% and BNOC probably thinks the "normal" price of gas oil is now closer to $350 per tonne. The influence of product price on the profitability of the refinery is shown in Table 1, where a 10% increase in product prices, crude oil remaining constant, leads to a very high return on investment for Saudi Light, and North Sea oil becomes marginal.

7. The main conclusion from the above results is that a local refinery in Iceland is a cheap insurance against fluctuations in the Rotterdam Spot Market, as its gross margin is only 15% of product value, when returning sufficient profit. One upswing in the R.S.M. above crude prices of the same order as shown in fig. 2 is sufficient to repay fully the capital cost of the refinery.

8. Pictures 1 and 2 show how the price of gas oil has developed in the R.S.M. and the export price of Saudi crude during the same period. They also show how the ratio between these prices has developed. The RSM price in January 1981 is the most favourable from early 1977 as measured by this ratio, but also the most unfavourable for running a refinery.

9. Lummus reached the conclusion that it is not possible to build a refinery, suitable for the Icelandic market product mix, using heavy crude oil or bunker C. Such a refinery would only cover part of the

local market, or alternatively export the surplus products. A feasibility study based on exports of products is unreliable, and according to our requests Lummus assumed negligible exports of products.

10. The report assumes that all steam is produced from residual oil and gas, which has the energy equivalence of 83 GWh elctrical. If this oil and gas can be sold at resident oil prices, then it is feasible to use electricity at 20 mills to produce the steam.

The electrical use for motors in normal refinery operations is estimated at 30 GWh per annum.

For hydrogen production it is planned to use propan, as there is no assured market for it. If however a market is found at $300 per tonne, then it is feasible to use electrivity at 20 mills to produce hydrogen. The electrical requirement is 61 GWh per annum.

It is the considered opinion of the National Energy Authority that the result of this study is encouraging and warrants a further study of the merits of an oil refinery in Iceland. It is apparent that the source and price of crude is critical to the profitability of the refinery, and this leads us to the question of the relative importance og oil price on the one hand and security of supply on the other when formulating an oil policy. Our general trade interests must also be included in the formulation of policy.

Everything considered the NEA suggest that the Ministry of Industry form a study group including members from the Ministry of Industry, Ministry of Trade, the NEA and the oil companies. The task of the group would be to study this matter more thoroughly taking into consideration the commercial aspect of oil imports, and giving a report to the respective ministries.

The Lummus Company Limited
Member of the Combustion Engineering Group
P O Box 64
100 FETTER LANE
LONDON EC4P 4BA

Tel: 01-831 7300
Cables: LUMMUS London EC4
Telex: 8812931

Registered in England No. 460749.

LUMMUS

6 February 1981

National Energy Authority
Grensavegur 9
109 Reykjavik
Iceland

For the attention of Mr Jakob Bjornsson - Director General

Dear Sirs

Further to our letter of 25th February 1981, please find enclosed four copies of the completed Refinery Feasibility Study Report.

We look forward to discussing the report with you in due course.

Very truly yours

M E BARHAM
for A C Loader
Study Manager

TABLE OF CONTENTS

LUMMUS

TABLE OF CONTENTS

LUMMUS

LUMMUS

In response to a letter dated 24 August 1979 from the National Energy Authority of Iceland (N.E.A.), the Lummus Company Limited submitted a proposal in November 1979 for a refinery feasibility study.

The required objective of the study was to determine the technical and economic viability of establishing a petroleum refinery in Iceland to meet the internal demand in the country for refined products like motor gasoline, jet fuel, diesel oil and fuel oil. Future demand of the products were to be projected up to the year 2000.

Lummus proposed to conduct the study in two distinct stages in order to facilitate economic analysis and to enable an early termination if preliminary conclusions were unfavourable. The proposed stages are outlined as follows:

- Stage I

  The Preliminary investigation and evaluation of several refinery processing schemes, with a comparative study of their technical and economic viability to select the scheme showing the highest potential.

- Stage II

  An examination of the selected scheme in further detail with more accurate scrutiny of capital and operating costs and the inclusion of Venture Analyses.

  In addition to crudes, examine and consider the use of imported F-5 fuel oil as a supplementary feed stock and evaluate the use of geothermal energy to reduce the consumption of imported hydrocarbon energy.

In September 1980, N.E.A. requested Lummus to include in Stage I, the use of F-5 fuel oil as supplementary feed stock and also to evaluate the economics of supplying hydrogen at a fixed price from an external electrolytic source compared to producing it within the refinery using surplus hydrocarbon source. On the basis of a revised proposal from Lummus dated 9th October, 1980, a contract was awarded by N.E.A. on 24th November, 1980 to carry out Stage I of the study.

This present report is the result of the Stage I study.

LUMMUS

SUMMARY

A 15,000 Barrels per Stream Day(BPSD)refinery with a distillate hydrocracker and a visbreaker is technically the most suitable scheme for Iceland's requirement. The scheme is definitely feasible and produces a yield pattern which matches very closely the county's future internal demand for all the refined petroleum products.

The total installed cost of the grass-root refinery including cost of all the process plants, all necessary utility services, storage tanks, product loading and jetty facilities, is estimated to be around 115 million U.S. dollars based on U.S. Gulf Coast prices as of January 1981.

Economically the scheme looks promising when processing Light Arabian or Russian crude, giving a gross margin of 10.3 million dollars per annum for the Light Arabian case and 5.7 million dollars for the Russian crude case. This 'gross margin' is defined as the margin between the product values and the cost of crude plus all the operating costs such as utilities, catalysts and chemicals, labour charges, maintenance and depreciation, but excluding all the financial charges like interest, taxes, insurance, etc., which are to be determined by N.E.A.

The gross margin will go up by 1.5 million dollars in all cases, if the 17 dollars/metric ton premium, presently being paid for the superior grade F-5 fuel oil, is added to the value of the No. 6 fuel oil produced in the refinery scheme. The present cost calculations do not include this premium in order to reflect more realistic product values.

Although it looks promising, the actual economic viability of the scheme can only be correctly determined by N.E.A. after establishing the capital related charges and investigating the terms and conditions of a long term crude supply agreement. Before the final economic evaluation, a firm, definitive cost estimate of the scheme needs to be carried out including on-the-spot site investigations, etc. The present cost estimate is only a budget type estimate, derived from Lummus in-house cost curves.

LUMMUS

Apart from commercial aspects, for strategic reasons and to meet unforseen changes in the future demand pattern, it is much more desirable to have an indigenous refinery. This ensures an in-built flexibility particularly with regard to importing only the crude feedstock, rather than depending on spot market supply for every petroleum product requirement.

In addition an important aspect is that this refinery scheme would give employment directly to 112 personnel and indirectly to many more by opening up opportunities for related service industries.

LUMMUS

DISCUSSION

Refinery Schemes

A 15,000 BPSD refinery scheme processing crude as a feedstock, compared to F-5 fuel oil or residue as a supplementary or alternate feed, is found to be more economical and technically more suitable for producing a balanced yield pattern which matches closely Iceland's future internal demand of refined petroleum products.

In addition to conventional refinery units like crude and vacuum distillation, reformer etc., the scheme includes a distillate hydrocracker to increase diesel oil production and a visbreaker to reduce the viscosity of the heavy residue thereby releasing more gas oil for diesel oil use rather than using it as cutter stock for fuel oil blending.

The scheme is technically feasible, using commercially proven processes and standard unit capacities, and has the built-in flexibility and capacity to meet minor fluctuations in future product demand. The refinery as proposed can handle any of the following crudes or crude blends:

- Ninian/Ekofisk Blend (North Sea Crude)
- Light Arabian (Saudi Arabia)
- Romashkinskaja (USSR)
- Light Arabian/Ekofisk Blend
- Light Arabian/Ekofisk/Heavy Arabian Blend

The heavy Arabian Crude cannot be handled on its own in the present scheme. Due to the higher yield of high sulphur residue and heavy distillate this crude needs a more expensive residue hydrocracking unit in place of distillate hydrocracking and a residue visbreaking and additional distillate hydrodesulphurisation unit.

This increases the investment cost of the process units to about 70 million dollars compared to 50 million dollars in the present scheme. Even with the addition of these units, the product yield from the refinery with a maximum throughput of 15,000 BPSD of crude will not be a balanced one, it will produce more fuel oil and less diesel oil than required.

Similar criteria apply to the processing of F-5 fuel oil or straight-run atmospheric residue as a supplementary or alternate feed stock.

North Sea Crude (Ninian/Ekofisk 70/30 vol% Blend)

This is a typical blend in the light and sweet crude category similar to Nigerian, Libyan or Algerian crude blends. The Ekofisk crude on its own is very much lighter and produces an excess of gasoline with shortfalls in diesel and fuel oil production.

When blended with Ninian, another North Sea crude but heavier than Ekofisk, it produces a balanced yield with a small surplus (8,000 tonnes/yr) of premium gasoline for export. All the fuel oil produced in this case is of high quality, low sulphur (1.0 wt%).

Technically, this is the most suitable crude blend for the required product slate.

Light Arabian (Saudi Arabia) Crude

This is a typical medium category crude. It produces all the required product amounts but provides a net surplus of No. 6 fuel oil, which is about 5,600 tonnes per annum over and above the required quantity of 88,000 tonnes. This surplus fuel oil with a somewhat higher sulphur content (3.2 wt%) than the North Sea Crude will be difficult to export.

Romashkinskaja (USSR) Crude

This is another medium category crude but with a lower sulphur content. Due to this reason, and as it does not require a large amount of gas oil cutter stock to be blended with fuel oil, by adjusting the cut points of the crude, fuel oil (3.0 wt% sulphur) production can be balanced and a nominal surplus of gasoline produced (6,600 tonnes/year).

Light Arabian/Ekofisk (70/30 vol%) Blend

The operation with this crude is similar to the Romashkinskaja case, but due to the lower sulphur content in the crude blend, it produces a better quality fuel oil (2.5 wt% sulphur) with a greater surplus of gasoline (8,000 tonnes/year).

Light Arabian/Ekofisk/Heavy Arabian (40/40/20 vol%) Blend

According to the latest information available it might not be possible, in future, to purchase Light Arabian crude on its own at the Government contract price. Saudi Authorities insist on selling one barrel of Heavy Arabian crude with every two barrels of Light Arabian. This aspect needs to be further investigated, but due to this reason, this 40/40/20 blend was studied. It produces a balanced yield of products with 3.0 wt% sulphur fuel oil and a net surplus of 12,000 tonnes/year of Premium gasoline for export.

Investment Costs

The estimated Total Installed Cost (TIC) of this grass-roots refinery scheme, including all the process plants, storage and other off-sites facilities and jetties, is around 115 million U.S. dollars based on U.S. Gulf Coast prices as of January 1981. The total cost is constituted as follows:

All process plants	- 50 million dollars
Off-site facilities, including storage tanks and pumps, water treatment and all other utility services	- 47 million dollars
Jetty and Product loading facilities	- 18 million dollars

The total cost on a U.K. basis would be around 127 million dollars. It must be emphasised here that these cost figures are budget type estimates only and not a firm definitive estimate. They are derived from Lummus in-house cost information.

There is some scope for bringing down the cost of storage facilities if the total capacity is reduced. The present capacity of 90 days crude storage is somewhat on the high side, but was considered necessary for the smooth running of the refinery. If a firm and regular supply arrangement for crude can be secured in future, this storage capacity may be reduced to 60 or even 30 days.

Economic Criteria

The economic criteria used to evaluate each case of operation is the 'Gross Margin'. This is defined as the margin between the product values and the cost of crude plus all other operating costs like electricity, chemicals and catalysts, labour charges, maintenance and supervision and depreciation but excluding all the financial charges like interest, taxes, insurance, etc., which are to be estimated by N.E.A.

Product values are calculated from their respective spot market price at Rotterdam, plus the estimated freight cost from Rotterdam to Iceland, and the cost of crude is calculated from the respective Government contract price plus the freight cost from source to Iceland. All the prices and freight costs are based on average figures for January 1981 as published in Platt's Oilgram. The depreciation is calculated on the basis of a standard straight-line relation for 15 years of plant life.

The gross margins calculated for each case are given below:

North Sea Crude Blend

Technically, this is the most suitable crude blend for Iceland's product demand but for its high cost (average $39,9/Bbl landed price) it produces a product value margin of only 5.4 million dollars per annum, once all the operating costs like electricity, catalyst and chemicals, labour costs, maintenance and supervision and depreciation are deducted from the value margin, the gross margin is negative, - 12.6 million dollars.

LUMMUS

Light Arabian Case

If a market is found for the surplus fuel oil produced, this case provides the highest margin. The product value margin is 29.1 million dollars and gross margin is 10.3 million dollars per annum. Whether Light Arabian crude can continue to be purchased on its own at the Government Contract price has to be investigated.

Romashkinskaja (USSR) Crude

This case produces a product value margin of 24.5 million dollars per annum and gross margin of 5.7 million dollars. If Light Arabian crude cannot be purchased on its own at the Government contract price, this is the second most promising case.

Light Arabian/Ekofisk Blend

The product value margin in this case is 20.2 million dollars and the gross margin is 1.4 million dollars.

Light Arabian/Heavy Arabian/Ekofisk Blend

The product value margin in this case is 18.9 million dollars with a gross margin of only 121,000 dollars per annum.

Scope of Work

Consider potential crude feedstocks and corresponding refinery configuration using in-house judgement and know-how, identify potentially economic schemes giving consideration to:

- Licensor selection and proven processes
- Flexibility
- Simplicity of processing sequences
- Seasonal fluctuations in product demand
- Minimisation of investment and operating costs
- Availability and security of feedstock supply
- Self containment with respect to energy requirements

Consider use of imported heavy fuel oil as supplementary/ alternate feedstock in part/whole replacement of crude feedstock for residue hydrocracking scheme.

Evaluate comparative cost for producing hydrogen required for hydrocracker and other unit, by electrolytic process or by conventional hydrocarbon based process. Electrolytic hydrogen to be supplied by N.E.A. at $1,400 per ton.

Evaluate economics from in-house information and economic indicators to determine and recommend whether the project can be potentially viable.

Prepare the report for submission to N.E.A.

General Specifications

Codes

General API, ASME, ASTM standards for petroleum refinery will be used for this study.

Language

English language will be used for the study.

Units

All units will be in metric.

Economic Criteria

No definite financing has been arranged yet for the refinery. For this study, total installed costs (TIC), total investments, depreciations, interest rates, will be based on standard commercial data as applicable to any coastal location in North European and Scandinavian countries.

Equipment supply should preferably be also from the same countries as above but not necessarily restricted to them. For technical and economic reasons, imports from sources outside Europe may be considered, particularly if overall economy justifies, by shortening construction time and reducing total investments the import of prefabricated modular type plants may be considered.

For economic analysis, overall useful plant life would be considered as 15 years.

No escalation data will be used for this phase of the study, all costs and prices will be based on data for January 1981.

Environmental Data

There are no special environmental regulations in Iceland. Standard industrial regulations as applicable in a coastal location in North European and Scandinavian countries shall be followed for gaseous and liquid effluents.

Refinery Capacity and Product Slate

The refinery product slate should match as closely as possible the anticipated internal demand for petroleum products in Iceland for the year 1990 as given over:

	Thousand Metric Tons Per Year
LPG (Propane & Butane)	5.0
Aviation Gasoline	3.0
Regular Gasoline	120.0
Jet Fuel - Grade A	58.0
Kerosene	3.0
Light Diesel (Road)	170.0
Marine Diesel	100.0
Fuel Oil No. 6	88.0
Bitumen	15.0
	562.0

There is a seasonal fluctuation in demand of different products as reflected in the average figures for the years 1978 and 1979 given below:

Month	Gasoline Wt%	Diesel Oil Wt%	Fuel Oil Wt%	Jet Fuel Wt
January	7.0	9.7	7.1	5.3
February	7.1	9.8	9.6	4.8
March	7.6	9.6	13.0	5.5
April	8.1	8.8	6.4	7.1
May	8.7	7.9	4.5	9.0
June	9.0	8.0	5.4	12.6
July	10.4	8.2	8.3	13.5
August	10.0	7.2	9.8	13.4
September	8.3	7.9	11.1	10.8
October	7.9	8.4	11.1	7.7
November	7.7	8.0	8.2	5.3
December	8.1	6.5	5.5	5.0
	100.0	100.0	100.0	100.0
Total Tonnes/Year	89,265	295,387	147,165	68,084

No flexibility is to be built into the refinery design to meet the seasonal fluctuations in demand, as the existing tankage of the local oil distributors has enough built-in capacity to absorb these fluctuations.

Based on the projected demand for 1990 as given above, the nominal refinery throughput works out to be approximately 12000 barrels per stream day (BPSD) with 330 stream days in one year. In view of providing extra flexibility with a very nominal increase in cost, the crude distillation unit shall be designed for a crude throughput of 15000 barrels per stream day. The other downstream units will be designed in such a way as to meet the internal demand for all the finished products, especially diesel fuel.

If it is found to be more economical, export of net surplus products like gasoline and jet fuel or import of net deficit of diesel fuel may be considered, keeping the maximum crude throughput of 15000 BPSD.

Feed Specifications

One typical crude from each of the three following categories will be considered for the refinery study, in addition imported heavy fuel oil may be considered as supplementary or alternative feed stock.

Crudes

a) High price, light gravity, low sulphur - North Sea and North African crudes, Ekofisk, Forties, Arzew Mix and Libyan etc. Ekofisk crude assay shall be used as a typical example of crudes of this category.

b) Medium price, medium gravity and medium sulphur - Light Arabian, USSR (Romashkinskaya) crudes. Light Arabian crude assay shall be used as a typical example of this category.

c) Low price, heavy gravity, high sulphur - Kuwait, Heavy Arabian, whichever is cheaper and more easily available shall be used as typical examples of this category.

Recent up-to-date crude assays as far as available in detail shall be used in the study and will be given in the final report. Typical assay for each category of crude is given in Appendix 1.

Fuel Oil

Fuel oil No. 5 or No. 6, whichever is found to be more economica may be imported as supplementary/alternative feed stock.

An assay of fuel oil No. 5 supplied by N.E.A. is given in Appendix 2. Lummus in-house assay for fuel oil No. 6 will be used in the study and will be given in the final report.

Product Specifications

These are given in Appendix 3.

Feed and Product Prices

Posted price for crudes and Rotterdam Spot Market price for fuel oil and other products as published in Platt's Oilgram publication average for month of January 1981, will be used.

Fuel Oil and Crude

Prices for the Crude Oil feedstocks, Fuel-oil, and products are based on the following plus cost of freight, for example,

1) Fuel Oil - Mean quotation (between low and high) published in Platt's Oilgram Price Service under heading "European Bulk FOB barges Rotterdam" for Fuel Oil (sulphur max. 3.0%) on the date of completion of loading.

2) Motor gasoline AI-93 - Mean quotation (between low and high) published in Platt's Oilgram Price Service under heading "European Bulk barges FOB Rotterdam" for motor gasoline (regular) on the date of completion of loading.

3) Gas oil - Mean quotation (between low and high) published in Platt's Oilgram Price Service under heading "European Bulk Barges FOB Rotterdam" for gas oil on the date of completion of loading.

In case there is no Platt's Oilgram publication on the date of shipment, the previous quotation will be applied.

Cost of Freight per Metric Ton

Cost of freight per metric ton is to be stipulated on the basis of "Worldscale":

For carrying motor gasoline and gas oil from Black Sea U.S.$ 5.93

For carrying fuel oil from Baltic Sea U.S.$ 3.97

For carrying gas oil from Baltic Sea U.S.$ 4.01

If freight index per Mullion Tankers (Shipbroking) Limited (ex Harley Mullion) exceeds freight index Worldscale 110, the Buyers will pay the whole difference between the above-mentioned freight index (WS110) and the higher freight index stipulated by Mullion Tankers (Shipbroking) Limited in effect on the date of completion of loading, but not higher than Worldscale 250 for tankers above 12.000 DWT and for tankers smaller than 11.999 DWT not higher than Worldscale 300.

Should the tanker be discharged at two or more ports, Buyers are to pay Sellers extra-freight for each additional port of discharge at the rate of 50 (fifty) U.S. Cents per ton vessel's deadweight.

Storage and Distribution

Normal refinery off-sites storage of feed and products shall be provided, for this grass-root coastal location. Jetty facilities to be provided for import of feed stock in 20,000 to 50,000 ton tankers and shipping of products up to 2,000 ton barges for coastal distribution. Some products will also be distributed by road.

Inventory

90 days storage of feed stock.

15 days storage of each product

All the inventories are to be based on internal market demand and given in projection for 1990 and not on the design capacity of the crude unit.

Site Data

- Proposed site is on Hvalfjorduhr Creek across the bay about 50 km North-East of Reykjavik.
  No detailed soil investigation at the site has been done yet, but it is known from other surrounding industrial sites, there is permanent rock structure existing below 1 to 2 meters of the surface. No special pilings required for industrial structures, at least need not be included in the cost estimate for this report.

- The site is at 10 meters above sea level.

- Wind directions and speeds - see appendix 4.

- Maximum and minimum dry and wet bulb temperature - see appendix 4. Design air cooling temperature = 15°C.

- Maximum rainfall - 1 cm in 10 minutes. See also appendix 4.

- Earthquake factor - 0.1G.

Utility Data

Process Make-Up Water

Natural spring and river water.	
Total dissolved solids	46.4 ppm
$CaCo_3$	11.1 ppm
Chlorine	8.5 ppm
Temperature	

Cooling Water

Maximum air cooling shall be used in the design, any trim cooling and machinery cooling can be provided by the water as above.

Design cooling water temperature = 5°C.

Electric Power

Electric power will be available at 132 KV from the grid at the following price:

Utilisation 4000 hours/year 2.9 U.S. cents/KWH
Utilisation 6000 hours/year 2.1 U.S. cents/KWH
Utilisation 3000 hours/year 1.7 U.S. cents/KWH

Refinery Configurations to be Studied

Based on three categories of crudes, eg. light, medium and heavy and imported fuel oil as feed stock, several refinery schemes to be studied to determine the most economic viable one.

From a simple hydroskimming refinery processing light crude and importing any nominal shortfall of diesel product, the complexity of the schemes will be increased when processing heavier high sulphur crudes due to the necessity of additional conversion units like gas oil hydrocracker, visbreaker and thermal cracker, etc. With heavy crude and the alternative feed stock, imported fuel oil, a residue hydrocracking scheme eg. LC Fining may be considered.

For the hydrogen requirement of the refinery, an externally supplied electrolytic hydrogen may be considered at a price of $1,400 per ton. Also if there is surplus LPG production over and above market demand of 5000 tonnes/year this surplus LPG may be considered at FOE prices for in-plant generation of hydrogen. The price of 5000 tonnes/year marketable LPG shall be considered the same as for motor gasoline.

General Discussion

The objective of this conceptual study is to determine a technically feasible and economical refinery scheme, which will produce a yield pattern that matches closely the future internal demand for all the refined petroleum products in Iceland. If economically justifiable, the export of net surplus products and/or import of net deficit products might also be considered.

In order to have a wider choice for the most economic operation of the refinery, it was decided to consider F-5 fuel oil or atmospheric residue as a supplementary or alternate feed stock to three categories of crude feedstocks; light, medium and heavy.

After studying several schemes, it has been concluded that a 15,000 BPSD refinery scheme with a distillate hydrocracker and a visbreaker and processing either light or medium or any combination of these crudes, is the most suitable scheme for Iceland's requirement.

Iceland's product requirement is mostly diesel biased; marine and road diesel together constitute 48% of the total product demand, whereas fuel oil demand is only about 16%.

From this product slate it is obvious that conventional refinery units would not be able to produce this yield pattern. Therefore, a distillate hydrocracker is added to convert heavy gas oils from the vacuum unit into high quality ligher gas oils with low sulphur, and a high octane number suitable for road diesel. Also to reduce the yield of fuel oil and increase further the yield of diesel oil, a visbreaker is added. A visbreaker reduces the viscosity of the residue and thereby releases more gas oil for diesel oil production rather than using it as cutter stock for blending with residue for fuel oil production. The net effect of the addition of a hydrocracker and a visbreaker would be to increase the yield of diesel oil and decrease the yield of fuel oil.

The proposed refinery scheme would have the following process units:

Crude Unit	15,000 BPSD
Vacuum Unit	6,000 BPSD
Hydrocracker Unit	3,500 BPSD
Visbreaker Unit	2,000 BPSD

Naphtha HDS and Catalytic Reformer	3,000 BPSD
Sulphur Plant	15 MT/SD
Hydrogen Plant	2.0 MM SCFD

plus the required amine treatment and gas recovery unit and naphtha and kerosene merox treatment units. A typical process flow diagram and description of the major process units is attached at the end of this Section (IV G).

Crude is fractionated in the atmospheric distillation column in the crude unit. Butane and lighter goes to amine treatment and gas recovery, light naphtha is merox treated to remove odour producing mercaptan sulphur compounds and then to gasoline blending. Heavy naphtha is sent to the hydrotreater and catalytic reformer, where it is converted into high octane gasoline component with good anti-knock properties. Kerosene is also merox treated to remove mercaptan sulphur and then sent to storage. Light gas oil is sent to diesel oil blending.

Atmospheric residue from the crude unit is further distilled under vacuum in the Vacuum Unit, the light vacuum gas oil is sent to diesel oil (marine) blending. Vacuum gas oil is sent to the hydrocracker. Part of the vacuum residue is sent to the Bitumen plant for the production of road bitumen and the rest goes to the visbreaker unit, where it is cracked into several lighter products and residue tar. Visbreaker heavy gas oil is sent to the hydrocracker for diesel oil production. Visbreaker light gas oil is sent to fuel oil blending where it is mixed with hydrocracker gas oil product as required to meet the sulphur and viscosity specifications of the fuel oil.

All the blended finished products meet the respective product specification.

The refinery as proposed can handle any of the following crudes or crude blends:

- Ninian/Ekofisk Blend (North Sea Crude)
- Light Arabian (Saudi Arabia)
- Romashkinskaja (USSR)
- Light Arabian/Ekofisk Blend
- Light Arabian/Ekofisk/Heavy Arabian Blend

The heavy Arabian crude cannot be handled on its own in the present scheme. Due to the higher yield of high sulphur residue and heavy distillate this crude needs a more expensive residue hydrocracking unit in place of distillate hydrocracking and a residue visbreaker and an additional distillate hydrodesulphurisation unit.

This will increase the investment cost of the process units to about 70 million dollars compared to 50 million dollars in the present scheme. Even with the addition of these units, the product yield from the refinery with the maximum throughput of 15,000 BPSD of crude will not be a balanced one, it will produce more fuel oil and less diesel oil than required. Similar criteria apply to the processing of F-5 fuel oil or straight-run atmospheric residue as a supplementary or alternate feed stock.

LUMMUS

LIGHT CRUDE

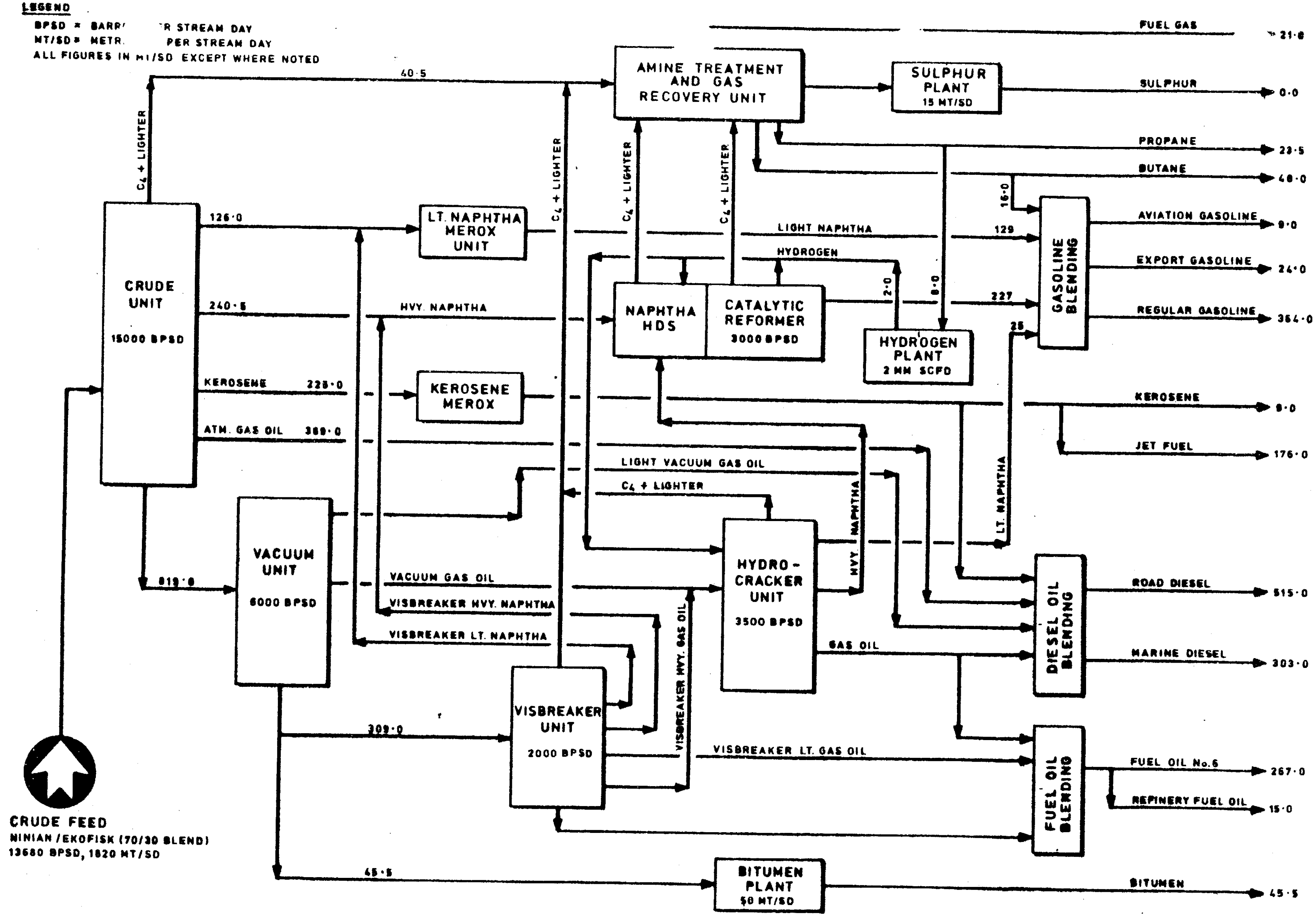
North Sea Crude (Ninian/Ekofisk 70/30 vol% Blend)

This is a typical blend in the light and sweet crude category similar to Nigerian, Libyan or Algerian crude blends. The Ekofisk crude on its own is very much lighter and produces a lot more gasoline than required, with shortfalls in diesel and fuel oil production. Blended with Ninian, another North Sea Crude but heavier than Ekofisk, it produces a balanced yield, with a small surplus (8,000 tonnes/year) of Premium gasoline for export and all the fuel oil produced in this case is of high quality, low sulphur (1.0 wt%). Technically, this is the most suitable crude blend for the required product slate.

Material Balance

Feed	MT/SD
Ninian/Ekofisk (70/30 Blend)	
13680 BPSD	1820.0
Products	
Butane	40.0
Aviation gasoline	9.0
Export gasoline	24.0
Regular gasoline	364.0
Kerosene	9.0
Jet Fuel	176.0
Road diesel	515.0
Marine diesel	303.0
No. 6 Fuel Oil	267.0
Bitumen	45.5
Fuel used in refinery	
Fuel gas	21.0
Fuel oil	15.0
Propane	23.5
	1812.0
Losses	8.0
	1820.0

LEGEND
BPSD = BARR/ 'R STREAM DAY
MT/SD = METR. PER STREAM DAY
ALL FIGURES IN MT/SD EXCEPT WHERE NOTED



NATIONAL ENERGY AUTHORITY
ICELAND
REFINERY FEASIBILITY STUDY

LUMMUS — THE LUMMUS COMPANY LIMITED, LONDON

REFINERY BLOCK FLOW DIAGRAM
NINIAN/EKOFISK BLEND CASE

Approved [signature] Issued 22/2/81

LUMMUS

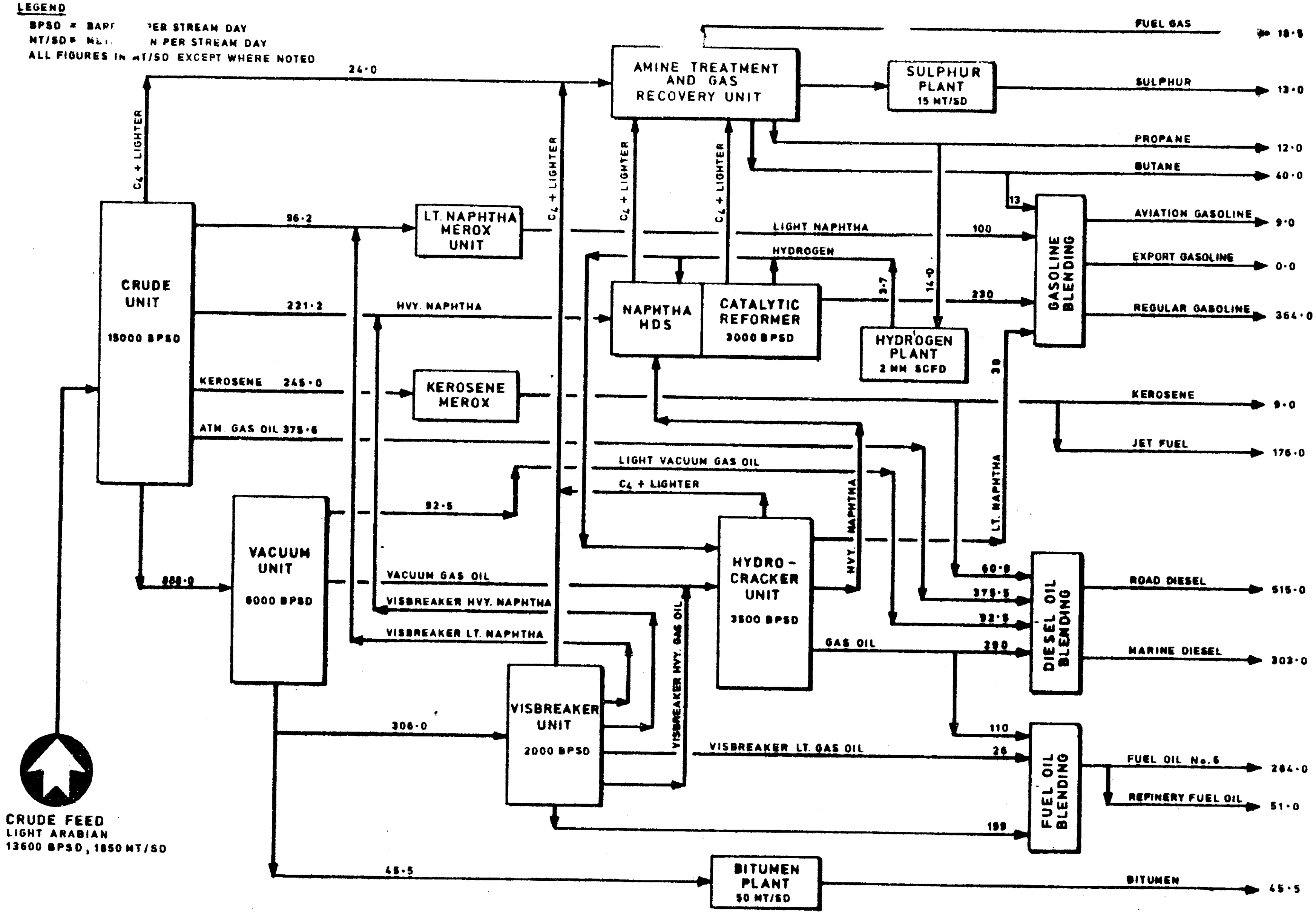
MEDIUM CRUDE

Light Arabian (Saudi Arabia) Crude

This is a typical crude of the medium category. It produces all the required amounts of products but throws up a net surplus of No. 6 fuel oil, about 5,600 tonnes per annum over and above the required quantity of 88,000 tonnes. This surplus fuel oil with a somewhat higher sulphur content (3.2 wt%) than the light crude will be difficult to export.

Material Balance

Feed	MT/SD
Light Arabian Crude	
13,600 BPSD	1850.0
Products	
Sulphur	13.0
Propane	12.0
Butane	40.0
Aviation gasoline	9.0
Regular gasoline	364.0
Kerosene	9.0
Jet fuel	176.0
Road diesel	515.0
Marine diesel	303.0
No. 6 fuel oil	284.0
Bitumen	45.5
Fuel used in the refinery	
Fuel gas	18.5
Fuel oil No. 6	51.0
	1840.0
Losses	10.0
	1850.0



NATIONAL ENERGY AUTHORITY
ICELAND
REFINERY FEASIBILITY STUDY

LUMMUS — THE LUMMUS COMPANY LIMITED LONDON

REFINERY BLOCK FLOW DIAGRAM
LIGHT ARABIAN CASE

Approved [signature] Issued 2/7/3/81

LUMMUS

MEDIUM CRUDE

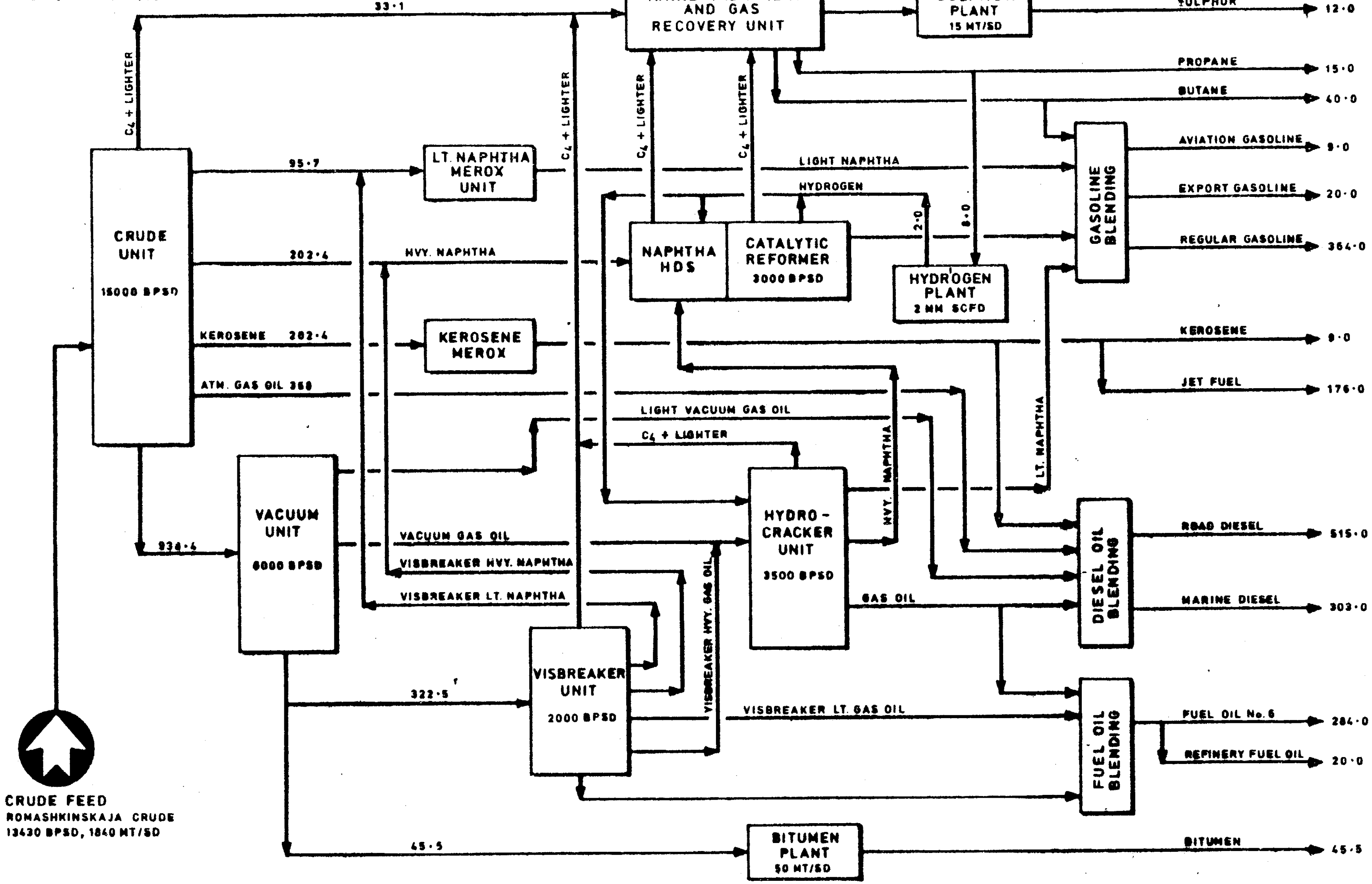
Romashkinskaja (USSR) Crude

This is another crude of the medium category, but with a lower sulphur content. As it does not require a large amount of gas oil cutter stock to be blended with the fuel oil, by adjusting the cut points of the crude, fuel oil (3.0 wt% sulphur) production can be balanced and a nominal surplus of gasoline produced (6,600 tonnes/year).

Material Balance

Feed	MT/SD
Romashkinskaja Crude 13,430 BPSD	1840.0
Products	
Sulphur	12.0
Butane	40.0
Aviation gasoline	9.0
Export gasoline	20.0
Regular gasoline	364.0
Kerosene	9.0
Jet fuel	176.0
Road diesel	515.0
Marine diesel	303.0
No. 6 fuel oil	284.0
Bitumen	45.5
Fuel used in the refinery	
Fuel gas	17.5
Fuel oil	20.0
Propane	15.0
	1830.0
Losses	10.0
	1840.0

LEGEND
BPSD = BARR... R STREAM DAY
MT/SD = METRI... , PER STREAM DAY
ALL FIGURES IN MT/SD EXCEPT WHERE NOTED



NATIONAL ENERGY AUTHORITY
ICELAND
REFINERY FEASIBILITY STUDY

LUMMUS — THE LUMMUS COMPANY LIMITED LONDON

REFINERY BLOCK FLOW DIAGRAM
ROMASHKINSKAJA CASE

Approved Kla — Issued 27/2/81

LUMMUS

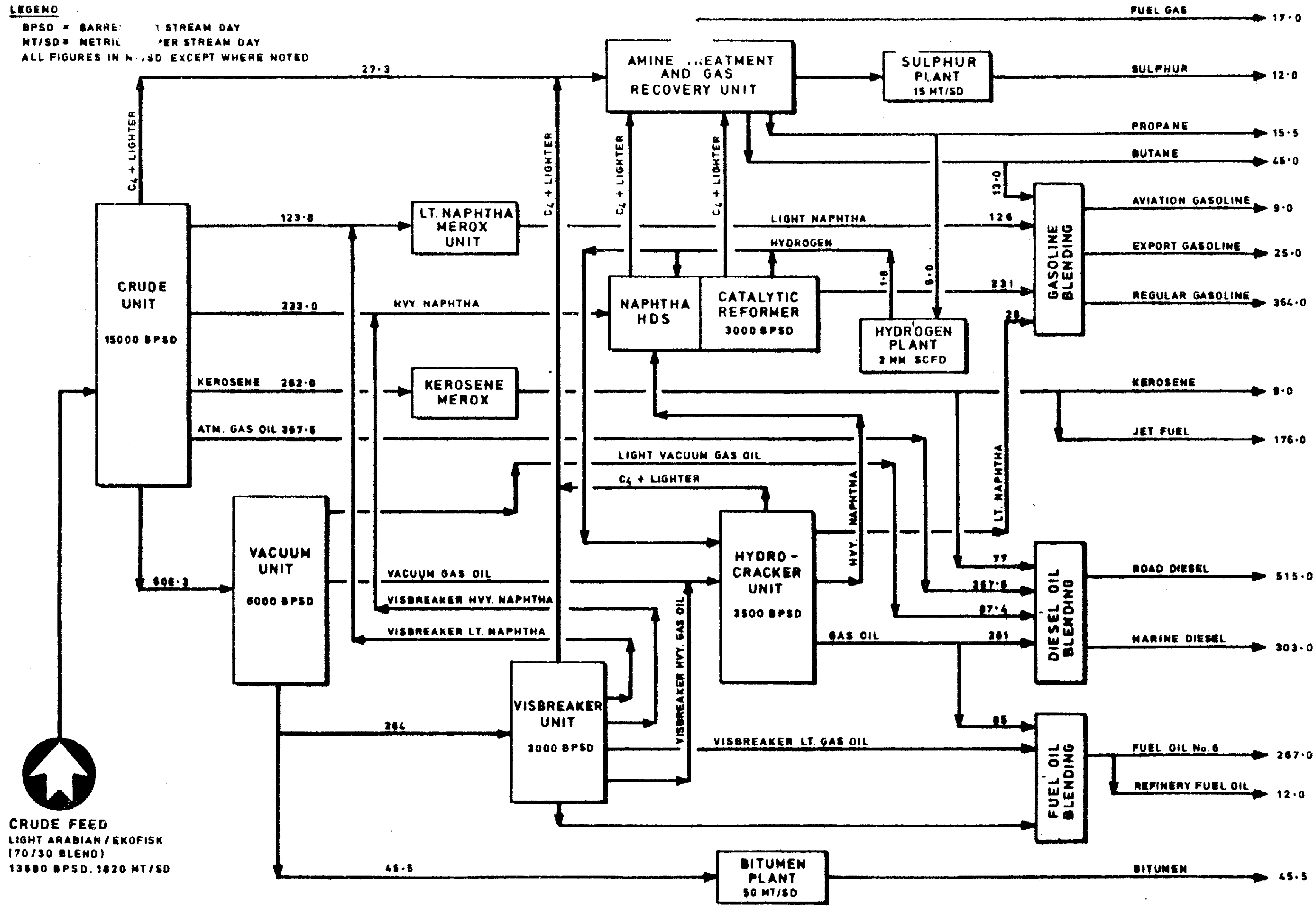
MEDIUM/LIGHT BLENDED CRUDE

Light Arabian/Ekofisk (70/30 vol%) Blend

The operation with this crude is similar to the Romashkinskaja case, but due to the lower sulphur content in the crude blend, it produces a better quality fuel oil (2.5 wt% sulphur) and somewhat more surplus gasoline (8,000 tonnes/year).

Material Balance

Feed	MT/SD
Light Arabian/Ekofisk Blend 13,680 BPSD	1820.0
Products	
Sulphur	12.0
Butane	26.0
Aviation gasoline	9.0
Export gasoline	25.0
Regular gasoline	364.0
Kerosene	9.0
Jet fuel	176.0
Road diesel	515.0
Marine diesel	303.0
Fuel oil No. 6	267.0
Bitumen	45.5
Fuel used in the refinery	
Fuel gas	17.0
Fuel oil	12.0
Propane	15.5
Butane	19.0
	1815.0
Losses	5.0
	1820.0



NATIONAL ENERGY AUTHORITY
ICELAND
REFINERY FEASIBILITY STUDY

LUMMUS — THE LUMMUS COMPANY LIMITED, LONDON

REFINERY BLOCK FLOW DIAGRAM
LT. ARABIAN/EKOFISK CASE

Approved [signature] Issued 23/2/81

LUMMUS

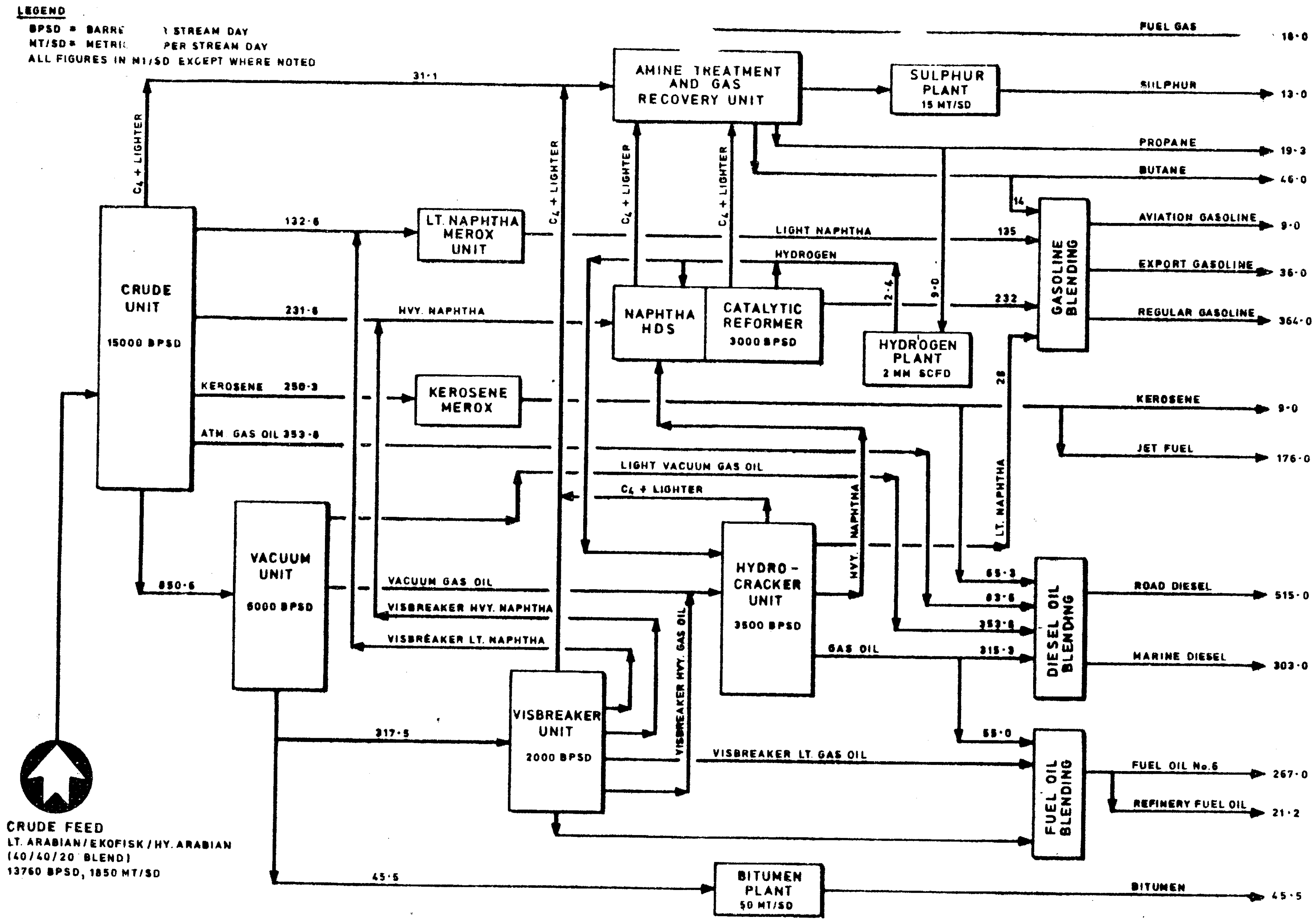
LIGHT/MEDIUM/HEAVY BLENDED CRUDE

Light Arabian/Ekofisk/Heavy Arabian (40/40/20 vol%) Blend

According to the latest information available to Lummus, in future it might not be possible to purchase Light Arabian crude on its own at the Government contract price. Saudi Authorities insist on selling one barrel of Heavy Arabian crude with every two barrels of Light Arabian. This aspect needs to be further investigated, but due to this reason, this 40/40/20 blend was studied. It produced a balanced yield of products with 3.0 wt% sulphur fuel oil and a net surplus of 12,000 tonnes/year of Premium gasoline for export.

Material Balance

Feed	MT/SD
Light Arabian/Ekofisk/Heavy Arabian Crude 13,760 BPSD	1850.0
Products	
Sulphur	13.0
Butane	40.0
Aviation gasoline	9.0
Export gasoline	36.0
Regular gasoline	364.0
Kerosene	9.0
Jet fuel	176.0
Road diesel	515.0
Marine diesel	303.0
Fuel oil No. 6	267.0
Bitumen	45.5
Fuel used in the refinery	
Fuel gas	18.0
Fuel oil	21.2
Propane	19.3
Butane	6.0
	1842.0
Losses	8.0
	1850.0

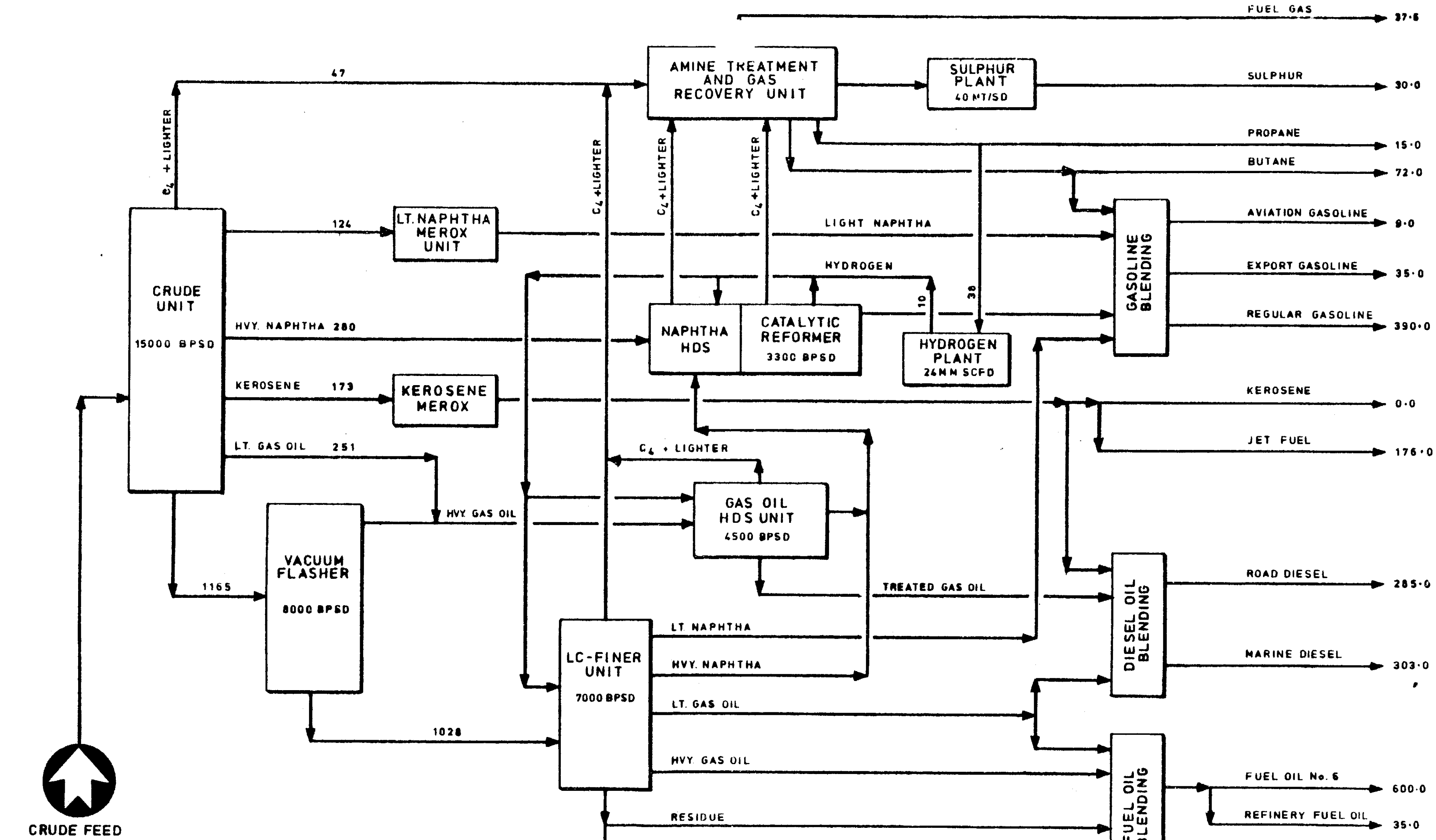


NATIONAL ENERGY AUTHORITY
ICELAND
REFINERY FEASIBILITY STUDY

LUMMUS | THE LUMMUS COMPANY LIMITED LONDON

REFINERY BLOCK FLOW DIAGRAM
LT. ARABIAN/EKOFISK/HY. ARABIAN CASE

Approved | Issued



LEGEND

BPSD = BARRELS PER STREAM DAY
MT/SD = METRIC TON PER STREAM DAY
ALL FIGURES IN MT/SD EXCEPT WHERE NOTED

NATIONAL ENERGY AUTHORITY
ICELAND
REFINERY FEASIBILITY STUDY

LUMMUS | THE LUMMUS COMPANY LIMITED LONDON

REFINERY BLOCK FLOW DIAGRAM
HEAVY ARABIAN CASE

Approved | Issued 21/7/81

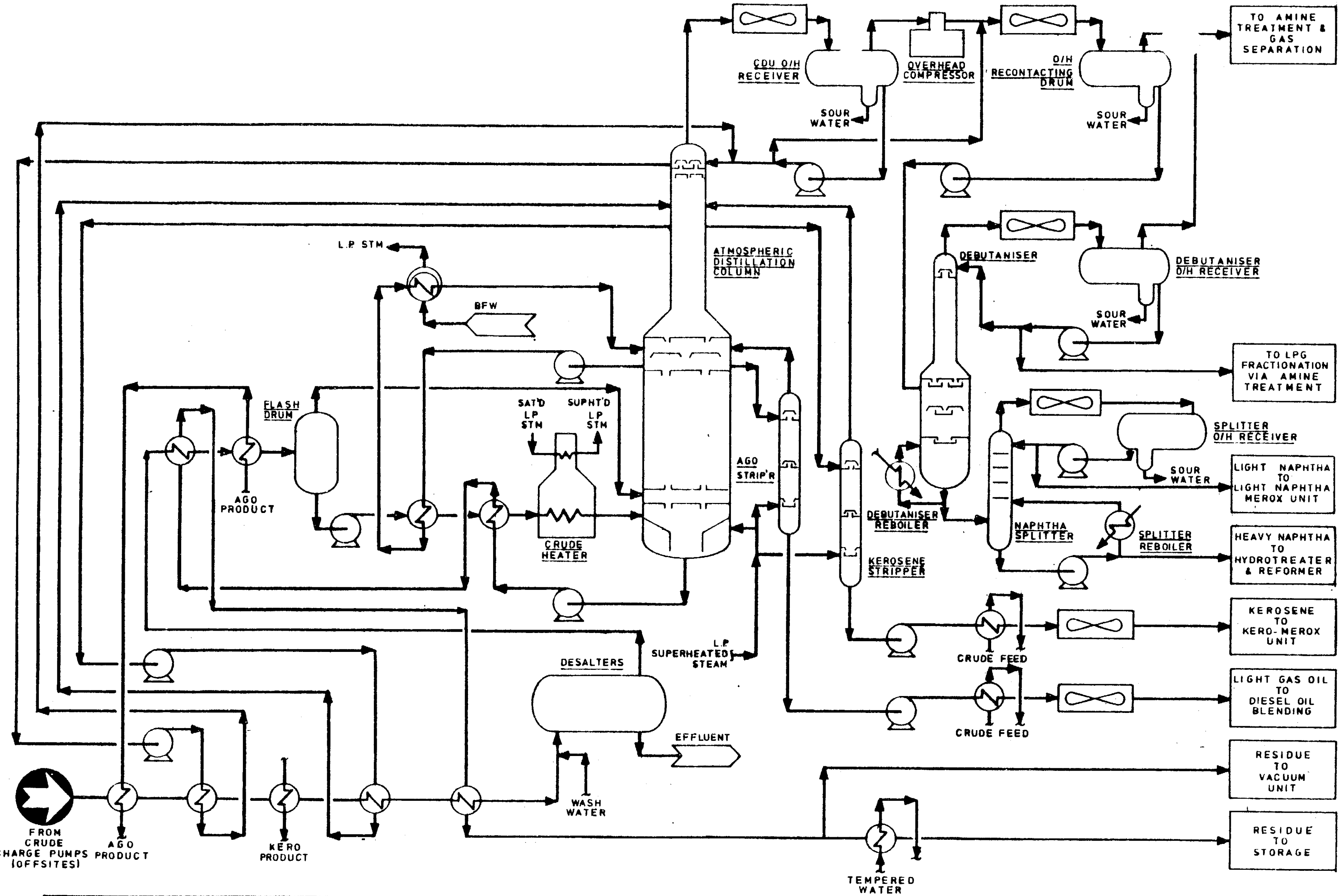
LUMMUS

HEAVY CRUDE

Heavy Arabian Case

Material Balance

Feed	MT/SD
Heavy Arabian Crude 14,500 BPSD	2040.0
Products	
Sulphur	30.0
Propane	15.0
Butane	72.0
Aviation gasoline	9.0
Export gasoline	35.0
Regular gasoline	390.0
Kerosene	0.0
Jet fuel	176.0
Road diesel	285.0
Marine diesel	303.0
Fuel oil No. 6	600.0
Bitumen	45.5
Fuel used in the refinery	
Fuel gas	37.5
Fuel oil	35.0
	2033.0
Losses	7.0
	2040.0



NATIONAL ENERGY AUTHORITY
ICELAND

REFINERY FEASIBILITY STUDY

LUMMUS — THE LUMMUS COMPANY LIMITED, LONDON

PROCESS FLOW DIAGRAM
CRUDE DISTILLATION UNIT

Approved: [signature] Issued: 27/2/81

LUMMUS

PROCESS DESCRIPTION

The Crude Distillation Unit

The crude oil from storage enters the unit battery limit under pressure from the crude charge pump situated in the off-sites area.

The stream flows through a single preheat train where the crude is heated from approximately 15°C by heat exchange with hot intermediate and final products from the main distillation column, in several heat exchangers in series, to a temperature of approximately 125°C. The stream is then mixed with wash water before being routed to the Desalter where salts in the crude are separated out in an aqueous phase under an electrostatic field. The desalted crude is then heated further in a series of heat exchangers before entering the Flash Drum at approximately 150°C.

Here the light ends in the crude feed are vapourised and routed to the Atmospheric Column. The flashed crude from the bottom of the Flash Drum is then pumped through another train of heat exchangers, to the charge heater. Final temperature control of the crude charge to the Atmospheric Colume (approximately 370°C) is maintained here by automatic adjustment of the fuel supply to the heater.

Partially vapourised crude from the heater enters the Atmospheric Distillation Tower. The distillate vapours pass through the trays above and the liquid component flows down to the bottom section of the column. Low pressure superheated steam is used to strip light ends off the heavier liquid at the bottom of the column.

Residue product is drawn out from the bottom of the column and pumped through several exchangers in the crude feed preheat train as described earlier, and is then either routed to the Vacuum Distillation Unit or is routed to tankage in the offsites area.

Atmospheric gas oil flows to the AGO Stripper where light ends are removed by means of stripping with LP superheated steam before being returned to the Atmospheric Column. The stripped AGO product is pumped out of the bottom of the stripper, cooled and sent to the Diesel Oil Blender. An AGO pump around stream is also circulated from the main column for heating the crude feed, generating LP steam and generating internal reflux in the column.

LUMMUS

PROCESS DESCRIPTION

Kerosene is routed to the Kerosene Stripper, similar to the scheme for AGO above. The stripped kerosene product is routed to the Kerosene Merox Unit for sweetening. Kerosene pump around is also used to preheat the crude feed and to generate internal reflux on its return to the main column.

There is a Top pump around internal stream to preheat crude feed and generate reflux in the main column.

The Column overheads consisting of sour gas, LPG, Naphtha and Stripping Steam is partically condensed in the air cooled overhead condenser and separated out in the overhead receiver. Here condensed steam with dissolved H_2S separates out in the boot of the drum and is routed to the Sour Water Stripper. Part of the hydrocarbon liquid is returned to the top of the Atmospheric Column as reflux, while the remainder is routed, together with compressed gas from the Overhead Receiver, to the Recontacting Drum. Unstabilised Naphtha from the bottom of the Recontacting Drum is sent to the Debutaniser, while the overhead gases are routed to the Amine Treatment Unit for gas sweetening.

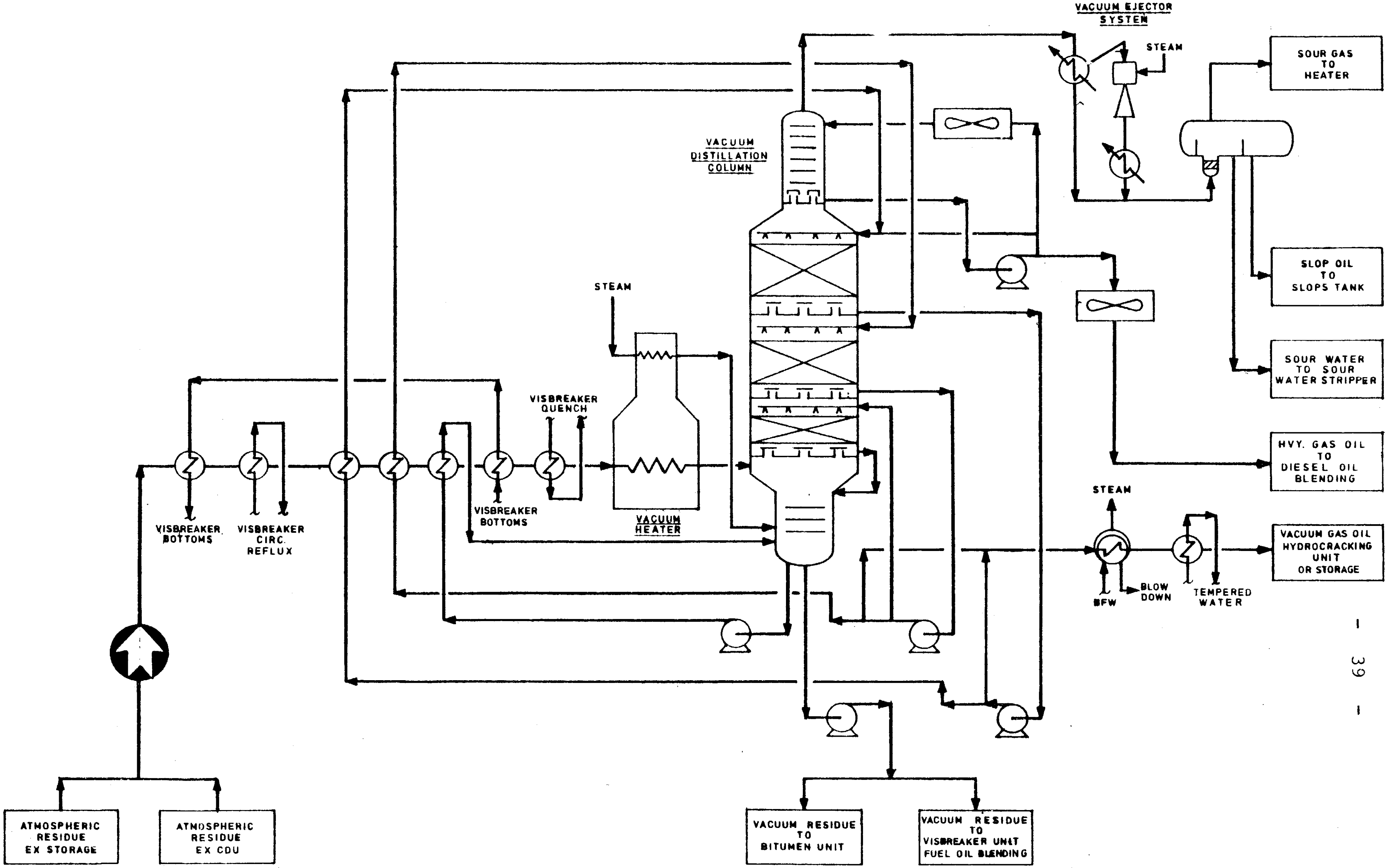
In the Debutaniser, butane and lighter material is removed from the top of the column, and partially condensed in the Debutaniser Overhead Condenser. Uncondensed vapour is routed to Amine Treating, while condensed LPG is partly returned to the top of the Debutaniser as reflux and partly routed to Amine Treatment before LPG fractionation. The material heavier than butane leaves the bottom of the Debutaniser and is routed to the Naphtha Splitter,

The Splitter fractionates the feed into two components. The Light Naphtha Overhead is condensed and the nett stream is routed to the Light Naphtha Merox Unit. The nett Heavy Naphtha bottoms product is pumped to the Naphtha Hydrodesulphurisation Unit and Naphtha Reformer.

The Vacuum Distillation Unit

Atmospheric Residue is heated in a preheat exchanger train before entering the Vacuum Column Heater. Here the feed is heated to approximately 400°C before entering the Vacuum Distillation Column. Simultaneously, low pressure saturated steam is superheated in the convection coils of the heater before being used as stripping steam in the Vacuum Column. Vacuum in the tower (approximately 60mm Hg) is maintained by a 3 stage steam ejector/condenser system. A final condensate separator routes a light hydrocarbon sour gas stream which is incinerated condensed hydrocarbon liquid to the slop and water to the Sour Water Stripper. A light vacuum gas oil stream is routed to the Diesel blender while a slip stream is either returned as wash oil or is cooled for internal reflux in the column.

A heavy vacuum gas oil stream is used to generate steam before being fed to the hydrocracker, while some is used to preheat the Column feed before returning as reflux to the Column. The Vacuum Column bottoms are passed through a strainer on the pump suction and either routed to the visbreaker or to the Bitumen Blowing Unit. Once again, a recycle stream is used to preheat the feed to the main column, before returning to the column as reflux.



NATIONAL ENERGY AUTHORITY
ICELAND
REFINERY FEASIBILITY STUDY

LUMMUS — THE LUMMUS COMPANY LIMITED LONDON

PROCESS FLOW DIAGRAM
VACUUM UNIT

Approved [signature] | Issued 27/2/81

LUMMUS

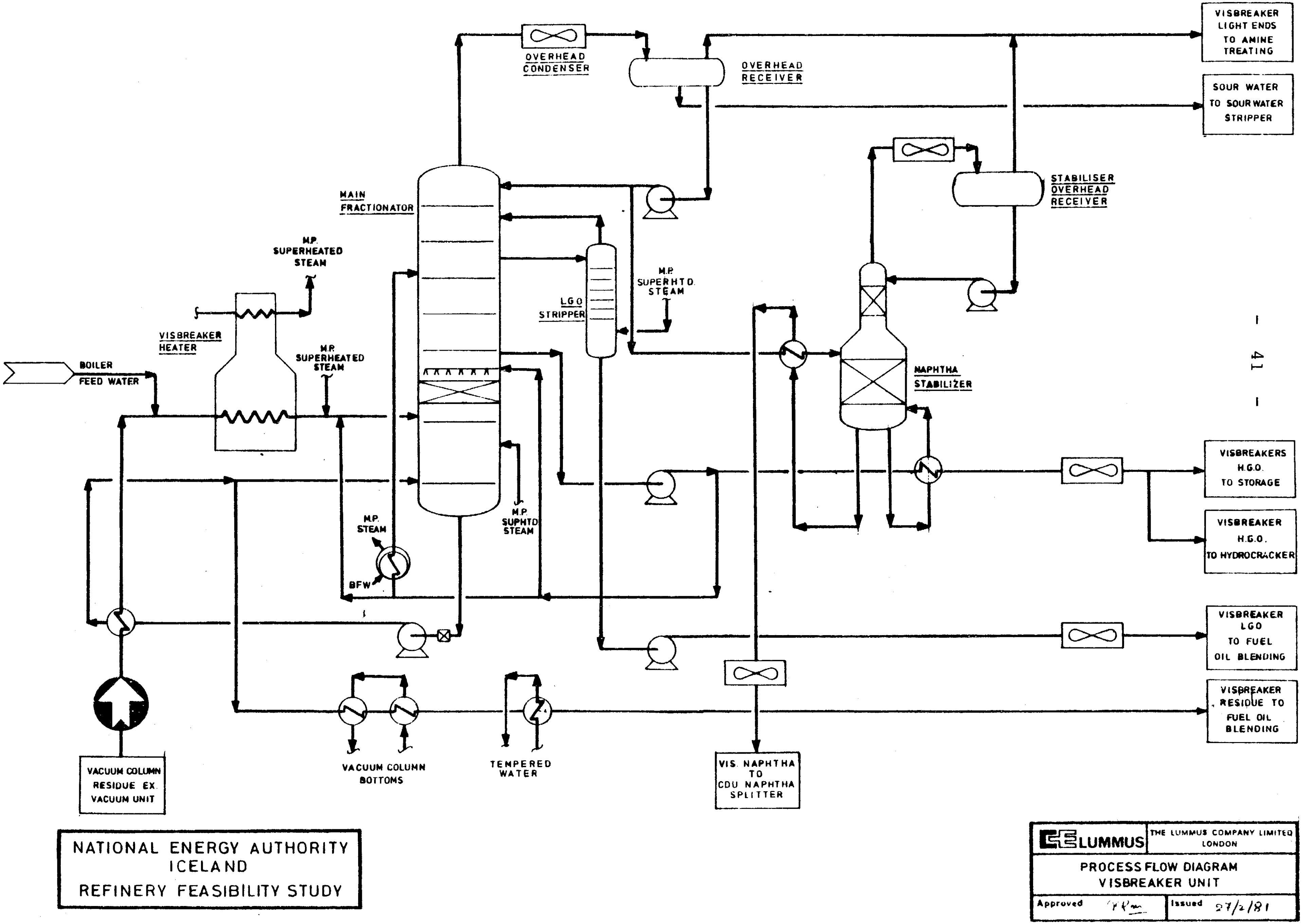
PROCESS DESCRIPTION

Visbreaker Unit

Vacuum Residue feed is heated by exchanging heat with bottoms product from the Main Fractionator before passing, together with a BFW vaporisation stream, through the Visbreaker Furnace. The stream leaves the furnace outlet at approximately 450°C and the product is then quenched to arrest the cracking reaction (and hence minimise coke formation) before entering the Main Fractionator. The overhead product from the fractionator tower is partially condensed and fed to an overhead receiver. Here the various components are separated out; the light hydrocarbon vapour is sent to the Amine Treating Unit, the sour water is fed to the Sour Water Stripper and the unstabilised naphtha is fed via a heat exchanger to the Naphtha Stabiliser. Here the light ends remaining are flashed off to the Amine Unit, while the stabiliser bottoms product is used to heat the Stabiliser feed stream before being routed to the CDU naphtha Splitter for fractionation (it will be noticed that the Overall Refinery Flow Scheme shows two separate Naphtha Streams leaving the Visbreaker - this is only to satisfy an overall refinery mass balance). Some unstabilised Naphtha is routed back to the top of the fractionator for internal reflux.

A light gas oil stream is routed to a Stripper Column where medium pressure superheated steam is utilised to strip out light ends. The stripped product is then pumped out to the Fuel Oil Blender.

A heavy gas oil stream is used to reboil material in the Naphtha Stabiliser before being routed to the hydrocracking unit. Slip streams of this material are used to generate medium pressure steam (before returning to the Fractionator as reflux) and to quench the Visbreaker Heater outlet to suppress coking formation. Superheated medium pressure steam is added to the bottom of the column to strip out light ends from the fractionated Residual Stream which, after being cooled, is routed to the Fuel Oil Blender.


VISBREAKER LIGHT ENDS TO AMINE TREATING
SOUR WATER TO SOUR WATER STRIPPER
OVERHEAD CONDENSER
OVERHEAD RECEIVER
STABILISER OVERHEAD RECEIVER
MAIN FRACTIONATOR
M.P. SUPERHEATED STEAM
VISBREAKER HEATER
M.P. SUPERHEATED STEAM
BOILER FEED WATER
LGO STRIPPER
M.P. SUPERHTD. STEAM
NAPHTHA STABILIZER
M.P. STEAM
BFW
M.P. SUPHTD STEAM
VISBREAKERS H.G.O. TO STORAGE
VISBREAKER H.G.O. TO HYDROCRACKER
VISBREAKER LGO TO FUEL OIL BLENDING
VISBREAKER RESIDUE TO FUEL OIL BLENDING
VACUUM COLUMN RESIDUE EX VACUUM UNIT
VACUUM COLUMN BOTTOMS
TEMPERED WATER
VIS. NAPHTHA TO CDU NAPHTHA SPLITTER
NATIONAL ENERGY AUTHORITY
ICELAND
REFINERY FEASIBILITY STUDY
LUMMUS
THE LUMMUS COMPANY LIMITED LONDON
PROCESS FLOW DIAGRAM
VISBREAKER UNIT
Approved
Issued 27/2/81

The Hydrocracking Unit

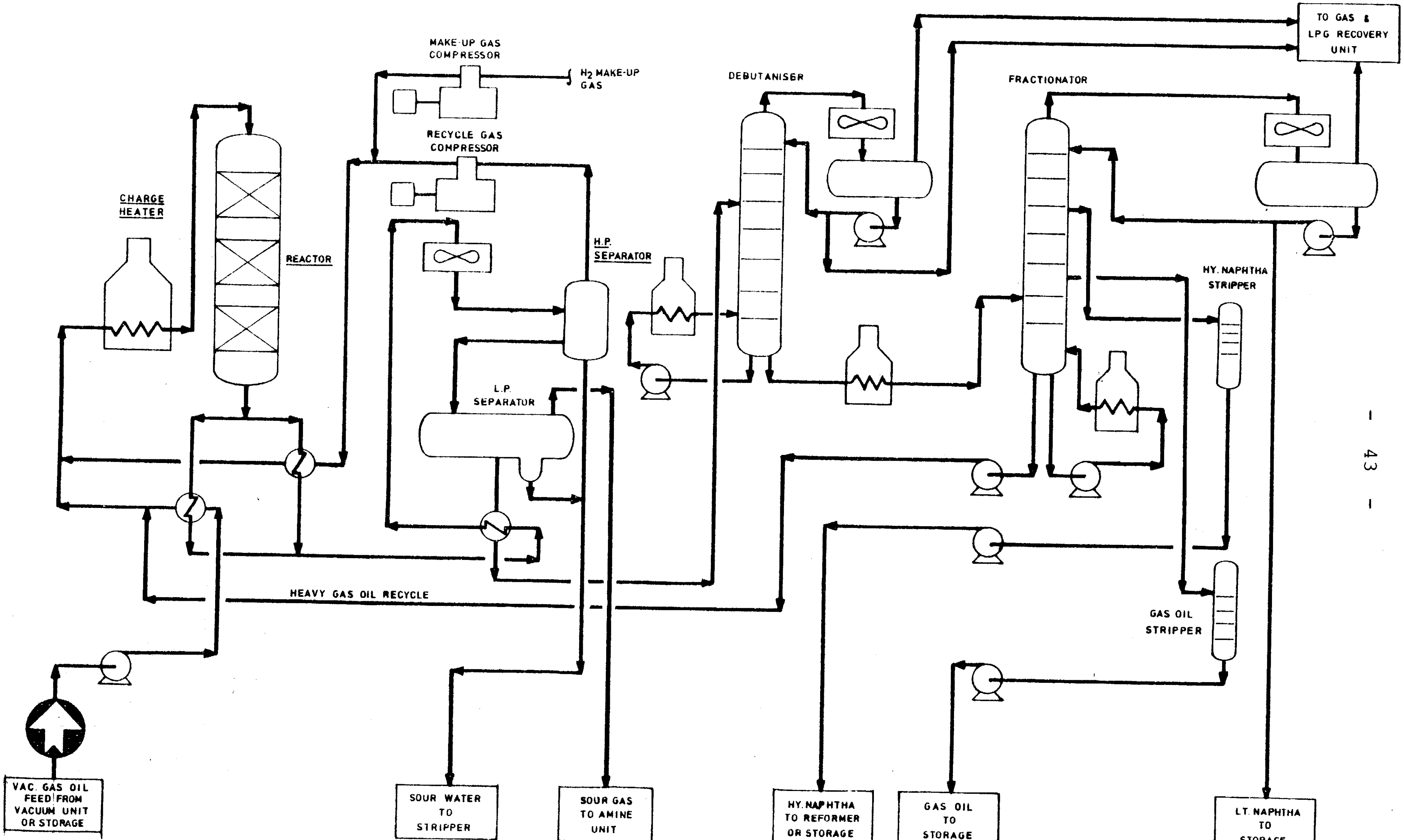
In the Hydrocracking Unit, vacuum gas oil from the Vacuum Distillation Unit is processed to produce products of Diesel oil quality and lighter.

Vacuum Gas Oil is preheated together with a heavy oil recycle stream from the Hydrocracking Unit Fractionator and a recycle hydrogen stream before entering the Reactor. Here the feed streams react over three catalytic beds at 350°C to 450°C and approximately 170 bar to produce a maximum of saturated, highly-branded, lower molecular weight compounds. Further the feed stream is desulphurised and denitrified. Intermediate hydrogen quench streams are fed to the Reactor to control the temperature due to the highly exothermic reactions. The Reactor product is cooled and partially condensed before separating out in the High Pressure Separator. From here, an uncondensed hydrogen-rich stream is routed back to the reactor via the Recycle Gas Compressor.

Condensed water is separated out from the liquid hydrocarbon product in the bottom of the HP Separator. The water is routed to the Sour Water Stripper while the liquid product is further flashed in the Low Pressure Separator. The overhead gas containing mainly hydrogen sulphide, ammonia and light hydrocarbons is routed to the Amine Treating Unit. Liquid water is routed to the Sour Water Stripper and liquid product is heated before entering the Debutaniser. The overhead stream from the Debutaniser is partially condensed and sent to an Overhead Receiver; the overhead gas stream is routed to the Gas Absorber in the Amine Treating Unit, while the nett liquid overhead is pumped to the LPG Absorber in the Amine Unit. The Debutaniser bottoms liquid is preheated before entering the Fractionator. The overhead product from this tower is partially condensed with the gas going to the Amine Treatment Unit while the nett liquid is pumped to storage as light naphtha.

The light side stream product from the Fractionator is steam stripped, the nett product being routed either to the Catalytic Reforming Unit or to storage, while the heavy side stream, after stripping, is routed to storage, either for diesel oil or fuel oil blending. The nett bottoms product of the Fractionator is recycled to extinction via the reaction section of the unit.

Hydrogen purity of the recycle gas loop is maintained by make-up from the Hydrogen Unit and, under certain operating conditions, from the Catalytic Reformer.



NATIONAL ENERGY AUTHORITY
ICELAND
REFINERY FEASIBILITY STUDY

LUMMUS — THE LUMMUS COMPANY LIMITED, LONDON

PROCESS FLOW DIAGRAM
DISTILLATE HYDROCRACKING UNIT

Approved — Issued 27/2/81

LUMMUS

PROCESS DESCRIPTION

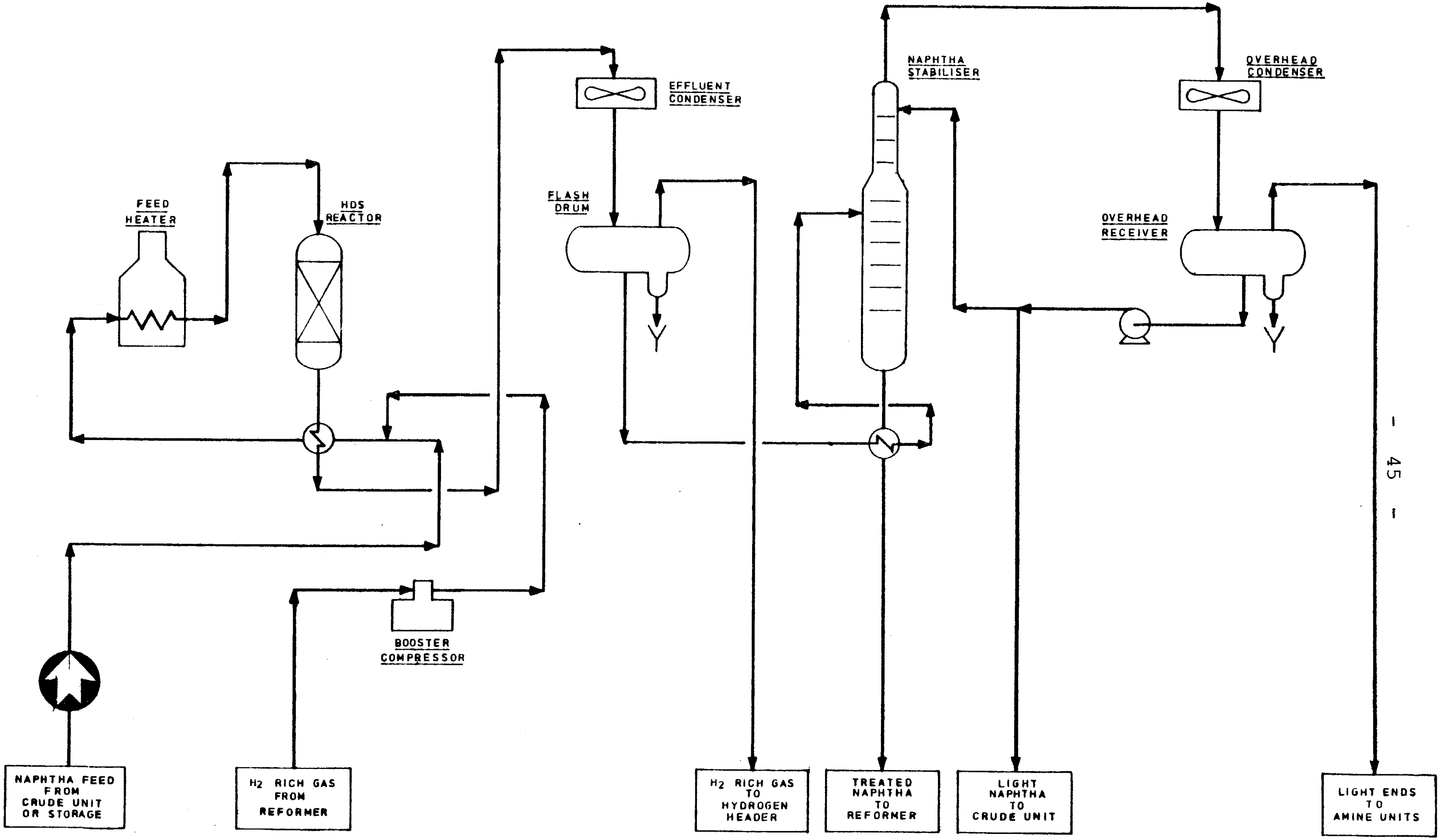
The Naphtha Hydrodesulphurisation Unit (HDS) and the Naphtha Catalytic Reformer

These are two separate units, but are so closely integrated that a combined flow scheme will be described here.

Sour, low octane, heavy naphtha, either from the Crude Distillation and Hydrocracker Units or from storage is heated and then routed to the HDS Reactor where the sour naphtha is reacted with hydrogen over a catalyst bed at approximately 360°C and 30 bar pressure primarily to remove sulphur, nitrogen and oxygen. The hydrogen sulphide, ammonia and water so-formed, are then removed, after cooling, in the Flash Drum.

The flashed H_2-rich gas is sent to the Hydrogen header and the sweetened naphtha is routed to the Naphtha Stabiliser. The overhead product of the stabiliser is partially condensed; the non-condensed vapour is routed to the Amine Treating Unit, while the nett overhead liquid is routed together with the light naphtha from the Crude Distillation Unit to the Light Naphtha Merox Unit. The bottoms product from the Stabiliser is then cooled and sent to the Catalytic Reforming Unit.

At the Reforming Unit, the sweetened, stabilised naphtha initially undergoes preheat and reaction over a catalyst bed in four stages in series. In each reactor, the naphtha is contacted with hydrogen at temperatures varying from 400 to 500°C, to increase the octane number of the naphtha through dehydrogenation, dehydrocyclization and aromatics maximisation. The effluent from the final reactor is partially condensed and then separated in the Flash Drum. The vapour overhead stream is routed via a liquid knock out drum to the Gas Recycle Compressor before returning to the reactor section. To maintain the hydrogen pressure of the recycle loop, an excess hydrogen stream is routed to the Naphtha Hydrodesulphurisation Unit. The liquid product from the Flash Drum is pumped to the Stabiliser Tower after being heated in a heat exchanger. The Stabiliser overhead is partially condensed; the overhead gas is routed to the fuel gas system, while the nett liquid overhead product is pumped to LPG recovery. The bottoms product from the Stabiliser Tower is cooled before being routed to storage as a potentially high octane gasoline blending component.

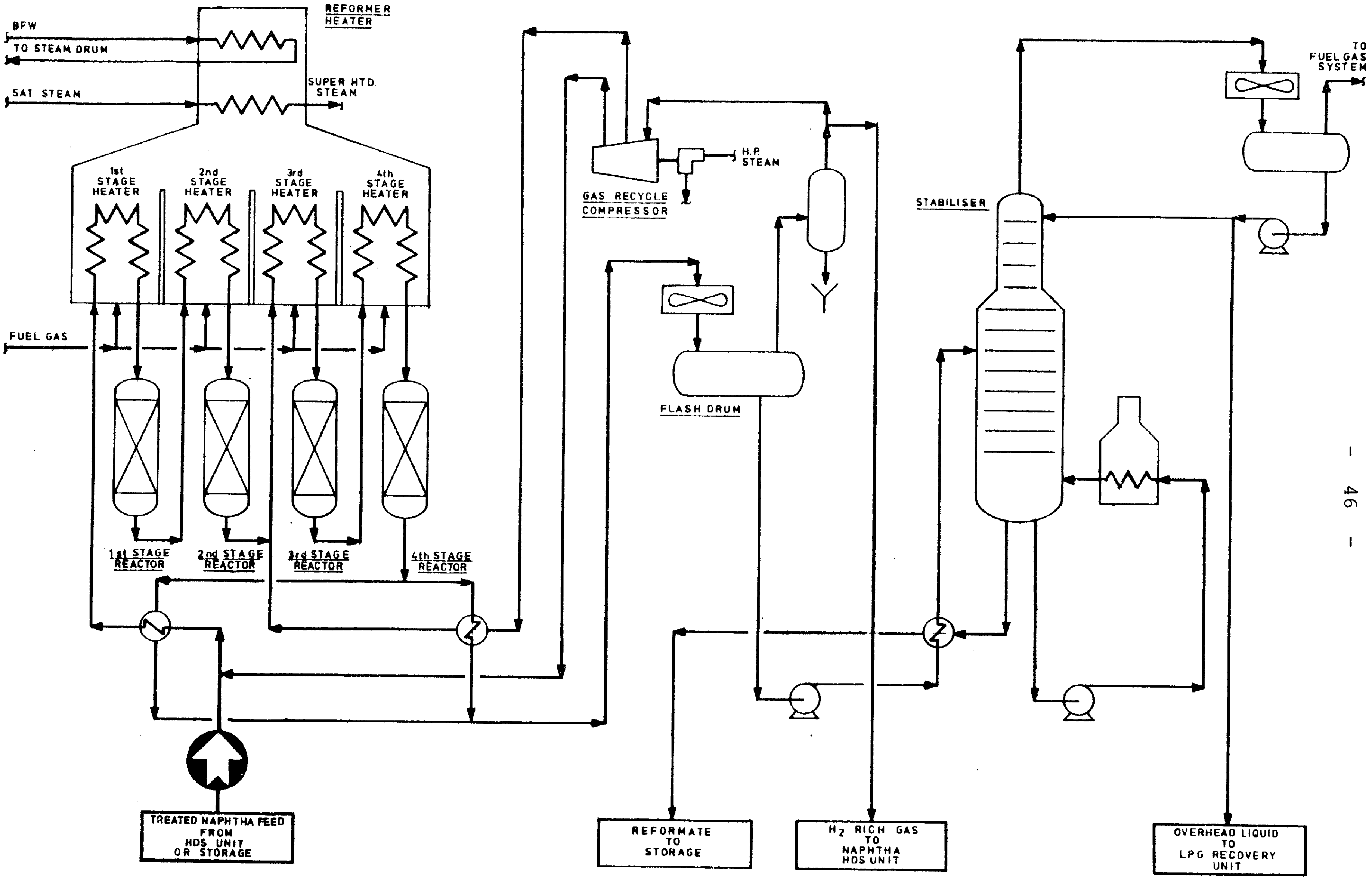


NATIONAL ENERGY AUTHORITY
ICELAND
REFINERY FEASIBILITY STUDY

LUMMUS — THE LUMMUS COMPANY LIMITED, LONDON

PROCESS FLOW DIAGRAM
NAPHTHA HDS UNIT

Approved KPm — Issued 27/2/81



NATIONAL ENERGY AUTHORITY
ICELAND
REFINERY FEASIBILITY STUDY

LUMMUS | THE LUMMUS COMPANY LIMITED LONDON

PROCESS FLOW DIAGRAM
CATALYTIC REFORMER

Approved [signature] | Issued 27/2/81

LUMMUS

PROCESS DESCRIPTION

Sulphur Recovery Unit

The flow scheme proposed, utilises the well-known Claus Process which is based on the combustion of hydrogen sulphide with a ratio controlled flow of air to evolve the complete oxidation of all hydrocarbons and ammonia present in the sour gas feed and to burn one third of the hydrogen sulphide to sulphur dioxide and water.

$$H_2S + \frac{3}{2}O_2 \longrightarrow SO_2 + H_2O + heat$$

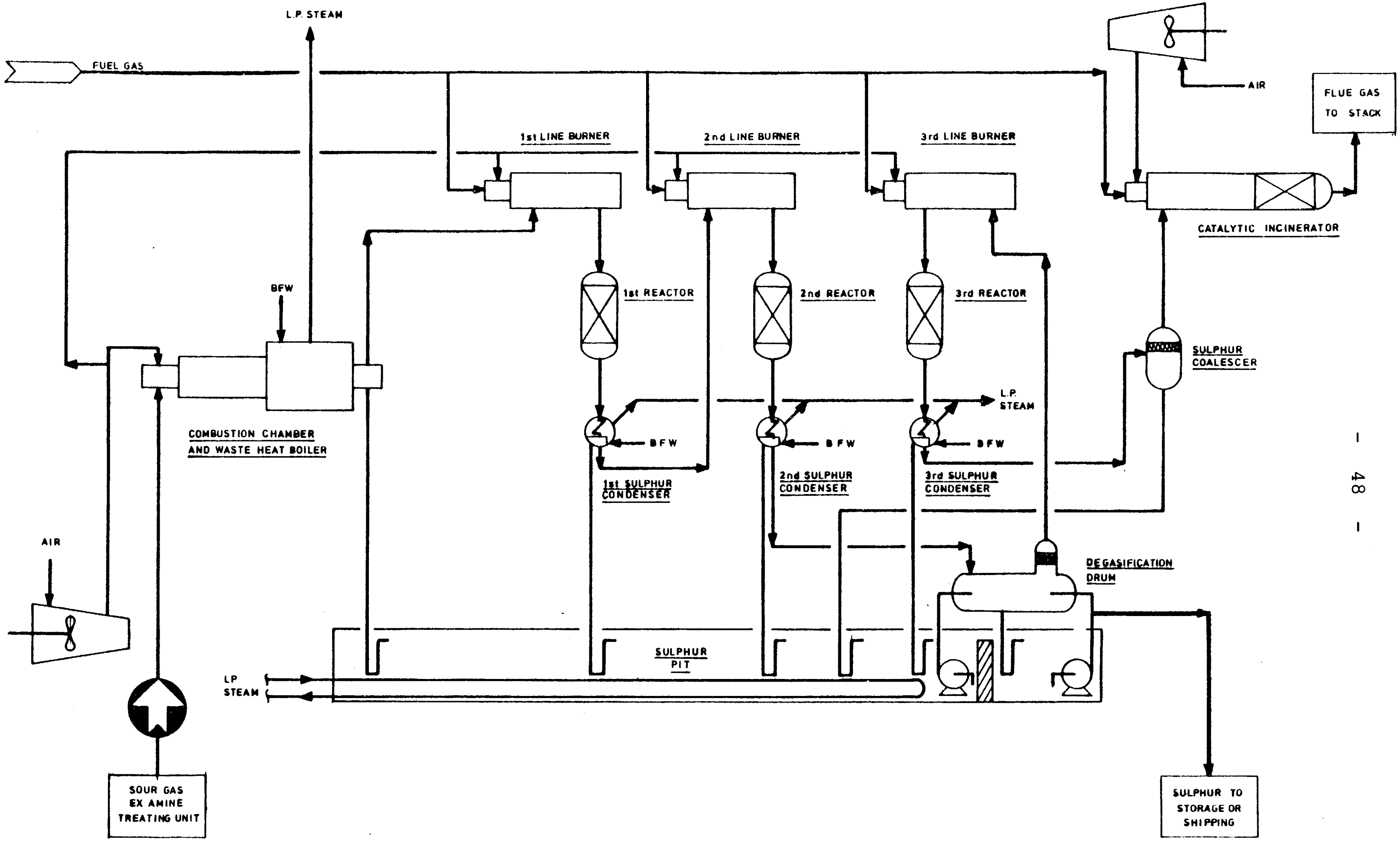
the residual H_2S then reacts with the SO_2 so formed to produce sulphur

$$2H_2S + SO_2 \rightleftharpoons 3S + 2H_2O + heat$$

The vapour phase sulphur formed in the combustion chamber is condensed in the Waste Heat Boiler by exchanging heat with LP BFW and so thereby generating LP Steam. The equilibrium of the sulphur-reforming reaction is favoured by low temperature so the unreacted H_2S and SO_2 is contacted at successively lower temperatures so as to maximise the recovery of sulphur. This is achieved by passing the stream through 3 burner/reactor/condenser stages in series, in each of which the gas stream is brought to an optimum reaction temperature, reacted over an Alumina catalyst bed and then partially condensed to remove the sulphur formed. Gas then passes through the Sulphur Coalescer Drum to remove entrained sulphur before being routed to SO_2 into the Catalytic Incinerator where the tail gas is reacted with air to covert all the hydrogen sulphide and sulphur vapour present to less noxious sulphur dioxide before being vented from the flue gas stack.

The liquid sulphur formed in any of the condensing stages is routed to the central Sulphur Pit via sulphur locks. The temperature and hence the viscosity of the liquid sulphur is maintained by an submersed low pressure steam coil at the bottom of the pit. A degasification drum ensures that hydrogen sulphide does not accumulate in the pit.

This process recovers over 97% of the sulphur fed to the unit and ensures a maximum H_2S in the flue gas of 20 ppm wt.



NATIONAL ENERGY AUTHORITY
ICELAND
REFINERY FEASIBILITY STUDY

LUMMUS — THE LUMMUS COMPANY LIMITED LONDON

PROCESS FLOW DIAGRAM
SULPHUR RECOVERY UNIT

Approved [signature] Issued 27/2/81

LUMMUS

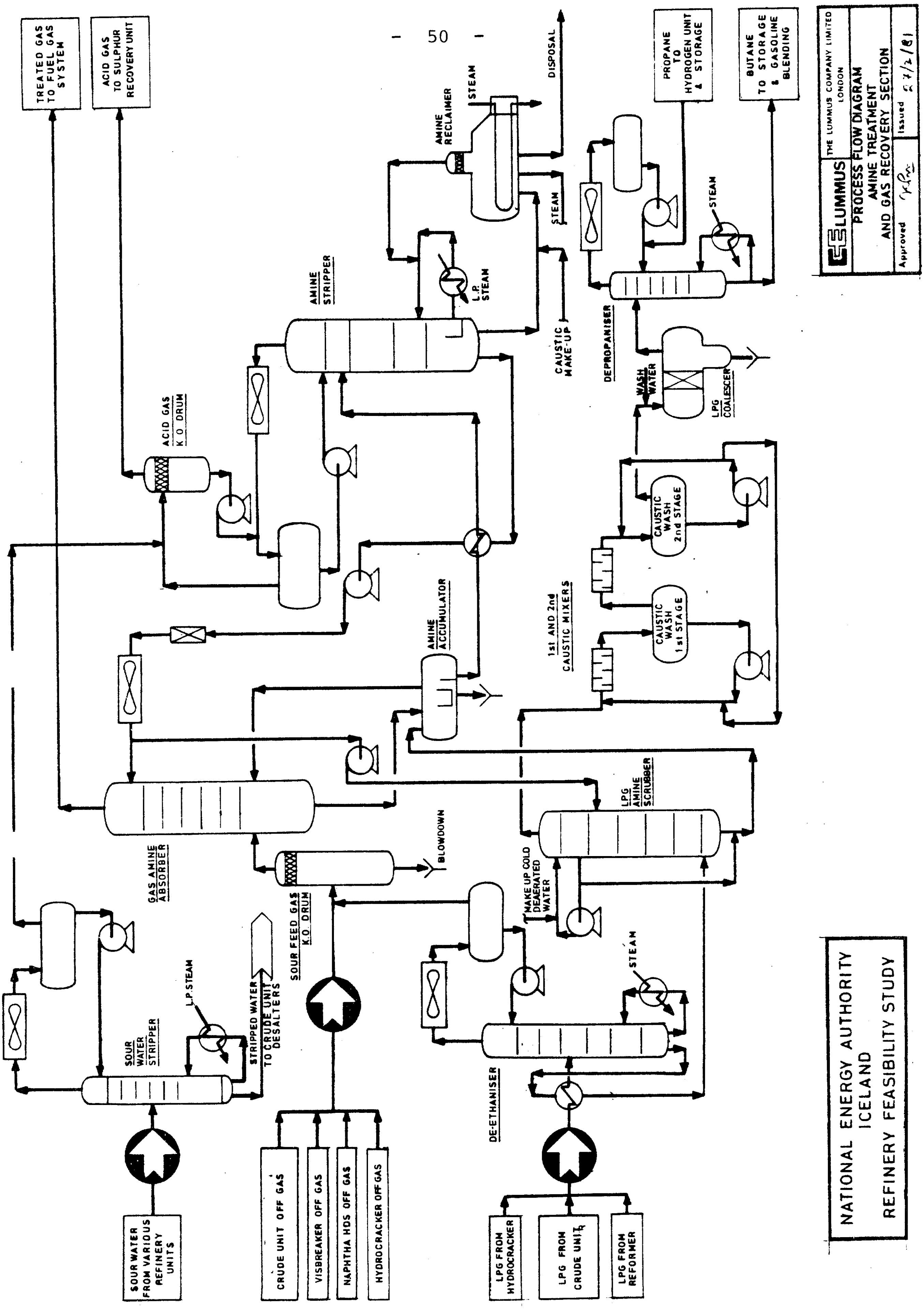
PROCESS DESCRIPTION

Amine Treating Unit and Gas Recovery

Sour LPG from the Crude Unit Debutaniser overhead Receiver is initially fed to a De-ethaniser to remove ethane and lighter components which are routed to the Amine Unit gas sweetening section. The bottoms liquid product from this column is then cooled and fed to the LPG Amine Scrubber where any dissolved H_2S and CO_2 are absorbed by the circulating lean Amine Solution. To reduce Amine losses in the outgoing LPG stream, a water wash section operates at the top of the tower. The LPG stream is then counter-currently contacted with caustic solution in two Caustic Mixers in series to remove mercaptans and residual H_2S. The treated LPG is then routed to the LPG Coalescer where entrained caustic solution is removed. The stream is finally fed to a Depropaniser where the product is fractionated into a propane-rich stream which is subsequently used as Hydrogen Unit feed and a butane-rich stream which is either marketed as LPG or is used as a blending component in the gasoline pool.

The off-gasses coming from the Crude Column overhead, Visbreaker, Hydrocracker, Naphtha Hydrodesulphuriser and the Naphtha Reformer are joined by the nett overhead product from the De-ethaniser (see above) and after water removal in a knock-out drum, the combined stream is contacted with the circulating amine solution in the Gas Amine Absorber. The sweetened gas is then routed to the refinery fuel gas header.

The cold Amine Solution, rich in H_2S and CO_2 from the Gas Amine Absorber and the LPG Amine Scrubber, is fed to the Amine Accumulator before being heated by hot lean Amine solution in a heat exchanger before being fed to the Amine Stripper. Here hot amine solution from two reboilers at the bottom of the column, together with steam and regenerated Amine from the Amine Reclaimer are used to strip acid gas components from the Rich Amine Solution. The acid gas passes out the top of the tower, is cooled and is charged to the Sulphur Recovery Unit via the Acid Gas Knock-Out Drum. The Lean Amine Solution passes out the bottom of the column, is cooled by heat exchange with Rich Amine Solution before being pumped, together with fresh Amine Makeup through a filter to the Amine Gas Absorber and the Amine LPG Scrubber.


TREATED GAS TO FUEL GAS SYSTEM
ACID GAS TO SULPHUR RECOVERY UNIT
DISPOSAL
STEAM
AMINE RECLAIMER
STEAM
PROPANE TO HYDROGEN UNIT & STORAGE
BUTANE TO STORAGE & GASOLINE BLENDING
LUMMUS
THE LUMMUS COMPANY LIMITED LONDON
PROCESS FLOW DIAGRAM
AMINE TREATMENT
AND GAS RECOVERY SECTION
Approved
Issued 27/2/81
STEAM
AMINE STRIPPER
L.P. STEAM
CAUSTIC MAKE-UP
DEPROPANISER
WASH WATER
LPG COALESCER
ACID GAS K.O. DRUM
CAUSTIC WASH 2nd STAGE
1st AND 2nd CAUSTIC MIXERS
CAUSTIC WASH 1st STAGE
AMINE ACCUMULATOR
LPG AMINE SCRUBBER
BLOWDOWN
GAS AMINE ABSORBER
SOUR FEED GAS K.O. DRUM
MAKE UP COLD DEAERATED WATER
STRIPPED WATER TO CRUDE UNIT DESALTERS
L.P. STEAM
SOUR WATER STRIPPER
STEAM
DE-ETHANISER
SOUR WATER FROM VARIOUS REFINERY UNITS
CRUDE UNIT OFF GAS
VISBREAKER OFF GAS
NAPHTHA HDS OFF GAS
HYDROCRACKER OFF GAS
LPG FROM HYDROCRACKER
LPG FROM CRUDE UNIT
LPG FROM REFORMER
NATIONAL ENERGY AUTHORITY
ICELAND
REFINERY FEASIBILITY STUDY

In most of the light and medium crude case operations, net hydrogen make-up requirement varies from 1 MT/SD for the North Sea crude case to 3.7 MT/SD in the light Arabian crude case.

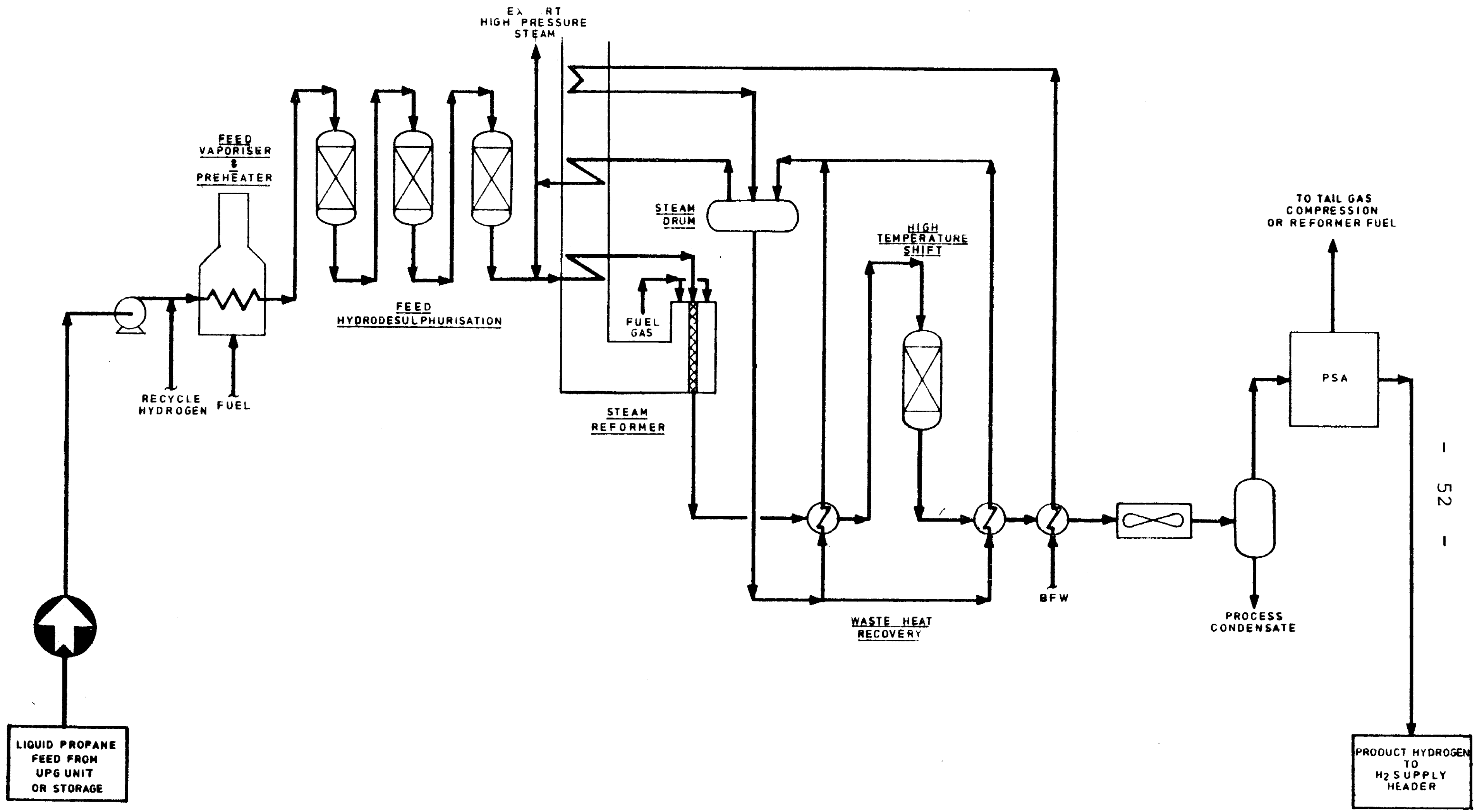
For the light Arabian crude case, H_2 consumption of 3.7 MT/SD means a hydrogen plant of 2 MM SCFD capacity based on propane as a feed stock. This plant will cost about 4 million dollars, whereas purchasing hydrogen from an external source, will cost about $5,200 per day @ $1,400/MT, or 1.7 million dollars per year, which will pay for the hydrogen plant in about 2.5 years time.

In all the crude cases, there is a surplus of propane and butane. It is preferable to export the butane as it is cheaper to transport and will find a ready market in domestic and camping use. Propane can be burnt in the refinery and partly used for H_2 production.

A typical process flow diagram for a hydrogen plant with a process description is given herewith.

Process Description

Liquid propane is mixed with a small amount of recycle hydrogen and fed to a heater where the feed is vaporised and heated to about 700°F. The heater effluent passes first to the Nimox reactor where any organic sulphur compounds contained in the feed are converted to H_2S. The gas then passes theough two zinc oxide desulphurisation reactors where the H_2S is removed down to about .1 ppm. The desulphurised gas is then mixed with high pressure steam in about a 3.5 steam/carbon ratio, heated to 1000°F in the convection section of the steam reformer and fed to the catalyst filled tubes of the reformer. The effluent from the reformer, at about 1575°F and 300 psig, is cooled in the transfer line exchanger to about 700°F by generating high pressure steam. The gas then passes to the high temperature shift reactor. The effluent from the shift reactor at about 820°F, is cooled by generating high pressure steam and preheating boiler feed water. Following residual heat removal and process condensate separation the gas passes to the pressure swing adsorption (PSA) unit where greater than 99.9% purity H_2 is obtained at about 250 psig. The tail gas from the PSA unit, at about 5 psig can be compressed and sent to the site fuel gas header or used at low pressure as supplemented reformer fuel if the reformer burners are so designed.



NATIONAL ENERGY AUTHORITY
ICELAND
REFINERY FEASIBILITY STUDY

LUMMUS | THE LUMMUS COMPANY LIMITED LONDON

PROCESS FLOW DIAGRAM
HYDROGEN PLANT

Approved KPm | Issued 27/2/81

LUMMUS

GENERAL

Storage tank layout and their sizes are estimated on the basis of the following specification.

Storage tanks shall be designed and constructed in accordance with British Standard BS-2654 - "Vertical Steel Welded Storage Tanks with Butt-welded Shells for the Petroleum Industry". L.P.G. Storage Bullets designed and constructed in accordance with American Society of Mechanical Engineers A.S.M.E. Section VIII.

Storage areas, tank spacing and bunding shall be arranged in accordance with The Institute of Petroleum "Refinery Safety Code" - Part III of the I.P. Model Code of Safe Practice in the Petroleum Industry.

Recommendations for the style of tank roof are as follows:-

Class 'A' Petroleum:
a) Floating Roof
b) "Non-Pressure" fixed roof with internal floating deck
c) "Pressure" fixed roof

Class 'B' Petroleum:
a) Floating Roof
b) "Non-Pressure" fixed roof with internal floating deck
c) "Non-Pressure" fixed roof with atmosphere vents

Class 'C' Petroleum:
a) "Non-Pressure" fixed roof with atmosphere vents.

Petroleum classifications are as defined in the above "Refinery Safety Code".

When the contents of a tank are heated the temperature shall be controlled at a safe margin below 100°C and an effective form of agitation or mixing shall be employed.

All tanks shall have local and remote level measurement in addition to the manual dipping facility.

The Design Contractor shall investigate the problem of ice and snow preventing a floating roof from rising and shall consider the use of an internal floating deck if a problem is identified.

Floating roofs shall be of the pontoon type. The size of tanks shall be chosen on the following basis:

a) The required pumpable capacity

b) lm unused level at bottom

c) lm unused level at top

d) Maximum ground loading

e) The height shall not exceed the diameter.

Tank heights given in the tankage schedule are to the nearest meter. This should be exceeded if the plate sizes used indicate that it is economical to do so; however, d) and e) above should not be exceeded.

L.P.G. Bullets shall be sized in accordance with the procedure given in the N.F.P.A. National Fire Codes Vol. 5. 1980.

LUMMUS

CRUDE STORAGE

The crude storage facility shall be designed to receive crude from the jetty in parcel sizes in the range 20,000 tonnes to 50,000 tonnes. The storage capacity shall be at least 90 days of refinery feed.

When the refinery is operating on a blend of three crudes, feed shall be taken from three different storage tanks by way of three separate feed pumps. In addition, one crude tank will be settling and two will be available to receive imported crude. Alternatively, three crude tanks will be settling. The sizes and pumpable capacities of the crude storage tanks are shown in The Schedule of Tankage (Section VI E). The arrangement of the Crude Tanks is shown on the Tankage Block Flow Diagram, (Section VI F

LUMMUS

INTERMEDIATE STORAGE

Intermediate storage shall be provided for feed to the following Process Units:-

Vacuum Unit
Visbreaker Unit
Hydrocracker Unit
Naphtha H.D.S. Unit.

The sizes and pumpable capacities of the intermediate storage tanks are shown in The Schedule of Tankage (Section VI E). The intermediate storage for feed to the vacuum, visbreaker and hydrocracker unit shall be heated to maintain the required feed conditions. The Design Contractor shall choose the most suitable system of heating, eg. internal steam coil with agitator or external heater with recirculation.

LUMMUS

FINISHED PRODUCT AND COMPONENT STORAGE

Component Storage

Component Storage shall be provided for Light Naphtha, Reformate, Light Atmospheric Gas Oil, Heavy Atmospheric Gas Oil, and Visbreaker Light Gas Oil. The size and capacity of each component storage tank is detailed in the Schedule of Tankage (Section VI E).

Kerosene for Jet Fuel Product will normally pass to the Kerosene Product tank prior to transfer to Jet Fuel.

Butane will be both Product and Gasolene component; feed to Gasolene Blending will be taken from the Butane Product storage.

Similarly, Propane feed to the Hydrogen Unit will be taken from the Propane Product Storage as detailed on the Tankage Block Flow Diagram (Section VI F).

Product Storage

Product Storage will be provided for Propane, Butane, Regular Gasoline, Aviation Gasoline, Jet Fuel, Kerosene, Marine Diesel, Road Diesel, No. 6 Fuel Oil and Bitumen.

Propane and Butane will be stored in pressurised bullets the remaining products will be stored in atmospheric storage tanks. The sizes and capacities of the product storage are detailed in the Schedule of Tankage (Section VI E).

The storage capacity for each Product will be sufficient for 15 days refinery production or will comprise two tanks per product each of the estimated export parcel size - if this provides the greater capacity.

Gasoline Products

Aviation and Regular Gasoline may be produced simultaneously in the blending package which will pass a pre-determined quantity of Reformate, Light Naphtha and Butane to a single Regular Gasoline Tank or a single Aviation Gasoline Tank or both simultaneously. T.E.L. will be added to a product tank by dosing into a recirculated gasoline stream. The recirculation pump will be designed to serve the purpose of jet mixing. It will be possible to transfer from Aviation Gasoline Storage to Regular Gasoline storage and vice-versa.

Jet Fuel and Kerosene

All Kerosene will normally pass to the single Kerosene Product storage tank. Kerosene will then be transferred to Jet Fuel Product storage and additivies will be dosed into the transfer stream as required. The transfer pump will be designed to serve the dual purpose of jet mixing the Jet Fuel Product by recirculation.

Marine and Road Diesel

Marine and Road Diesel Products will be blended from Light Atmospheric Gas Oil, Heavy Atmospheric Gas Oil, Hydrocracker Gas Oil and Kerosene. Metered quantities of Light Atmospheric Gas Oil and Heavy Atmospheric Gas Oil will be pumped to either a Marine or a Road Diesel Product Tank on the basis of tank contents sampling. Hydrocracker Gas Oil will normally run down to Diesel Product Storage. The facility shall be provided to add a metered quantity of Kerosene on the basis of tank contents sampling.

A transfer pump shall be designed such that the contents of one diesel tank may be transferred to any other diesel tank. The use of this pump for jet mixing a product tank by recirculation shall be considered.

No. 6 Fuel Oil

No. 6 Fuel Oil Product will be blended from Visbreaker Residue and Visbreaker Light Gas Oil, with the addition of Hydrocracker Gas Oil as required on the basis of tank sampling. In addition, the facility shall be provided to transfer from Diesel Product Storage to No. 6 Fuel Oil should a Diesel Product become irretrievably off-spec.

No. 6 Fuel Oil Product will be heated and continuously mixed by mechanical agitation.

Bitumen

Bitumen will be heated and mechanically agitated whilst awaiting export.

Study

The economics of insulating all heated tanks shall be studied to give an economical extent of insulation over the required payout period.

THE LUMMUS COMPA`V LIMITED

LONDON

N.E.A. REFINERY FEASIBILITY STUDY : ICELAND

SCHEDULE OF TANKAGE - FEED

TANK NO.	CONTENTS	STORAGE CAPACITY BBL/M^3		FILLING/PUMPOUT RATE M^3/HR.		DAYS STORAGE AT PUMPOUT RATE	FEED TO
FB-0801	Crude Receiving	204849 / 32,571		2000 / 79.5		17	Crude Unit
FB-0802	Crude Receiving	204849 / 32,571		2000 / 79.5		17	Crude Unit
FB-0803	Crude Settling	204849 / 32,571		2000 / 79.5		17	Crude Unit
FB-0804	Crude Feed	204849 / 32,571		2000 / 79.5		17	Crude Unit
FB-0805	Crude Feed	204849 / 32,571		2000 / 79.5		17	Crude Unit
FB-0806	Crude Feed	204849 / 32,571		2000 / 79.5		17	Crude Unit
TOTALS	CRUDE	1229094/195426	at	79.5	=	102	

THE LUMMUS COMF LIMITED

LONDON

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

SCHEDULE OF TANKAGE INTERMEDIATE & COMPONENT

TANK NO.	CONTENTS	STORAGE CAPACITY BBL/M^3	FILLING/PUMPOUT RATE M^3/HR.	DAYS STORAGE AT FILLING/PUMPOUT RATE	FEED TO
FB-0807	Atmos Residue	45,006 / 7156	- / 42	- / 7	Vac. Unit.
FB-0808	Hydrocracker Feed	22,685 / 3607	- / 25	- / 6	Hydrocracker
FB-0811	Vac.Residue	1,893 / 301	- / 2	- / 6.2	Visbreaker
FB-0813	Heavy Naphtha	25,685 / 4084	- / 25	- / 6.8	Reformer
	COMPONENT STORAGE				
FB-0809	Hvy.Atmos.Gas Oil	4,629 / 736	- / 5	- / 6	Diesel Blending
FB-0810	Lt.Atoms.Gas Oil	25,685 / 4084	- / 25	- / 6.8	Diesel Blending
FB-0812	Visbreaker L.G.O	1,579 / 251	- / 2	- / 5.2	Fuel Oil Blending
FB-0814	Reformate	11,113 / 1767	/ 20 Note 1.	- / 3.7	Gasoline Blending
FB-0815	Total Lt. Naphtha	1,113 / 1767	/ 20 Note 1.	- / 3.7	Gasoline Blending

NOTE: 1. Pump out is not continuous - component storage capacity is approx 7 days at production rate.

THE LUMMUS COMP   LIMITED

LONDON

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

SCHEDULE OF TANKAGE - PRODUCTS

TANK NO.	CONTENTS	STORAGE CAPACITY BBL/M^3	FILLING/PUMPOUT RATE M^3/HR. NOTE 2	DAYS STORAGE AT FILLING/PUMPOUT RATE	FEED TO
FB-0816	Regular Gasoline	18,151 / 2886	20.5 / 550	5.8 / -	Ship/Road Loading
FB-0817	Regular Gasoline	18,151 / 2886	20.5 / 550	5.8 / -	Ship/Road Loading
FB-0818	Regular Gasoline	18,151 / 2886	20.5 / 550	5.8 / -	Ship/Road Loading
TOTAL					
3 TANKS	REGULAR GASOLINE	54,453 / 8658	-	17.4 DAYS	
FB-0819	Aviation Gasoline	1,264 / 201	0.5 / 68	16.75 / -	Ship/Road Loading
FB-0820	Aviation Gasoline	1,264 / 201	0.5 / 58	16.75 / -	Ship/Road Loading
TOTAL					
2 TANKS	AVIATION GASOLINE	2,528 / 402	-	33.5 DAYS	
FB-0821	Jet Fuel Grade 'A'	18,151 / 2886	9.9 / 550	12 / -	Ship/Road Loading
FB-0822	Jet Fuel Grade 'A'	18,151 / 2886	9.9 / 550	12 / -	Ship/Road Loading
TOTAL					
2 TANKS	JET FUEL	36,302 / 5772	-	24 DAYS	

THE LUMMUS COM Y LIMITED

LONDON

N.E.A. REFINERY REASIBILITY STUDY: ICELAND

SCHEDULE OF TANKAGE - PRODUCTS

TANK NO	CONTENTS	STORAGE CAPCACITY BBL/M^3	FILLING/PUMPOUT RATE M^3/HR. NOTE 2.	DAYS STORAGE AT FILLING/PUMPOUT RATE	FEED TO
FB-0823	Kerosene	1,264 / 201	9.9 / 68	1.0 / -	Ship/Road Loading/ Jet Fuel
TOTAL					
3 TANKS	KEROSENE + JET FUEL	37,566 / 5973	-	25 DAYS	

NOTE 2 : Filling Rate quoted is daily average.

THE LUMMUS COMP LIMITED

LONDON

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

SCHEDULE OF TANKAGE - PRODUCTS

TANK NO	CONTENTS	STORAGE CAPACITY BBL/M^3	FILLING/PUMPOUT RATE M^3/HR.	DAYS STORAGE AT FILLING/PUMPOUT RATE	FEED TO
FB-0824	Light Road Diesel	18,151 / 2886	24.8 / 550	4.8 / -	Ship/Road Loading
FB-0825	Light Road Diesel	18,151 / 2886	24.8 / 550	4.8 / -	Ship/Road Loading
FB-0826	Light Road Diesel	18,151 / 2886	24.8 / 550	4.8 / -	Ship/Road Loading
TOTAL					
3 TANKS	LIGHT ROAD DIESEL	54,453 / 8658	-	14.4 DAYS	
FB-0827	Marine Diesel	16,635 / 2645	14.6 / 550	7.5 / -	Ship/Road Loading
FB-0828	Marine Diesel	16,635 / 2645	14.6 / 550	7.5 / -	Ship/Road Loading
TOTALS					
2 TANKS	MARINE DIESEL	33,270 / 5290	-	15 DAYS	
FB-0829	No.6 Fuel Oil	13,333 / 2120	11.5 / 500	7.6 / -	Ship/Road Loading
FB-0830	No.6 Fuel Oil	13,333 / 2120	11.5 / 500	7.6 / -	Ship/Road Loading
TOTALS					
2 TANKS	No.6 FUEL OIL	26,666 / 4240	-	15.2 DAYS	

THE LUMMUS COMPANY LIMITED.

LONDO.

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

SCHEDULE OF TANKAGE - PRODUCTS

TANK NO.	CONTENTS	STORAGE CAPACITY BBL/M^3	FILLING/PUMPOUT RATE M^3/HR.	DAYS STORAGE AT FILLING/PUMPOUT RATE	FEED TO
FB-0831	Bitumen	2,465.4 / 392	2 / 130	8.1 / -	Ship/Road Loading
FB-0832	Bitumen	2,465.4 / 392	2 / 130	8.1 / -	Ship/Road Loading
TOTALS					
2 TANKS	BITUMEN	4,930.8 / 794	-	16.2 DAYS	

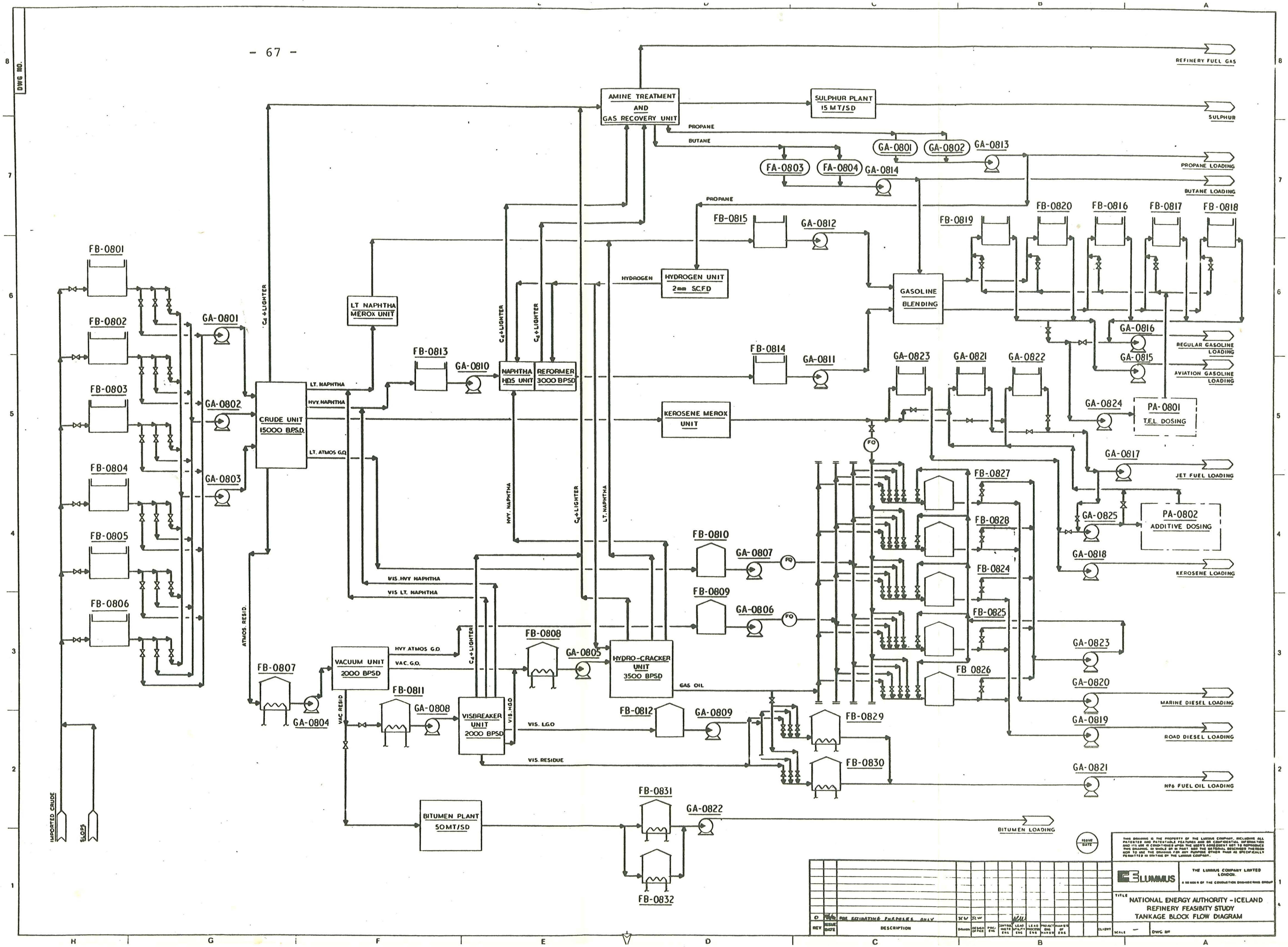
THE LUMMUS COMPANY LIMITED

LONDON

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

SCHEDULE OF TANKAGE - PRODUCTS

TANK NO.	CONTENTS	STORAGE CAPACITY BBL/M^3	FILLING/PUMPOUT RATE M^3/HR.	DAYS STORAGE AT FILLING/PUMPOUT RATE	FEED TO
FA-0801	Liquid Propane	1,429.4 / 227.27	0.63 / 68	15 / -	Loading
FA-0802	Liquid Propane	1,429.4 / 227.27	0.63 /68	15 / -	Loading
TOTAL					
2 BULLETTS	LIQUID PROPANE	2,858.8 / 454.54	-	30 DAYS	
FA-0803	Liquid Butane	1,429.4 / 227.27	0.63 / 68	15 / -	Loading
FA-0804	Liquie Butane	1,429.4 / 227.27	0.63 / 68	15 / -	Loading
TOTAL					
2 BULLETTS	LIQUID BUTANE	2,858.8 / 454.54	-	30 DAYS	


DWG NO.
REFINERY FUEL GAS
AMINE TREATMENT AND GAS RECOVERY UNIT
SULPHUR PLANT 15 MT/SD
SULPHUR
PROPANE
BUTANE
GA-0801
GA-0802
GA-0813
FA-0803
FA-0804
GA-0814
PROPANE LOADING
BUTANE LOADING
FB-0815
GA-0812
FB-0819
FB-0820
FB-0816
FB-0817
FB-0818
HYDROGEN
HYDROGEN UNIT 2mm SCFD
GASOLINE BLENDING
GA-0816
GA-0815
REGULAR GASOLINE LOADING
AVIATION GASOLINE LOADING
FB-0801
FB-0802
FB-0803
FB-0804
FB-0805
FB-0806
GA-0801
GA-0802
GA-0803
C4+LIGHTER
LT NAPHTHA MEROX UNIT
CRUDE UNIT 15000 BPSD
LT. NAPHTHA
HVY. NAPHTHA
LT. ATMOS G.O.
FB-0813
GA-0810
NAPHTHA HDS UNIT
REFORMER 3000 BPSD
FB-0814
GA-0811
GA-0823
GA-0821
GA-0822
GA-0824
PA-0801 T.E.L. DOSING
KEROSENE MEROX UNIT
GA-0817
JET FUEL LOADING
FB-0827
FB-0828
FB-0824
FB-0825
FB 0826
GA-0825
PA-0802 ADDITIVE DOSING
GA-0818
KEROSENE LOADING
HVY. NAPHTHA
LT. NAPHTHA
FB-0810
GA-0807
FB-0809
GA-0806
VIS. HVY NAPHTHA
VIS LT. NAPHTHA
ATMOS. RESID.
FB-0807
GA-0804
VACUUM UNIT 2000 BPSD
HVY ATMOS G.O.
VAC. G.O.
VAC RESID
FB-0811
GA-0808
VISBREAKER UNIT 2000 BPSD
VIS. HGO
VIS. LGO
VIS. RESIDUE
FB-0808
GA-0805
HYDRO-CRACKER UNIT 3500 BPSD
GAS OIL
FB-0812
GA-0809
FB-0829
FB-0830
GA-0823
GA-0820
MARINE DIESEL LOADING
GA-0819
ROAD DIESEL LOADING
GA-0821
Nº6 FUEL OIL LOADING
BITUMEN PLANT 50MT/SD
FB-0831
GA-0822
FB-0832
BITUMEN LOADING
IMPORTED CRUDE
SLOPS
0
FOR ESTIMATING PURPOSES ONLY
REV
ISSUE DATE
DESCRIPTION
LUMMUS
THE LUMMUS COMPANY LIMITED LONDON
TITLE
NATIONAL ENERGY AUTHORITY - ICELAND
REFINERY FEASIBITY STUDY
TANKAGE BLOCK FLOW DIAGRAM
SCALE
DWG Nº

THE LUMMUS COMPANY LIMITED

LONDON

Rev. No. O Date 13-2-81

Sheet 1 of 7

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

TANKAGE - AREA -08

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
FA-0801	Propane Bullet	3m Dia. x 17 m T/T	Des. Press = 17.6 Kg/cm^2G
FA-0802	Propane Bullet	3m Dia. x 17 m T/T	Des. Press = 17.6 Kg/cm^2G
FA-0803	Butane Bullet	3m Dia. x 17 m T/T	Des. Press = 7 Kg/cm^2G
FA-0804	Butane Bullet	3m Dia. x 17 m T/T	Des. Press = 7 Kg/cm^2G
FB-0801	Crude	48m Dia. x 22m HT	Floating Roof
FB-0802	Crude	48m Dia. x 22m HT	Floating Roof
FB-0803	Crude	48m Dia. x 22m HT	Floating Roof
FB-0804	Crude	48m Dia. x 22m HT	Floating Roof
FB-0805	Crude	48m Dia. x 22m HT	Floating Roof
FB-0806	Crude	48m Dia. x 22m HT	Floating Roof
FB-0807	Atmos Resid	22.5m Dia. x 20m HT	Cone Roof, Heater & Agitator
FB-0808	Vacuum Gas Oil	17.5m Dia. x 17m HT	Cone Roof, Heater & Agigator
FB-0809	Hvy. A.G.O.	12.5m Dia. x 8m HT	Cone Roof
FB-0810	Lt. A.G.O.	20m Dia. x 15m HT	Cone Roof

THE LUMMUS COMPANY LIMITED

LONDON

Rev. No. O Date 13-2-81

Sheet 2 of 7

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

TANKAGE - AREA -08

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
FB-0811	Vac Residue	8m Dia. x 8m HT	Cone Roof, Heater & Agitator
FB-0812	Visbreaker L.G.O.	8m Dia. x 7m HT	Cone Roof
FB-0813	Heavy Naphtha	20m Dia. x 15m HT	Floating Roof
FB-0814	Reformate	15m Dia. x 12m HT	Floating Roof
FB-0815	Total Lt. Gasoline	15m Dia. x 12m HT	Floating Roof
FB-0816	Regular Gasoline	17.5m Dia. x 14m HT	Floating Roof
FB-0817	Regular Gasoline	17.5m Dia. x 14m HT	Floating Roof
FB-0818	Regular Gasoline	17.5m Dia. x 14m HT	Floating Roof
FB-0819	Aviation Gasoline	8m Dia. x 6m HT	Floating Roof
FB-0820	Aviation Gasoline	8m Dia. x 6m HT	Floating Roof
FB-0821	Jet Fuel Grade 'A'	8m Dia. x 6m HT	Floating Roof
FB-0822	Jet Fuel Grade 'A'	8m Dia. x 6m HT	Floating Roof
FB-0823	Kerosene	8m Dia. x 6m HT	Floating Roof

THE LUMMUS COMPANY LIMITED

LONDON

Rev. No. 0 Date 13-2-81

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

TANKAGE - AREA -08

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
FB-0824	Lt. Road Diesel	17.5m x 14m HT	Cone Roof
FB-0825	Lt. Road Diesel	17.5m x 14m HT	Cone Roof
FB-0826	Lt. Road Diesel	17.5m x 14m HT	Cone Roof
FB-0827	Marine Diesel	17.5m x 13m HT	Cone Roof
FB-0828	Marine Diesel	17.5m Dia. x 13m HT	Cone Roof
FB-0829	No. 6 Fuel Oil	15m Dia. x 14m HT	Cone Roof, Heater & Agitator
FB-0830	No. 6 Fuel Oil	15m Dia. x 14m HT	Cone Roof, Heater & Agitator
FB-0831	Bitumen	10m Dia. x 7m HT	Cone Roof, Heater & Agitator
FB-0832	Bitumen	10m Dia. x 7m HT	Cone Roof, Heater & Agitator
GA-0801	Hvy. Crude Feed Pump	$79.5m^3$/Hr 198m Hd 71 Kw	
GA-0801S	Spare Pump		
GA-0802	Med. Crude Feed Pump	$79.5m^3$/Hr x 198m Hd 71 Kw	
GA-0802S	Spare		

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

TANKAGE - AREA -08

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
GA-0803	Lt. Crude Feed Pump	79.5m^3/Hr x 198m Hd 71 Kw	
GA-0803S	Spare		
GA-0804	Atmos Resid. Feed Pump	42m^3/Hr x 90m Hd. 17 Kw	
GA-0804S	Spare		
GA-0805	Vac. Gas Oil Feed Pump	25m^3/hr x 120m Hd 14 Kw	
GA-0805S	Spare		
GA-0806	Hvy. A.G.O. Feed Pump	5m^3/hr x 120m Hd 3.5 Kw	
GA-0806S	Spare		
GA-0807	Lt. A.G.O. Feed Pump	25m^3/Hr x 120m Hd 14 Kw	
GA-0807S	Spare		
GA-0808	Vac. Residue Feed Pump	2m^3/hr x 440m Hd 4 Kw	

THE LUMMUS COMPANY LIMITED

LONDON

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

TANKAGE - AREA -08

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
GA-0808S	Spare		
GA-0809	Visbreaker L.G.O. Feed Pump	$2m^3$/Hr x 120m Hd 1.5 Kw	
GA-0809S	Spare		
GA-0810	Hvy. Naphtha Feed Pump	$25m^3$/hr x 80m Hd 9 Kw	
GA-0810S	Spare		
GA-0811	Reformate Blending Pump	$20m^3$/Hr x 50m Hd 5 Kw	
GA-0811S	Spare		
GA-0812	Total Lt. Gasoline Blending Pump	$20m^3$/Hr x 50m Hd 5 Kw	
GA-0812S	Spare		
GA-0813	Propane Loading Pump	$68m^3$/Hr x 254m Hd 70 Kw	
GA-0813S	Spare		

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

TANKAGE - AREA -08

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
GA-0814	Butane Loading Pump	68m^3/Hr x 254m Hd 70 Kw	
GA-0814S	Spare		
GA-0815	Aviation Gasoline Loading Pump	68m^3/Hr x 180m Hd 43 Kw	
GA-0816	Regular Gasoline Loading Pump	550m^3/Hr x 333m Hd 527 Kw	
GA-0817	Jet Fuel Loading Pump	550m^3/Hr x 333m Hd 527 Kw	
GA-0818	Kerosene Loading Pump	68m^3/Hr x 180m Hd 43 Kw	
GA-0819	Road Diesel Loading Pump	550m^3/Hr x 468m Hd 865 Kw	
GA-0820	Marine Diesel Loading Pump	550m^3/Hr x 468m Hd 865 Kw	
GA-0821	No. 6 Fuel Oil Loading Pump	550m^3/Hr x 367m Hd 684 Kw	

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

TANKAGE - AREA -08

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
GA-0822	Bitumen Loading Pump	$130m^3$/Hr x 523m Hd 315 Kw	
GA-0823	Diesel Transfer & Jet Mixing Pump	$550m^3$/Hr x 468m Hd 865 Kw	
GA-0824	Gasoline Transfer & Jet Mixing Pump	$550m^3$/Hr x 333m Hd 527 Kw	
GA-0825	Jet Fuel Transfer & Jet Mixing Pump	$68m^3$/Hr x 180m Hd 43 Kw	
PA-0801	Tel Dosing Set	200 Ltrs/Day	
PA-0802	Jet Fuel Dosing Set	200 Ltrs/Day	

THE LUMMUS COMPANY LIMITED

LONDON

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

WATER TREATMENT - AREA -12

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
GA-1201	Raw Water Pump	$50m^3$/Hr x 100m Hd 23 Kw	Vertical Centrifugal
GA-1201S	Spare		
FG-1201	Pressure Filter	$30m^3$/Hr; $12m^3/m^2$/Hr	Vertical Vessel
FG-1202	Pressure Filter	$30m^3$/Hr; $12m^3/m^2$/Hr	Vertical Vessel
FB-1201	Filtered Water Storage Tank	12.5m Dia. x 11m Ht	Cone Roof with Winterisation
GA-1202	Service Water Pump	20m/Hr x 100m Hd 9 Kw	Horizontal Centrifugal
GA-1202S	Spare		
GA-1203	Treatment Plant Feed Pump	$30m^3$/Hr x 100m Hd 13 Kw	Horizontal Centrifugal
GA-1203S	Spare		

THE LUMMUS COMPANY LIMITED

LONDON

Rev. No. O Date 13-2-81

Sheet 2 of 2

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

WATER TREATMENT - AREA -12

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
PA-1201	Water Treatment Package	$30m^3$/hr	
PA-1202X	Water Treatment Dosing Set	By Vendor	
GA-1204	Neutralised Effluent Pump	$5m^3$/Hr x 50m Hd 1 Kw	
GA-1205	Neutralised Sludge Pump	$1m^3$ / Hr x 100m Hd 0.5 Kw	
FB-1207	Treated Water Storage Tank	10m Dia. x 10m Ht	Cone Roof Internally Coated

THE LUMMUS COMPANY LIMITED

LONDON

Rev. No. 0 Date 13-2-81

Sheet 1 of 5

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

UTILITIES - AREA -11 FUEL OIL AND FUEL GAS

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
FB-1101	Fuel Oil Storage Tank	6m Dia. 6m Ht	Cone Roof with Heater & Agitator
EA-1101	Fuel Oil Suction Heater	27,000 Kcal/hr Des. Press 3.5 Kg/cm^2g	Steam Heater Shell/Tube
FG-1101	Fuel Oil Suction Filter	$4m^3/Hr$ Des. Press 3.5 Kg/cm^2G	Duplex
GA-1101	Fuel Oil Pump	$4m^3/Hr$ x 300m Hd 5 Kw	Pos. Disp.
GA-1101S	Spare	$4m^3/Hr$ x 300m Hd 5 Kw	Pos. Disp.
FA-1101	Fuel Gas K.O. Pot	1.5m Dia. x 3.5m T/T	

THE LUMMUS COMPANY LIMITED

LONDON

Rsv. No. O. Date 13-2-81

Sheet 2 of 5

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

UTILITIES - AREA -11 PLANT AND INSTRUMENT AIR

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
GB-1101	Plant & Instrument Air Comp.	2000 Nm^3/Hr 8.5 Kg/cm^2G 280 Kw	
GB-1101S	Spare		
FD-1101 X	Intake Filter/Silencer	By Vendor	
FA-1102 X	Air Inter Cooler	By Vendor	
FA-1103 X	Air After Cooler	By Vendor	
FA-1102	Air Receiver	5.5 m T/T x 3m Dia. 8.5 Kg/cm^2G	
KA-1101	Inst. Air Dryer	1000 Nm^3/Hr -55°C Dew Point at Atmos.	

THE LUMMUS COMPANY LIMITED

LONDON

Rev. No. O Date 13-2-81

Sheet 3 of 5

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

UTILITIES - AREA -11 STEAM AND POWER GENERATION

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
BF-1101	Steam Generator	250 Tonnes/Day 17 Kg/cm^2G	Package
GA-1102 X	Boiler F.W. Pump	By Vendor	
GB-1102 X	F.D. Fan	By Vendor	
BF-1102	Steam Generator	250 Tonnes/Day 17 Kg/cm^2G	Package
GA-1103 X	Boiler F.W. Pump	By Vendor	
GB-1103 X	F.D. Fan	By Vendor	
FA-1103	Intermittant B/down Drum	1.Om Dia. x 3m T/T D. Press 5.5 Kg/cm^2G	Vertical
FA-1104	Continuous B/down Drum	1.Om Dia. x 3m T/T D. Press 5.5 Kg/cm^2G	Vertical
EA-1102	Blowdown Cooler	O.1 kCals/Hr	
PA-1101	Emergency Generator	500 Kw	Diesel Drive

THE LUMMUS COMPANY LIMITED

LONDON

Rev. No. O. Date 13-2-81

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

UTILITIES - AREA -11 BOILER FEED WATER AND CONDENSATE

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
FG-1101	Deaerator	550 Tonnes/Day 5.5 Kg/cm^2G	
GA-1104	B.F.W. Pump	$10m^3$/Hr x 200m Hd 10 Kw	Horiz. Centrif.
GA-1104S	Spare		
PA-1102	Sulfite Dosing Set	250 Ltrs/Hr	
PA-1103	Phosphate Dosing Set	250 Ltrs/Hr	
GA-1105	Deaerator Make-up Pumps	$10m^3$/Hr x 50 m Hd 3 Kw	Horiz. Centrif.
GA-1105S	Spare		
FA-1105	Condensate Collection Pot	1.5m Dia. x 3m T/T 5.5 Kg/cm^2G	Vert.
FA-1106	Condensate Collection Pot	1.5m Dia. x 3m T/T 5.5 Kg/cm^2G	Vert.

THE LUMMUS COMPANY LIMITED

LONDON

Rev. No. 0 Date 13-2-81

Sheet 5 of 5

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

UTILITIES - AREA -11 BOILER FEED WATER & CONDENSATE & COOLING WATER

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
GA-1106	Condensate Return Pump	$8m^3$/Hr x 50m Hd 2.5 Kw	Horiz. Centrif.
GA-1106S	Spare		
GA-1107	Condensate Return Pump	$8m^3$/Hr x 50m Hd 2.5 Kw	Horiz. Centrif.
GA-1107S	Spare		
GA-1108	Closed Circuit C/W Circ. Pump	$150m^3$/Hr x 60mHr. 40 Kw.	Horiz. Centrif.
GA-1108S	Spare		
GA-1109	Sea Cooling Water Pump	150 m^3/Hr x 60m Hd 40 Kw	Vert. Centrif. on Jetty
GA-1109S	Spare		
EA-1103	Cooling Water Cooler	1.5×10^6 x Cal/Hr	Titanium Plate
EA-1103S	Spare		

THE LUMMUS COMPANY LIMITED

LONDON

Rev. No. O. Date 13-2-81

Sheet 1 of 1

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

FLARE SYSTEM - AREA -13

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
CB-1301	Flare Stack For Normal and Acid Gas	37,280 Kg/Hr 195,500 Kg/Hr Dia. 24" Ht. 60m	- Smokeless - Non-Smokeless Includes Mol. Seal
FA-1301	Knock-out Drum	4m Dia. x 12m T/T 3.5 Kg/cm^2G	
GA-1301	Slops Pump	$12m^3$/Hr. x 50m Hd. 2Kw	Horiz. Centrif.
PA-1301	Flame Front Gen.		For Flare

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

FIRE PROTECTION - AREA -14

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
FB-1401	Fire Water Storage Tank	10m Dia. x 10m Ht	Cone Roof with Steam Coil
FB-1402	Fire Water Storage Tank	10m Dia. x 10m Ht	Cone Roof with Steam Coil
GA-1401	Fire Pump	900 m^3/Hr x 175m Hd 700 Kw	Horiz. Centrif.
GA-1401S	Spare	900 m^3/Hr x 175m Hd. 700 Kw	Horiz. Centrif.
GA-1402	Fire Water Jockey Pump	20 m^3/Hr x 175m Hd 15 Kw	Horiz. Centrif.
GA-1403	Fire Pump - Sea Water	900 m^3/Hr x 175m Hd 700 Kw	Vert. Centrif. Located on Jetty
PA-1401	Fire Tender with Foam Making Equipment		
PA-1402	Fixed Foam Making Equipment	1200 m^3/Hr 1 Hr Capacity	At Jetty

THE LUMMUS COMPANY LIMITED

LONDON

Rev. No. O. Date 13-2-81

Sheet 1 of 1

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

LOADING FACILITIES - AREA -09

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
PA-0901A/B/C	10" Loading Arm	with P.E.R.C.	Crude Unloading
PA-0902	4" Loading Arm	With P.E.R.C.	L.P.G. Loading
PA-0903 A/B/C/ D/E	4" Loading Hose		Berth No. 1 Fuel Oil Loading
PA-0904 A/B/C/ D/E/F	4" Loading Hose		Berth No. 2 Fuel Oil Loading
PA-0905	8" Loading Hose		Berth No. 2 Bitumen Loading
PA-0906 A/B/C/D	4" Loading Hose		Berth No. 3 Gasoline Loading
PA-0907	Road Loading Terminal	2 bays 10 products	Includes meters
GA-0901	Slops Pump	2.5 m^3/Hr 100m Hd. 1.2 Kw	Inside FA-0901 Vert. Spindle
FA-0901	Slops Drum	1m Dia. x 2m T/T Atmos.	Located at Jetty Head

THE LUMMUS COMPANY LIMITED

LONDON

Rev. No. 0 Date. 13-2-81

Sheet 1 of 3

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

EFFLUENT TREATMENT - AREA -10

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
GA-1001	Emulsion Transfer Pump	125 m^3/Hr. 30m Hd. 17 Kw	Horiz. Centrif.
GA-1002	Emulsion Circulation Pump	125 m^3/Hr. 30m Hd 17 Kw	Horiz. Centrif.
GA-1002S	Spare		
GA-1003	Treated Emulsion Transfer Pump	68 m^3/Hr 20m Hd. 7 Kw	Horiz. Centrif.
GA-1004	Emulsion Slop Oil Pump	5 m^3/Hr 50m Hd. 1.2 Kw	Horiz. Centrif.
GA-1005 X	Bilge Water Slop Oil Pump	5 m^3/Hr. 50m Hd. 1.2 Kw	By Vendor with PA-1001
GA-1006 X	Bilge Water Sludge Pump	5 m^3/Hr. 50m Hd. 1.2 Kw.	By Vendor with PA-1001
GA-1007 X	Bilge Water Transfer Pump	68 m^3/Hr. 30m Hd. 10 Kw.	By Vendor with PA-1001
GA-1007S/X	Spare		
GA-1008 X	API Separator Sludge Pump	5 m^3/Hr. 50m Hd. 1.2 Kw	By Vendor with PA-1002
GA-1009 X	API Slop Oil Pump	5 m^3/Hr. 120m Hd. 1.2 Kw	By Vendor with PA-1002

THE LUMMUS COMPANY LIMITED

LONDON

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

Rev. No. O Date 13-2-81

Sheet 2 of 3

EFFLUENT TREATMENT - AREA - 10

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
GA-1010 X	D.A.F. Unit Recirc. Pump	64 m^3/Hr 120m Hd. 35 Kw	By Vendor with PA-1003
GA-1010 X/S	Spare		
GA-1011	D.A.F. Slop Oil Pump	5 m^3/Hr. 50m Hd. 1.2 Kw	Horiz. Centrif.
GA-1012	Sludge Transfer Pump	1.5 m^3/Hr. 50m Hd. 0.5 Kw	Horiz. Centrif.
GA-1012S	Spare		
GA-1013	Emergency Slop Oil Pump	5 m^3/Hr. 50m Hd. 1.2 Kw	Horiz. Centrif.
GA-1014	Slop Oil Transfer Pump	300 m^3/Hr. 100m Hd. 116 Kw	Horiz. Centrif.
FB-1001	Sludge Holding Tank	50 m^3 4m Dia. x 4m Ht	Cone Roof - Lined with Agitator
FB-1002	Emulsion Hold Tank	500 m^3 10 m Dia. x 9m Ht	Cone Roof
FB-1003	Emulsion Breaking Tank	500 m^3 10m Dia. x 9m Ht	Cone Roof
FB-1004	Emulsion Settling Tank	500 m^3 10 m Dia. x 9m Ht	Cone Roof with Floating Skimmer
FB-1005	Bilge Water Tank	1000 m^3 12.5 m Dia. x 11m Ht	Cone Roof with Floating Skimmer
FB-1006	Bilge Water Tank	1000 m^3 12.5m Dia. 11m Ht.	Cone Roof with Floating Skimmer
FB-1007	Slop Oil Tank	7155 m^3 25m Dia. x 17m Ht.	Cone Roof

THE LUMMUS COMPANY LIMITED

LONDON

Rev. No. 0 Date 13-2-81

Sheet 3 of 3

N.E.A. REFINERY FEASIBILITY STUDY: ICELAND

PRELIMINARY EQUIPMENT LIST

EFFLUENT TREATMENT - AREA -10

EQUIPMENT NUMBER	DESCRIPTION	SIZE CAPACITY POWER	REMARKS
A-1001	API Equilisation Basin	1040 m^3	
A-1002	Effluent Outlet Channel		With Emergency Skimmer
EA-1001	Emulsion Breaking Recirc. Heater	1 x 10^6 KCal/Hr. Des. Press. 5 Kg/cm^2G	Steam on Shell Side
PA-1001	Bilge Water T.P.I.	68 m^3/Hr. Inflow 50 ppm Oil at Outlet	Design by Vendor
PA-1002	API Oily Water Separator	123.5 m^3/Hr. Inflow 50 ppm Oil at Outlet	Design by Vendor
PA-1003	Dissolved Air Floatation Unit	128.5 m^3/hr inflow at 50 ppm oil 25 ppm oil at outlet	With floc. dosing set floc. scraper and aeration vessel
PA-1004	Sludge Thickener	Inflow 1.5 m^3/Hr at 4% solids by wt. 24 hours capacity outflow at 8% solids by wt.	Thickener to be lined
PA-1005	Rotary Vac. Filter	Inflow 1.2m^3/hr at 8% solids by wt. outflow at 50% solids by wt. 0.2 m^3/Hr. of sludge	
GD-1001	Agitator	5 Kw	Used on FB-1001

LUMMUS

WATER TREATMENT

Raw water will be pumped from a nearby lake at the approximate rate of 50 m^3/hr. Two 60% pressure filters will improve the water quality to a turbidity of 1 ppm as SiO_2 using a filtration rate of 30 m^3/m^2/hr.

The filtered water will be stored and distributed to the various users as required. These will include:-

Service water system,
Closed circuit water system make-up
Boiler feed water system make-up (via treating).

The filtered water storage tank will be sufficient for 24 hours capacity.

LUMMUS

BOILER FEED WATER SYSTEM

Make-up to the boiler feed water system shall be pumped from the filtered water storage tank at an estimated rate of 30 m^3/hr and passed through a secondary treatment unit to reduce the total hardness to 10 mg/l in terms of $CaCO_3$. The treated water shall be stored in a tank of 24 hours capacity from where it will be pumped as boiler feed water make-up to the Deaerator.

Deaeration of returned condensate and boiler feedwater make-up will be followed by chemical dosing. The boiler feed water quality at the boiler inlet shall conform with British Standard BS 2486 - "Treatment of Water for Land Boilers".

Feed water shall be of at least the following quality:-

pH	8.5 to 9.5
Oxygen as O_2	0.05 mg/l
No detectable oil	

Boiler feedwater will be pumped from the deaerator to the various process users and steam generators. It is expected that the Utility steam boilers will be of the package type with integral boiler feed water.

LUMMUS

STEAM GENERATION

Steam generation will be achieved by waste heat generation in the Process Units and by Utility Boilers in the central utilities area.

It is anticipated that steam will be distributed at the following two pressure levels:

- 17 $Kg/cm2g$ superheated
- 3.5 Kg/cm^2g superheated.

It is estimated that 200 tonnes of steam per day will be generated in the Process units of which 170 tonnes per day will be used or condensed in the Process units.

It is estimated that 330 tonnes per day will be used or condensed in the Utilities and Off-sites for tank heating, winterisation etc. Thus an estimated normal operating demand of 300 tonnes per day will be generated by utility boilers which will also be used for Plant start-up.

It is estimated that 50% condensate recovery will be achieved. The design contractor should consider the advisability of condensate recovery from tank heating coils and winterisation of offsites. Recovered condensate shall be collected in a local condensate flash vessel and pumped to the deaerator.

LUMMUS

COOLING WATER

The Refinery will maximise on air cooling, however, it is expected that a closed circuit cooling water system will be required for machinery cooling purposes. It is estimated that the cooling duty of this system will be 1.5 x 10^6 kCal/hr with a circulation rate of 150 m3/hr.

The system will be closed circuit with a small head tank receiving make-up water as required from the filtered water supply. The cooling water return will be passed through a plate type heat exchanger where heat will be rejected to a seawater stream. The sea cooling water which will be used only for this purpose will be provided by pumps at the jetty. However, the design contractor should study the economics of secondary air cooling instead of sea water cooling.

LUMMUS

PLANT AND INSTRUMENT AIR SYSTEM

It is estimated that the compressed air system should have the capacity to supply 1000 Nm^3/hr of Plant Air at 7 Kg/cm^2g and 1000 Nm^3/hr of Dry Instrument Air at 7 Kg/cm^2g. Both supplies should be provided by a common compressor and a common air receiver. The air receiver shall be designed to provide 50% of the full Instrument air demand for a period of 10 minutes with a 50% decrease in pressure.

The instrument air dryer shall provide a dew point of pressurised air 5°C less than the maximum ambient. It is estimated that this will correspond to a Free Dew Point of approximately -55°C.

LUMMUS

FUEL OIL AND FUEL GAS SYSTEMS

The estimated Refinery Fuel Oil consumption is 2 m^3/hr of No. 6 Fuel Oil or equivalent. The Fuel Oil system shall be designed for 100% recirculation. The Fuel Oil supply shall be taken from a heated tank of 2 days capacity. The tank level shall be maintained by the transfer of fuel oil from the refinery product storage.

It is estimated that 50% of the Refinery heating duty will be provided by fuel gas taken from the refinery and possibly augmented by vapourised excess L.P.G. The fuel gas will pass through a condensate K.O. Pot prior to distribution.

LUMMUS

POWER REQUIREMENTS

The Refinery will maximise on electric motor drivers for normal operation.

It is estimated that the absorbed Power requirement of the Process units will be 2680 Kw and 820 Kw for the Utilities and offsites. Thus the total refinery absorbed power is estimated to be 3500 Kw.

The maximum connected load is estimated to be 15,000 Kw.

The Power system will be fed from the grid at 132 KV through one or more transformers. A diesel driven emergency generator will be provided to ensure a supply to vital users in case of grid failure. This has been estimated at 500 Kw.

NITROGEN SYSTEM

The requirements for Nitrogen shall be established by the design contractor. The supply shall be provided by a pressurised liquid storage vessel and a vapouriser.

Collection and Pre-treatment

- Process Units

Liquid effluent from the Process units shall be separated into streams dependent on degree and type of contamination. Effluent containing chemical or toxic contaminants shall be pre-treated by settlement and or neutralisation. The neutralised liquid shall be discharged to the chemical sewer, or re-used if possible. The settled sludge shall be discharged as a separate stream.

Oily water effluent will include storm water run-off from paved areas and this will be routed to the oily water sewer.

Clean or uncontaminated effluent will be routed to the clean water sewer.

- Utilities

Liquid effluent from the central utilities area will be treated and separated into streams as for the Process effluent.

- Off-sites

Liquid effluent from the Off-sites will principally emanate from the storage area.

Water draw-off from the tanks shall be collected in a local draw-off sump and pumped as a separate stream to the emulsion breaking system.

Run-off from paved and bunded areas shall be routed to the oily water sewer together with the oily drains from off-site pump stations.

Slop oil shall be routed to the slop oil storage tank.

Bilge water from the jetty shall be routed to one of two bilge water tanks for settling, oil skimming and sludge removal.

Domestic Sewage shall be routed to local septic tanks. The neutralised liquor shall be routed to the outlet channel and the sludge shall be pumped intermittantly to the thickener.

EFFLUENT SYSTEM
- LIQUID EFFLUENTS

Effluent Treatment

Liquid effluent shall be treated in a two stage treatment system as shown on the Effluent System flow diagram. The first stage shall be oil separation in an A.P.I. or proprietary type of plate separator. The second stage shall be a proprietary design, dissolved air floatation type of unit.

Preliminary treatment of effluents containing oil/water emulsions shall be carried out prior to entering the first stage of treatment.

Separated sludges shall be thickened dried and disposed of by landfill.

All liquid effluent streams shall finally discharge to the effluent channel and pass an emergency skimmer prior to discharge from the site via the outfall to sea.

In designing the system the contractor shall consider the re-use of waste water - particularly in the process areas, such that the flow of liquid to the effluent treatment system is kept to a minimum.

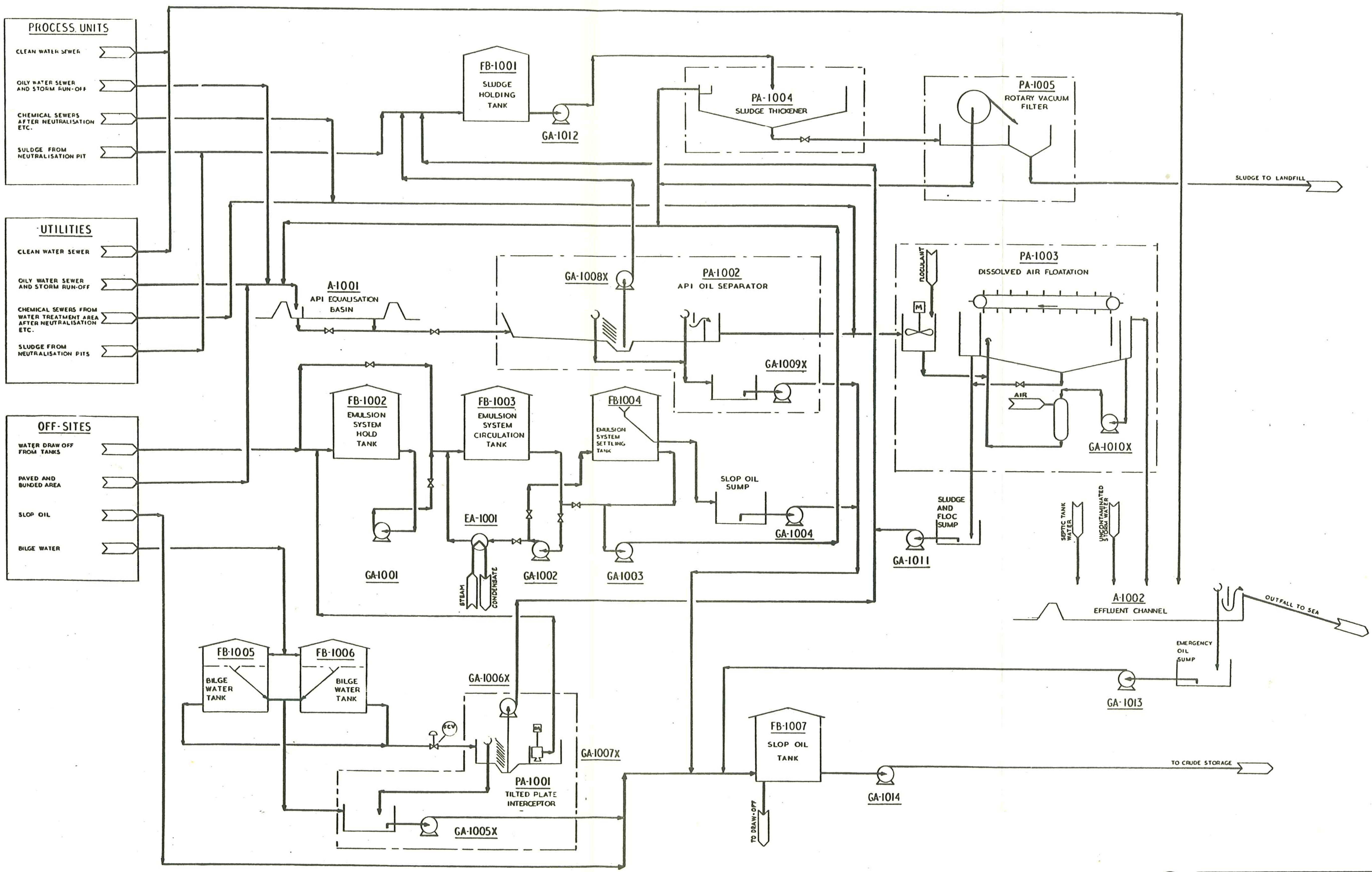
Plot space shall be allowed to accommodate a third stage treatment unit, should a change in process or local regulations cause the need to arise.

Standards of Treatment

The effluent treatment equipment shall be designed such that the effluent water from the second stage of treatment conforms with the "Concawe" standards.

The French regulations for type (a) new refineries shall apply as detailed in the "Concawe" "Report on Published Regulatory Guidelines of Environmental Concern to the Oil Industry in Western Europe" - latest issue. In addition, there shall be no visible oil and final sludge effluent shall be at least 50% solids by weight.

To ensure the proper operation of the effluent treatment equipment, the design contractor shall study the extent of winterisation required.



THIS DRAWING IS THE PROPERTY OF THE LUMMUS COMPANY, INCLUDING ALL PATENTED AND PATENTABLE FEATURES AND OR CONFIDENTIAL INFORMATION AND ITS USE IS CONDITIONED UPON THE USER'S AGREEMENT NOT TO REPRODUCE THIS DRAWING, IN WHOLE OR IN PART, NOR THE MATERIAL DESCRIBED THEREON NOR TO USE THE DRAWING FOR ANY PURPOSE OTHER THAN AS SPECIFICALLY PERMITTED IN WRITING BY THE LUMMUS COMPANY.

LUMMUS

THE LUMMUS COMPANY LIMITED LONDON
A MEMBER OF THE COMBUSTION ENGINEERING GROUP

TITLE NATIONAL ENERGY AUTHORITY - ICELAND
REFINERY FEASIBILITY STUDY
EFFLUENT TREATMENT SYSTEM

REV.	ISSUE DATE	DESCRIPTION	DRAWN	DESIGN OFFICE	PROJ ENG	CONTROL INSTR ENG	LEAD UTILITY ENG	LEAD PROCESS ENG	PROJECT ENG MANAGER	MANAGER OF ENG			CLIENT
0		FOR ESTIMATING PURPOSES ONLY	JCW	JCW									

SCALE — DWG No

EFFLUENT SYSTEM
- GASEOUS EFFLUENTS

Flue gases from furnaces, steam generators etc. shall be exhausted to atmosphere by individual stacks. The stacks shall be designed such that the ground level concentration of SO_2 is in accordance with the ultimate provisions of Table 1 of "Concawe" Report No. 3/72 - "The Control of SO_2 Emission in Western Europe".

Hydrocarbon and noxious vapours, collected from safety relief and blowdown devices shall be routed to the flare K.O. Drum and from there to an elevated flare.

The pressure relieving facilities shall be in accordance with the recommendations given in A.P.I. - RP 520 "Recommended Practices for the Design and Installation of Pressure Relieving Systems in Refineries" (Part I: Design; Part II: Installation), and A.P.I. - RP 521 "Guide for Pressure Relief and Depressuring Systems".

The Flare Stack shall be of the derrick supported type complete with molecular seal at the top, but preferably with no water seal at the base. Oxygen shall be excluded from the system by use of continuous gas purge and oxygen analysers.

The Flare shall be designed for smokeless burning at the normal or planned relief load or 15% of the maximum relief load, whichever is the lesser. Smokeless burning shall be achieved by the injection of steam.

The flare stack shall be designed to give a maximum radiation intensity of 2000 btu/ft^2hr at a radius of 45 m from the base of the stack. In addition, the ground level concentration of any H_2S which may be vented via the flare, shall not exceed 10 mg/m^3.

Fire Protection will generally be in accordance with the N.F.P.A. National Fire Codes except where it is specifically stated that other requirements will apply.

A continuously pressurised, underground piping network shall provide a supply of Firewater to a system of hydrants and fixed monitors at strategic locations.

The firewater network will normally be filled with filtered lake water drawn from one of the two firewater storage tanks, each of 30 minutes pump capacity.

The main will be pressurised by use of a continuously running jockey pump. A main fire pump shall be controlled to start automatically on loss of main pressure.

Two main firepumps (one spare) will be available to operate from the filtered lake water supply, a third pump being available to provide a secondary supply of seawater if required. Fixed hose reels will be available inside buildings, hose boxes containing 2½ inch hose will be strategically located around the plant.

A mobile fire tender will be available with a pump, foam making equipment and foam cannon.

Fixed foam making equipment will be installed for the automatic extinguishing of fires around the peripheral seals of floating roof tanks.

Fixed foam making equipment shall be provided at the jetty berths for the manual extinguishing of fires at the loading facilities.

Foam makers shall be provided in the fixed piping installation on each hydrocarbon storage tank of the cone roof type. Cone roof tanks containing hydrocarbon with a viscosity greater than 25 SSU at 50°C will use top side entry foam injection. Cone roof tanks containing hydrocarbon with a viscosity less than 25 SSU at 50°C will use subsurface foam injection.

Fixed spray water systems of the open pipe type shall be installed at the L.P.G. ang Gasoline loading berth and at the road loading terminal. A similar fixed spray water system shall be installed for cooling each of the L.P.G. Bullets. The coverage rate of the spray system shall be 10.2 Lt/min/m^2 of surface to be sprayed.

NOISE CONTROL

General

The proposed refinery shall be subject to reasonable and appropriate noise control measures in relation to criteria associated with the following:

Hearing Conservation	-	To protect plant personnel against permanent hearing damage.
Speech & Work Interference	-	To maintain practical noise levels in areas such as control rooms and plant offices.
Community Impact	-	To maintain acceptable noise levels in any surrounding community areas.

Practices and Procedures

The application of noise control to the proposed refinery shall be generally in accordance with the technical and procedural recommendations of the OCMA documents NWG 1 and NWG 3 referred to at the end of this section (VIII D) together with any specific requirements of the owner.

Scope of Work

The application of noise control involves two basic stages, details of the associated scope are given in OCMA specification NWG 1, Part 1.

Limits for the complete plant must be specified as a basis for design, such limits refer to accumulative in-plant and community noise levels.

- Due to employee health and public relations implications this stage is normally regarded as the owner's responsibility. In the absence of in-house expertise, the owner may require either the design contractor or an independant consultant to carry out this work on his behalf.

- Advice on this stage is provided in Part 1 of OCMA Publication NWG 3. OCMA Specification NWG 1 provides a model format for the associated design specification.

Limits for equipment and plant items shall be derived from limits specified for the complete plant. Appropriate noise emission statements shall be obtained from prospective equipment vendors. Noise control measures shall be applied to vendor's equipment and to general plant items as agreed by the owner.

- The engineering contractor will be responsible for this aspect of noise control work providing recommendations to the owner and ensuring that the resulting definition of requirements is satisfied.

- OCMA documents NWG 1 and NWG 3 provide advice on this stage of the work, a model format for the specification of equipment noise limits is included.

- The engineering contractor must advise the owner of any situation where the specified limits for the complete plant might be exceeded. Where for reasons of safety or practicability the application of noise reduction treatment is restricted the contractor shall provide details of the situation achievable by the best practicable means.

General Recommendations

Noise Limits for Complete Plant

See OCMA NWG 1 Appendix D and NWG 3 Part 1.

In-Plant Limits

- It is recommended that Absolute Limits AL.1 and AL.2 be set at 115 dB(A) and 120 dB(A) respectively.

- It is recommended that the General Work Area Limit G be set at 85 dB(A). This alternative is referred to in Section 1.3.2.2 of OCMA NWG 3.

Community Limits

- The situation of existing and prospective community areas should be examined on the basis of OCMA NWG 3 and BS 4142. If it is considered necessary to impose a community noise limit it should be advisable to establish existing noise levels. It is recommended that the owner should retain the services of an experienced consultant to carry out such work.

General

- Unless an unusually stringent community noise limit is specified it is expected that the General Work Area Limit be more stringent than Community Requirements. Special consideration may be required on air fin cooler fans with respect to community impact.

Appendix

The OCMA Publications on Noise NWG 1 and NWG 3.

- Oil Companies Materials Association;

  Specification No. NWG 1 (Rev. 2) March 1980
  - Noise Procedure Specification

  Publication No. NWG 3 (Rev. 2) September 1980
  - Guide to the Use of Specification NWG 1

- NWG 1 and NWG 2 were prepared by the Industrial Noise Committee of the Oil Companies Materials Association. The committee includes specialist engineers from a number of companies within the petroleum, petrochemical and allied industries.

- These documents provide a detailed basis for the application of noise control to an industrial development such as that proposed. They are of particular use as a reference basis where the owner does not have developed practices or relevant in-house expertise.

- The Contents and Foreword summaries of the two documents are attached to this section.

- NWG 1 and NWG 3 can be purchased from the publishers:-

  - Heyden & Son Limited
    Spectrum House,
    Hillview Gardens,
    London
    NW4 2JQ
    England.

PRODUCT LOADING AND JETTY FACILITIES

LUMMUS

Product Loading

The following products will be loaded to coastal barges via the Jetty Facilities:

Bitumen
No. 6 Fuel Oil
Marine Diesel
Road Diesel
Kerosene
Jet Fuel Grade 'A'
Regular Gasoline
Aviation Gasoline
Propane
Butane

Additional facilities will be provided to load all, or some of the above products into road tankers.

The storage capacity for each product will be approximately 15 days of refinery production for that product. Based on the assumption of continuous refinery production of each product, the loading facilities will be designed to export 15 days production in 15 days.

Loading Rates

The Product export parcel size shall be the size of the largest anticipated export vessel (ie. 2,000 tonne coastal barge) or the 15 day production rate - whichever is the smaller.

The loading rate shall be such that the export vessel may be turned round in 6 hours approximately.

The following table 'A' gives provisional loading rates and parcel sizes for each of the products considered. The design contractor should carry out a check using finalised process information. It has been assumed that L.P.G. will be exported in pressurised form.

TABLE 'A'

PRODUCT EXPORT

Product	Parcel Size Tonnes	Loading Rate m^3/hr	Loading Line Size
Bitumen	500	130	8"
No. 6 Fuel Oil	2,000	500	10"
Marine Diesel	2,000	550	2 x 6"
Road Diesel	2,000	550	2 x 6"
Kerosene	150	68	4"
Jet Fuel 'A'	2,000	550	8"
Regular Gasoline	2,000	550	8"
Aviation Gasoline	150	68	4"
Propane/Butane	100 each	70 each	4" each

FEED IMPORT

		Unloading	
Crude	50,000 max. 20,000 min.	2,000	18"

Feed Import Unloading Rates

The feed import unloading facilities shall be based on a maximum parcel size of 50,000 tonnes with the aim of turning round the import vessel in 3 days. The proposed unloading rate is shown in Table 'A'.

Jetty Facilities

Berthing facilities shall be designed to accommodate the required number of shipping movements in a 15 day period. The number of shipping movements shall be based on product carrier average size of 1,000 tonnes and a crude tanker size of 25,000 tonnes. To take account of late arrivals, bad weather, etc., 50% availability of berths should be considered.

Based on the currently identified import ant export requirements of the refinery it is estimated that three berths will be required each with loading and unloading facilities as identified in Table B.

Transfer of products from Jetty to ship shall be accomplished by way of loading hoses and loading arms as appropriate; details to be established by the design contractor after an investigation of the facilities available on the product barges.

Transfer of oils from ship to jetty shall be accomplished by swivel jointed loading arms.

It is not anticipated that any deballasting will be required for barges of 2,000 tonnes capacity, however, this should be re-investigated if larger product carriers are to be used. Facilities for the removal and treatment of ships' bilge water should be provided. Bunkering of ships may be achieved by use of the normal product loading facilities; a potable water supply line should be provided at each berth.

TABLE 'B'

USE OF BERTHING FACILITIES

Product	Max. Estimated Ship Movements /15 days	Berth 1	Berth 2	Berth 3
Bitumen	1	No facility	1	No facility
No. 6 fuel oil	4	2	2	No facility
Marine diesel	4.5	2	2.5	No facility
Road diesel	8	3	5	No facility
Kerosene	1	No facility	1	No facility
Jet fuel 'A'	3	No facility	No facility	3
Regular Gasoline	6	No facility	No facility	6
Aviation Gasoline	1	No facility	No facility	1
L.P.G.	1	No facility	No facility	1
<u>Feed</u>				
Crude	2	2	No facility	No facility

<u>Assumptions</u>:-

a) A 25,000 tonne crude oil tanker will occupy a berth for 2 days

b) Product barges do not arrive or leave between 8.00 pm and 8.00 am.

LUMMUS

Loading Lines

When the final loading rates have been confirmed, the design contractor should establish the economic line size or combination of line sizes to load each product. The currently proposed use of loading lines as shown in Table 'A', which shows all loading lines are dedicated with the exception of two common 6" lines for Marine and Road Diesel Loading. If a need is identified for the use of a line for two dissimilar products, the line shall be cleaned by pigging and not by the use of water separation.

Road Loading

The requirement that all products could, from time to time, be exported in road tankers, should be accommodated by the use of a 2 bay road loading terminal. The rate of loading into road tankers should be less than 68 m^3/hr and all loading lines should be dedicated.

Metering and Fiscalisation

Metering of imported refinery feed shall be achieved by gauging the receiving tank or tanks before and after unloading.

Metering of products exported by road tankers shall be achieved by use of an integral meter/visual register/ticket printer in each loading arm.

Metering of products exported by barge shall be carried out by a totalising meter as this may coincide with a road loading operation from the same tank. Consideration shall be given to the method of metering and meter proving to be used.

Loss Prevention

The following requirements shall be incorporated into the design of the loading and unloading facilities. These shall be in addition to the various requirements of the Statutory authorities and the design codes which will be applied.

a) Splash filling of tanks and vessels shall be avoided.

b) Flow velocities shall be restricted to lm/s when filling a tank, until the inlet nozzle is submerged.

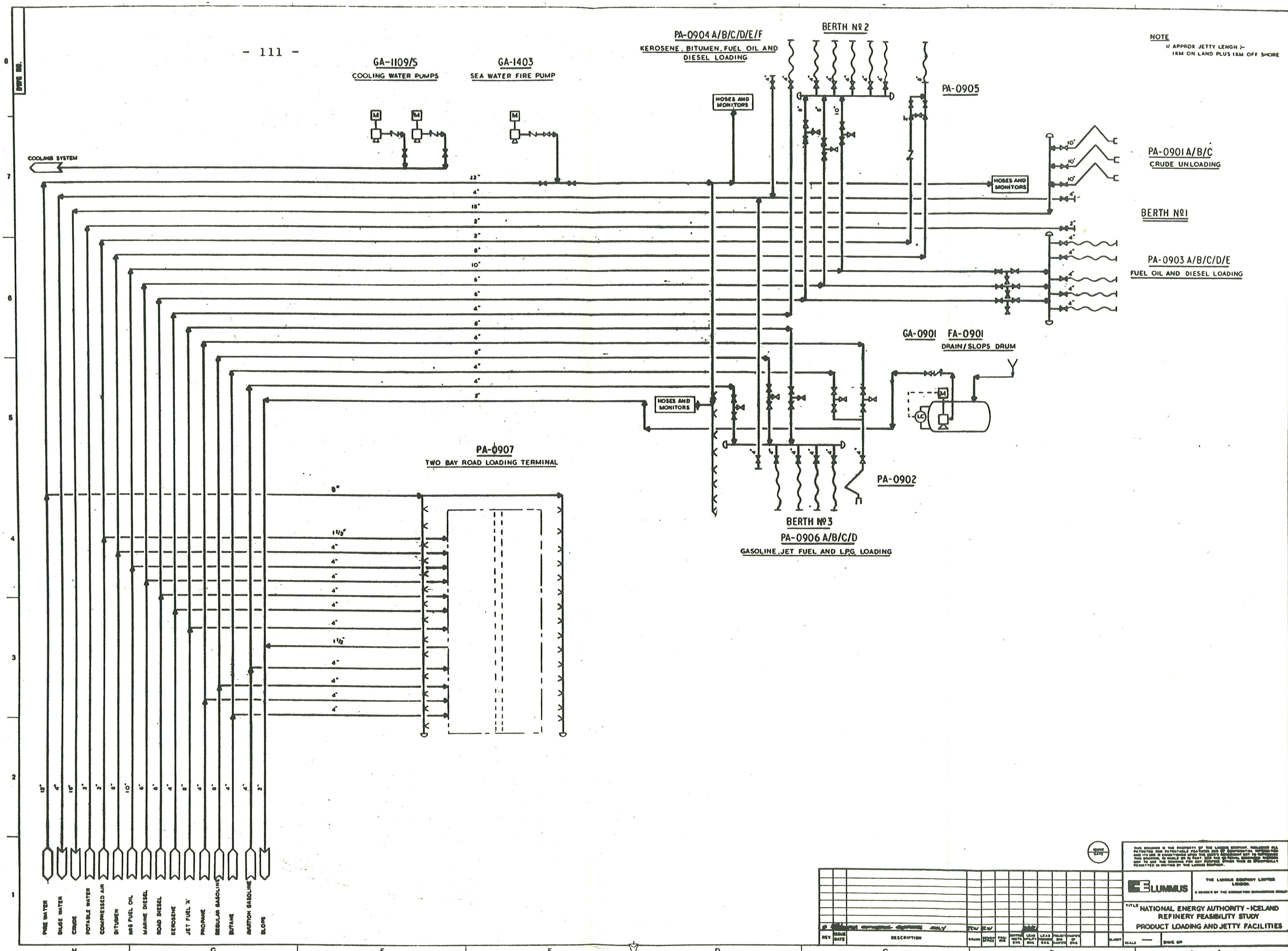
c) Water shall not be used to separate products in the same loading line or for line cleaning.

d) All slops and drains shall be collected into a central system and pumped to storage

e) A fixed spray water system shall be provided for loss prevention at the Gasoline and L.P.G. Loading Berth and at the Road Tanker Terminal.

The loading and unloading facilities should be in accordance with the Model Codes of Safe Practice of the Institute of Petroleum and the recommendations of the International Oil Tanker and Terminal Safety Guide (I.O.T.T.S.G).

Fire Protection Facilities shall be in accordance with the "National Fire Codes" of the N.F.P.A.


GA-1109/S
COOLING WATER PUMPS
GA-1403
SEA WATER FIRE PUMP
PA-0904 A/B/C/D/E/F
KEROSENE, BITUMEN, FUEL OIL AND DIESEL LOADING
BERTH № 2
PA-0905
NOTE
1/ APPROX JETTY LENGH :- 1KM ON LAND PLUS 1KM OFF SHORE
COOLING SYSTEM
HOSES AND MONITORS
PA-0901 A/B/C
CRUDE UNLOADING
BERTH №1
PA-0903 A/B/C/D/E
FUEL OIL AND DIESEL LOADING
GA-0901
FA-0901
DRAIN/SLOPS DRUM
LC
M
PA-0902
PA-0907
TWO BAY ROAD LOADING TERMINAL
BERTH №3
PA-0906 A/B/C/D
GASOLINE, JET FUEL AND LPG LOADING
FIRE WATER
BILGE WATER
CRUDE
POTABLE WATER
COMPRESSED AIR
BITUMEN
NO6 FUEL OIL
MARINE DIESEL
ROAD DIESEL
KEROSENE
JET FUEL 'A'
PROPANE
REGULAR GASOLINE
BUTANE
AVIATION GASOLINE
SLOPS
LUMMUS
THE LUMMUS COMPANY LIMITED LONDON
NATIONAL ENERGY AUTHORITY - ICELAND
REFINERY FEASIBILITY STUDY
PRODUCT LOADING AND JETTY FACILITIES
REV.
ISSUE DATE
DESCRIPTION

Administrative, Control Room and Laboratory Facilities

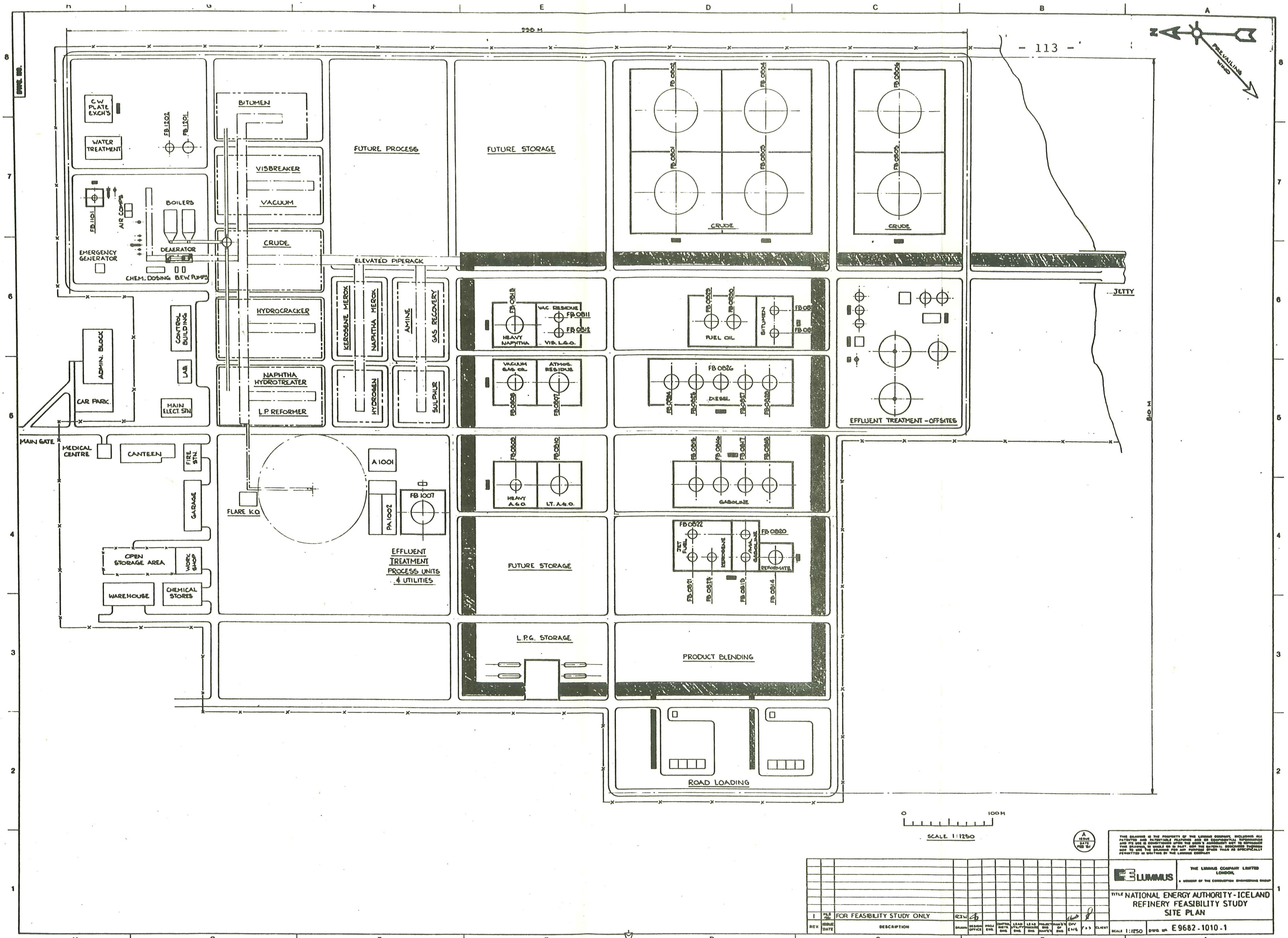
Process and Utility control functions shall in general be performed from the central control room. However, local controllers will be used on control loops where minimal operator attention is required. Mechanical equipment systems such as compressors or filters will have local control panels with malfunction alarms in the main control room.

It is anticipated that blending, loading and unloading operations will be controlled from the Shipping/Tankage Pump house. Tank level instrumentation will be duplicated in the main control room.

Offfices, lockers and operators changing rooms and showers shall be provided as part of the control building.

An adjacent laboratory building will be provided and equipped to check the quality and composition of feeds, intermediate streams and products. Equipment shall also be provided to check chemical and water qualitites. The laboratory shall be in accordance with the Institute of Petroleum Refinery Safety Code. In addition local analyser houses will be provided at various locations around the plant. It is estimated that the laboratory building will provide approximately 180 m^2 of floor area divided into several rooms with additional toilet and changing facilities.

A separate administrative and reception building shall be provided. The size of this building and the facilities required will be decided in the course of discussions with the client.



230 M
810 M
PREVAILING WIND
N
C.W. PLATE EXCH'S
WATER TREATMENT
FB 1202
FB 1201
FB 1101
AIR COMPS
BOILERS
EMERGENCY GENERATOR
DEAERATOR
CHEM. DOSING
B.F.W. PUMPS
BITUMEN
VISBREAKER
VACUUM
CRUDE
HYDROCRACKER
NAPHTHA HYDROTREATER
L.P. REFORMER
FUTURE PROCESS
FUTURE STORAGE
ELEVATED PIPERACK
KEROSENE MEROX
NAPHTHA MEROX
AMINE
GAS RECOVERY
HYDROGEN
SULPHUR
CONTROL BUILDING
LAB
ADMIN. BLOCK
CAR PARK
MAIN ELECT. STN
MAIN GATE
MEDICAL CENTRE
CANTEEN
FIRE STN.
GARAGE
FLARE K.O.
A 1001
PA 1002
FB 1007
EFFLUENT TREATMENT PROCESS UNITS & UTILITIES
OPEN STORAGE AREA
WORK SHOP
WAREHOUSE
CHEMICAL STORES
CRUDE
HEAVY NAPHTHA
VAC RESIDUE
FB 0811
FB 0812
VIS. L.G.O.
VACUUM GAS OIL
ATMOS. RESIDUE
FUEL OIL
BITUMEN
FB 0826
DIESEL
HEAVY A.G.O.
LT. A.G.O.
GASOLINE
EFFLUENT TREATMENT - OFFSITES
JETTY
FUTURE STORAGE
FB 0822
FB 0820
JET FUEL
KEROSENE
AVIAL GASOLINE
REFORMATE
FB 0821
FB 0819
FB 0814
L.P.G. STORAGE
PRODUCT BLENDING
ROAD LOADING
0
100 M
SCALE 1:1250
ISSUE DATE FEB '81
1
FOR FEASIBILITY STUDY ONLY
REV.
ISSUE DATE
DESCRIPTION
DRAWN
DESIGN OFFICE
PROJ. ENG.
CLIENT
LUMMUS
THE LUMMUS COMPANY LIMITED LONDON
TITLE NATIONAL ENERGY AUTHORITY - ICELAND
REFINERY FEASIBILITY STUDY
SITE PLAN
SCALE 1:1250
DWG. No. E 9682-1010-1

DATA FOR ECONOMIC EVALUATION

LUMMUS

INSTALLED COSTS OF PROCESS PLANTS

	U.S. Dollars (Millions)	
	Case I - IV *	Case V **
Crude Unit	7.8	7.8
Vacuum Unit	5.0	2.5 (Vacuum Flasher)
Naphtha HDS + Catalytic Reformer	7.8	7.8
Hydrocracker	13.0	-
Visbreaker	4.0	-
LC-Finer	-	33.0
Gas Oil HDS	-	3.6
Sulphur Plant	0.8	2.0
Merox Unit (two)	1.2	1.2
Bitumen Plant	1.0	1.0
Gas Recovery	2.5	2.5
Sour Water Stripper and Amine Treating	2.9	2.9
Hydrogen Plant	4.0	6.2
Total Installed Cost (TIC)	50.0	70.5

These costs are based on U.S. Gulf Coast prices as on January 1981.

Estimated cost based on U.K. prices would be around 55.0 and 78.0 million dollars.

* Refinery Scheme for light and medium crudes

**Refinery scheme for heavy crude and residue feed.

INSTALLED COSTS OF STORAGE AND OTHER OFFSITES FACILITIES

Offsites facilities include,

Crude,
Intermediate and finished product storage and pumps,
Water treatment facilities,
Effluent treatment facilities,
Steam generation,
Flare System and Stack

Total Installed Cost (TIC) 47.0 million U.S. Dollars

This cost is again based on U.S. Gulf Coast prices as on January 1981, the estimated cost based on U.K. prices would be around 52.0 million Dollars

Total Installed Cost (TIC) for

Product loading and jetty facilities including piping 18.0 million U.S. Dollars

This is again based on U.S. Gulf Coast prices as on January 1981 and the estimated cost on a U.K. basis would be around 20.0 million U.S. Dollars

TIC for whole grass-root refinery complex:

Process plants (ISBL)	50.0	
Offsites facilities (OSBL)	47.0	
Product loading and Jetties	18.0	
	115.0	million U.S. Dollars

TIC based on U.K. prices would be as on January 1981. 127.0 million Dollars

MANPOWER REQUIREMENT

		Foreman	Senior Operator	Operator
Area I	Crude Vacuum Visbreaker Bitumen	1	3 2	2
Area II	Hydrocracker Hydrogen and Gas recovery	1	3	2
Area III	Reformer, HDS and Merox	1	3	2
Area IV	Utilities	1	3	1
		4	14	7

(Total for 4 shifts - 100)

		Foreman	Senior Operator	Operator
Area V	Storage and Shipping	1	2	1

(Total for 3 shifts only - 12)

Total Manpower Requirement - 112

DATA FOR ECONOMIC EVALUATION

LUMMUS

COST OF CRUDE

The cost of crude is based on Government Contract prices average for January 1981 as published in Platt's Oilgram.

Crudes	Government Contract Price, $/Barrel	Estimated Freight Cost from source to Iceland $/Barrel
Light Arabian (Saudi Arabia)	32.0	2.23
Heavy Arabian (Saudi Arabia)	31.0	2.27
Ekofisk (North Sea)	40.15	0.54
Ninian (North Sea)	38.95	0.54
Romashkinskaja (USSR export)	34.2	1.60

DATA FOR ECONOMIC EVALUATION

LUMMUS

PRODUCT VALUES

The product values are calculated from their respective Rotterdam Spot Market prices plus the estimated freight costs from Rotterdam to Iceland, average for the month of January 1981 as published by Platt's Oilgram.

	Barges FOB Rotterdam $/MT	Estimate of Freight Cost to Iceland, $/MT
Aviation and Export Gasoline (priced as Premium gasoline in Platt's Oilgram)	379.0	13.0
Motor Gasoline (Regular)	359.0	13.0
Kerosene and Jet Fuel	348.0	13.0
Marine and Road Diesel (priced as Gas Oil)	302.0	13.0
Fuel Oil (3.0% Sulphur)	216.0	8.0
Fuel Oil (1.0% Sulphur)	238.0	8.0
Bitumen (priced as 3% S Fuel oil)	216.0	8.0

The following products are priced in accordance with the bulk selling prices in the U.K.

Propane	300 $/MT
Butane	320 $/MT
Sulphur	75 $/MT

Based on the above product values, product value margins are calculated for each case. This is the margin between the product values and the cost of the crude.

DATA FOR ECONOMIC EVALUATION

LUMMUS

PRODUCT VALUES

CASE I Ninian/Ekofisk (70/30 vol %) Blend

Feed Cost					$/day
Ninian Crude	9576 BPSD	@	39.49	$/Bbl	378,156
Ekofisk Crude	4104 BPSD	@	40.69	$/Bbl	166,992
			Total Feed Cost		545,148

Product Values

					$/day
Butane	40 MT/SD	@	320	$/MT	12,800
Aviation Gasoline	9 MT/SD	@	392	$/MT	3,528
Export Gasoline	24 MT/SD	@	392	$/MT	9,408
Regular Gasoline	364 MT/SD	@	372	$/MT	135,408
Kerosene and Jet Fuel	185 MT/SD	@	361	$/MT	66,785
Marine and Road Diesel	818 MT/SD	@	315	$/MT	257,670
Fuel Oil 1%s	267 MT/SD	@	246	$/MT	65,682
Bitumen	45.5 MT/SD	@	224	$/MT	10,192
			Total Product Value		561,473

Product Value Margin = 16,325 $/day

= 5,387,250 $/Year

CASE II.a   Light Arabian Crude

Feed Cost

						$/day
Light Arabian Crude	13,600	BPSD	@	34.23	$/Bbl	465,528

Product Values

						$/day
Sulphur	13	MT/SD	@	75	$/MT	975
Propane and Butane	52	MT/SD	@	300	$/MT	15,600
Aviation Gasoline	9	MT/SD	@	392	$/MT	3,528
Regular Gasoline	364	MT/SD	@	372	$/MT	135,408
Kerosene and Jet Fuel	185	MT/SD	@	361	$/MT	66,785
Diesel Oil	818	MT/SD	@	315	$/MT	257,670
Fuel Oil (3.2%s)	284	MT/SD	@	224	$/MT	63,616
Bitumen	45.5	MT/SD	@	224	$/MT	10,192
				Total Product Value		553,774

Product Value Margin = 88,246 $/day

= 29,121,180 $/Year

LUMMUS

PRODUCT VALUES

CASE II.b Romashkinskaja (USSR) Crude

Feed Cost

						$/day
Russian Export Crude	13430	BPSD	@	35.8	$/Bbl	480,794

Product Values

						$/day
Sulphur	12	MT/SD	@	75	$/MT	900
Butane	40	MT/SD	@	320	$/MT	12,800
Aviation Gasoline	9	MT/SD	@	392	$/MT	3,528
Export Gasoline	364	MT/SD	@	372	$/MT	135,408
Kerosene and Jet Fuel	185	MT/SD	@	361	$/MT	66,785
Diesel Oils	818	MT/SD	@	315	$/MT	257,670
Fuel Oil(3.0%s)	267	MT/SD	@	224	$/MT	59,808
Bitumen	45.5	MT/SD	@	224	$/MT	10,192
					Total Product Value	554,931

Product Value Margin = 74,137 $/day

= 24,465,210 $/Year

PRODUCT VALUES

CASE III Light Arabian/Ekofisk (70/30 vol %) Blend

Feed Costs					$/day
Lt. Arabian Crude	9506 BPSD	@	34.23	$/Bbl	325,390
Ekofisk Crude	4074 BPSD	@	40.69	$/Bbl	165,771
			Total Feed Cost		491,161

Product Values					$/day
Sulphur	12 MT/SD	@	75	$/MT	900
Butane	26 MT/SD	@	320	$/MT	8,320
Aviation Gasoline	9 MT/SD	@	392	$/MT	3,528
Export Gasoline	25 MT/SD	@	392	$/MT	9,800
Regular Gasoline	364 MT/SD	@	372	$/MT	135,408
Kerosene and Jet Fuel	185 MT/SD	@	361	$/MT	66,785
Diesel Oils	818 MT/SD	@	315	$/MT	257,670
Fuel Oil (2.5%s)	267 MT/SD	@	224	$/MT	59,808
Bitumen	45.5 MT/SD	@	224	$/MT	10,192
			Total Product Value		552,411

Product Value Margin = 61,250 $/day

= 20,212,500 $/Year

DATA FOR ECONOMIC EVALUATION

LUMMUS

PRODUCT VALUES

CASE IV Light Arabian/Ekofisk/Heavy Arabian (40/40/20 vol %)

Feed Cost

						$/day
Lt. Arabian Crude	5504	BPSD	@	34.23	$/Bbl	188,402
Ekofisk Crude	5504	BPSD	@	40.69	$/Bbl	223,958
Hy. Arabian Crude	2752	BPSD	@	33.27	$/Bbl	91,559
				Total Feed Cost		503,919

Product Values

						$/day
Sulphur	13	MT/SD	@	75	$/MT	975
Butane	40	MT/SD	@	320	$/MT	12,800
Aviation Gasoline	9	MT/SD	@	392	$/MT	3,528
Export Gasoline	36	MT/SD	@	392	$/MT	14,112
Regular Gasoline	364	MT/SD	@	372	$/MT	135,408
Kerosene and Jet Fuel	185	MT/SD	@	361	$/MT	66,785
Diesel Oils	818	MT/SD	@	315	$/MT	257,670
Fuel Oil (3.0 %s)	267	MT/SD	@	224	$/MT	59,808
Bitumen	45.5	MT/SD	@	224	$/MT	10,192
				Total Product Values		561,278

Product Value Margin = 57,359 $/day

= 18,928,460 $/Year

DATA FOR ECONOMIC EVALUATION

LUMMUS

OPERATING COSTS

Operating Costs of the refinery scheme for Case I to IV would be as follows:

	$/Year
Catalysts and Chemicals @ 750 $/day	247,500
Utilities (This is taken as electricity costs only. Fresh water drawn from the lake is assumed to be free of cost. All other utility costs are reflected as power consumption only. Continuous power consumed in the refinery would be 3500 KWH/Hr, based on $0.02/KWH electricity cost therefore the total power cost would be 1680 $/day	554,400
Direct Labour Costs	
112 men @ 25000 $/year (assumed)	2,800,000
Supervision and Overheads	
(150% of direct labour)	4,200,000
Maintenance (ISBL) @ 4% on ISBL TIC	2,000,000
(OSBL) @ 2% on OSBL TIC	1,300,000
Depreciation (straight line relation based on 15 years plant life ie. @ 6.7% on Total TIC)	7,705,000
TOTAL OPERATING COSTS	18,806,900

LUMMUS

GROSS MARGINS

This is the margin between Product Value and cost of feed plus the operating costs but excluding all the financial charges like interest on capital, taxes, insurance charges etc. These are to be estimated by N.E.A.

		$/annum
Case I	Ninian/Ekofisk Crude Blend	
	Product Value Margin	5,387,250
	minus Operating Costs	18,806,900
	Gross Margin	-13,419,650
Case II.a	Light Arabian Crude	
	Product Value Margin	29,121,180
	minus Operating Costs	18,806,900
	Gross Margin	10,314,280
Case II.b	Romashkinskaja Crude	
	Product Value Margin	24,465,210
	minus Operating Costs	18,806,900
	Gross Margin	5,658,310
Case III	Lt. Arabian/Ekofisk Blend	
	Product Value Margin	20,212,500
	minus Operating Costs	18,806,900
	Gross Margin	1,405,600
Case IV	Lt. Arabian/Ekofisk/Hy. Arabian Blend	
	Product Value Margin	18,928,470
	minus Operating Costs	18,806,900
	Gross Margin	121,570

PREMIUM PRICE FOR IMPORTED F-5 FUEL OIL

All the Gross Margin calculations (Section XI F) are based on the spot market price for similar fuel oil to that which will be produced in the refinery and therefore no premium values have been added to the fuel product value in the refinery product value margin calculations.

This was done in order to reflect more realistic product values for the proposed refinery scheme. If the 17 $/metric ton, presently being paid for importing superior grade, low pour point F-5 fuel oil is added to the value of the final oil produced in the refinery, the Product Value Margin and, consequently, the Gross Margins will go up by around 1.5 million dollars.

This added premium value is calculated as follows:

Additional 17 $/MT value added to 267 MT/SD fuel oil produced in the refinery

≐ 17 $/MT x 267 MT/SD x 330 days

= 1,497,870 $ per annum.

Introduction

If it is decided after the Stage 2 study to implement the design, engineering, procurement and construction of this refinery, Lummus with its extensive refinery experience both worldwide and in Europe is well placed to manage the entire execution of the project.

Although an extensive assessment has not been made of the project or construction requirements, certainly the following section should show the areas of project and construction management which together with technical integrity and experience forms the core of a successful project.

Project Management and Organisation

The function of project management is essentially a matter of communications between the client and those responsible for job execution. The Project Manager is the centre of this communications network. He obtains from the client a number of criteria as overall project requirements. These include the basic design objectives, the total project time and the maximum costs based on the Definitive Estimate prepared by his team. He transmits these criteria to the execution group in the form of project procedures, contract requirements, manhour budgets, cost budgets and the project schedule.

Execution

In order to ensure these challenging objectives are successfully met, careful planning and organisation in the initial stage of the project is vital. Such planning must include consideration of all the influencing factors known and envisaged at the time. Our approach to the Management of Projects is highlighted in the following key features:

- an experienced Project Manager committed full time and with full responsibility for the project planning and execution.

- a project organisation defined at the start and assembled from experienced Lummus staff with the requisite skills and experience in the design and engineering of the technology areas being considered.

- a complete and thorough project plan and detailed schedules.

- early establishment of budgets adequately detailed for cost control.

- an effective system of day-to-day monitoring of costs and progress to meet the budget and schedule.

Control

The key function of project management is to control the project in terms of quality, time span and cost. In these days of rapid inflation, control is more important that ever before, and Lummus continuously strives to improve its techniques in this area.

A strong organisation will be established to continually monitor hours, commitments and expenditures, work progress, work scope and design integrity. Project progress and costs are compared against this plan to determine significant deviations or trends. From this trend analysis, project management, initiates quickly any corrective action required. Lummus system of fast measurement and reporting permits corrective action when it can be effective.

The following paragraphs outline the major methods by which such controls are executed during the project.

Quality Control

Engineering quality is primarily maintained by the use of design standards which reflect experience gained over many years, and by maintaining engineering departments fully staffed with specialists in their particular disciplines. Computer design programs developed over a long period also assist materially in maintaining the quality of designs. Frequent management and screening reviews are held to ensure that such standards are consistently applied and additionally meet client requirements.

Likewise, in the procurement area, quality is maintained by buying to established standards and by regularly inspecting equipment in vendor's works. Welding procedures for pressure vessels are reviewed and approved by a Lummus specialist and certain items, such as boilers and centrifugal compressors, are inspected by a representative from the engineering as well as the inspection department.

The quality of construction work is ensured by using Lummus' standards and by employing experienced craft supervisors as well as field engineers. Work which is sub-contracted is also inspected by Lummus craft supervisors to ensure the same high standards.

Schedule Control

Good control of manhours and time span is achieved firstly by detailed planning and scheduling, secondly by closely monitoring performance against the schedule and thirdly by swift action to correct any delays before they become serious. A master schedule is developed under the Project Manager's guidance and reviewed with Lummus management and the client. From this, detailed schedules are developed which establish target dates for each drawing and equipment requisition. Budget manhours are then allocated to each department based on these detailed schedules. Every week the Project Manager and his staff review the schedules, measure the past week's progress and plan work for the following two weeks. Progress is continuously measured against schedule and progress reports, showing both planned and achieved work are issued. A computerised reporting system provides early warning of any deviation from the schedule so that the Project Manager can take prompt action. Delivery of materials from vendors is urged by expeditors who report each month to the Project Manager via a Project Procurement Coordinator. Each month a material status report is prepared detailing the status of all equipment and materials on order.

Cost Control

When Lummus manages a complete project, cost control begins with the project definition and is continued through all subsequent stages of the project. It is not exercised only by the Project Manager and Cost Control Engineer but is the responsibility of technical and engineering staff during all stages of the project. It begins with conceptual process design and plant layout and continues through detailed engineering, purchasing and construction.

Effective control of project costs is achieved by applying proven home office procedures, purchasing practices and project mangement techniques, and by constantly monitoring the Client performance against budget. Good relations between Client and Lummus are a vital part of cost control. Decisions must often be made quickly to minimise delays and costs. Often, in the early stages of a project, only an approximate estimate of the plant cost is available to act as a guide. Once the process design has been set therefore, and the layout arranged in the most economical manner, a detailed estimate is made, based on P & I layout and equipment specifications. This estimate is then used by the Project Manager to control cost expenditure from that point on. Budgets are set for engineering and procurement and detailed schedules are developed to control manhour budgets.

Before developing this detailed estimate however, the design is formally screened by competent engineers of all disciplines. The engineering review and screening is immediately followed by a financial review to ensure minimum plant investment and operating costs consistent with good engineering practice. Expenditure on equipment is controlled by competitive bidding procedures and comparisons of bids against estimate. Commodity items are controlled by analysis and forecasting of unit costs, continuously monitoring quantities against detailed estimates.

In the field, construction progress and expenditures are again controlled by constantly comparing progress against a detailed plan and budget. Lummus construction specialists determine the most economic method of building and erecting large vessels, transporting heavy equipment to site and performing major lifts. They also develop detailed planning schedules to control essential pieces of work. Competitive bids are obtained from sub-contractors where possible and their progress is reviewed and controlled at weekly meetings. Performance in the field is controlled by the Construction Manager who reports progress weekly to the Project Manager.

Construction Execution

Our normal approach to any project being built in an area where there are limitations on resources and data on major installations works is to instigate a site survey, conducted by a team consisting of senior construction and project personnel. The teams' efforts would be directed into two channels:-

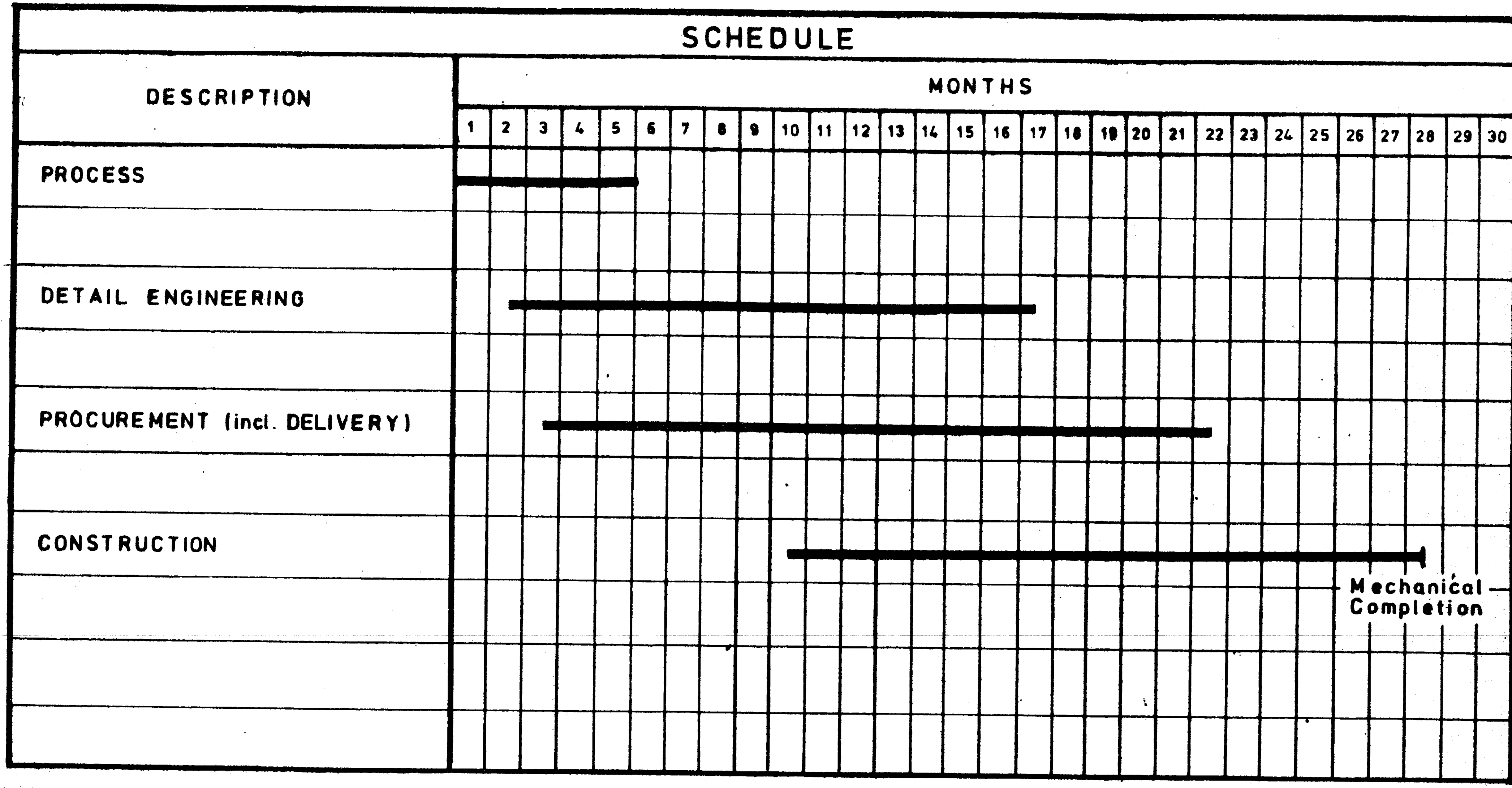
- Initial research in their home country to collect statistical and governmental data, interview contractors and associations who have been involved in the area, and review projects of a similar nature (if any). Based upon this data, a plan for a site survey would be formulated.

- The site visit and survey would be conducted to determine the construction facility requirements, the availability of local fabricators, contractors, skilled and unskilled labour, construction supplies and materials. Interviews would be conducted with government bodies on labour and other laws and the social impact of major installation works into the area. Based upon this site survey and preliminary project data regarding the scope of work, etc., a construction plan of execution would be formulated.

Dependent on the criteria listed above the refinery could either be built in the conventional manner or it may be considered that modularisation presents the better method of execution.

Lummus has experience of both methods of construction execution and is therefore well placed to provide the optimum execution plan and an experienced Construction Management Team.

Lummus can additionally provide Commissioning Assistance and can also train or provide operating and maintenance personnel.

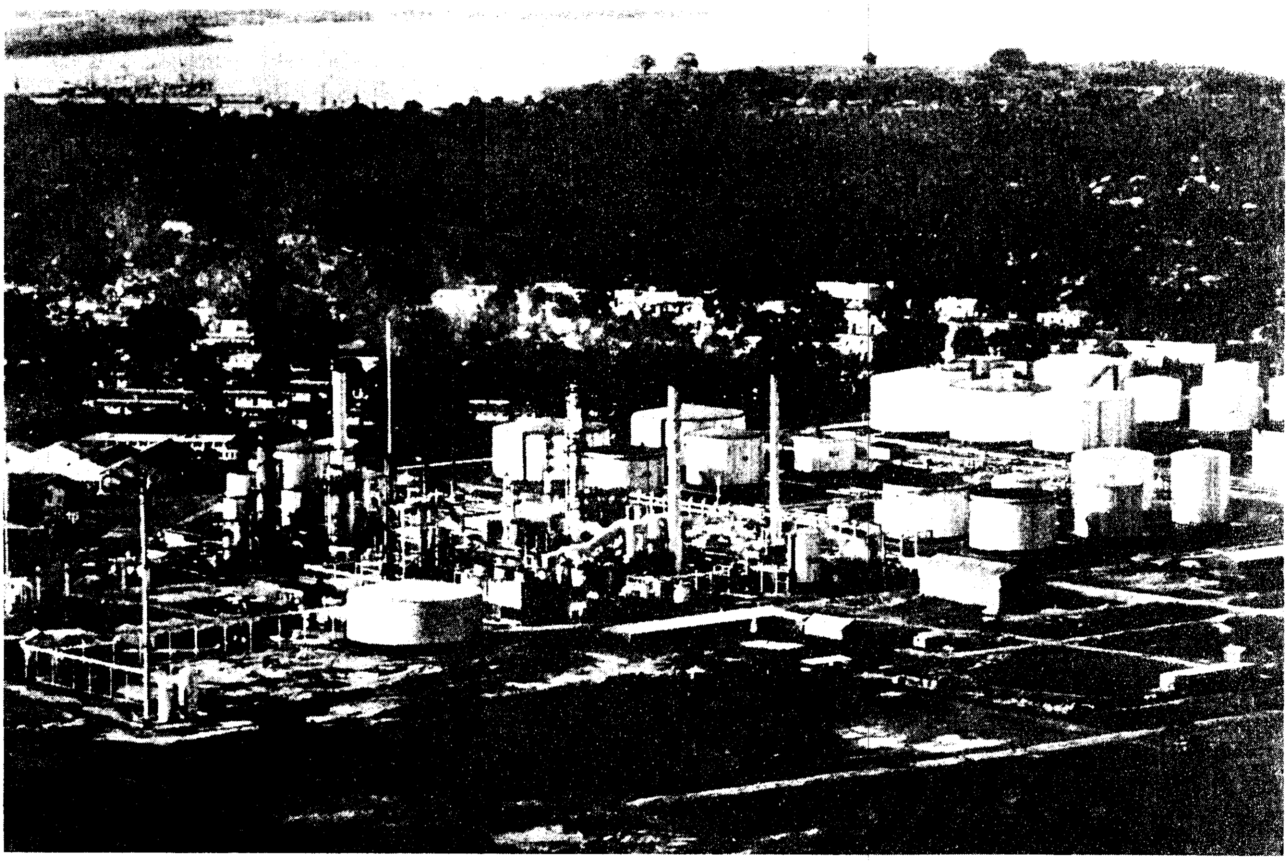


LUMMUS
THE LUMMUS COMPANY LIMITED
LONDON

REFINERY-ICELAND

NATIONAL ENERGY AUTHORITY
ICELAND

Date .... Sheet 1 of 1



**EAST AFRICAN OIL REFINERIES LTD.
MOMBASA REFINERY, KENYA
REFINERY EXPANSION**

The refinery expansion, an important addition to the EAOR existing installation, has boosted capacity by 65% to 86,000 barrels/day. Designed by Shell International Petroleum Maatschappij BV in The Hague, the expansion was engineered, procured and constructed by The Lummus Company Limited (LCL).

Work included a new crude distiller, naphtha hydrotreater, kerosene hydrotreater, platformer and stabiliser, LPG recovery unit, desalter and water stripper, water treatment and steam raising facilities, eleven new storage tanks, and a major loading system including a pipeline to Port Reitz.

On-time completion within 24 months was achieved mainly by local Kenya craftsmen, with only 10% of the work being performed by expatriates . . . . a record for local labour participation in a third-world process plant. Lummus set up an intensive training programme to make this possible.

MODULAR CONSTRUCTION

LUMMUS

A modular plant may be defined as one that has been designed and built in the form of prefabricated sub-assemblies in workshops which have the necessary equipment and experience for fabrication of this type of equipment and located in areas where skilled labour is available. These modules are then shipped to the construction site, where they are mounted on prepared foundations and inter-connected.

This type of engineering and construction has expanded extensively during the recent years and has now gained wide acceptance. It is especially attractive where the plant is to be erected in remote locations, where erection labour is in short supply and must be brought in or trained, and is subsequently therefore expensive. It has also been applied where climatic conditions are often very severe, which would result in low productivity.

Today, quite large modules can be erected, weighing up to 1500 tons with dimensions of 30 m x 30 m x 20 m height. There are many companies in Europe which have the experience and the facilities to manufacture and preassemble such modules.

Productivity in assembling plant modules in a workshop, under controlled conditions is always better than field construction productivity. Frequently, it results in investment cost reduction and always in improved completion dates and shorter start-up times.

It is impractical to predict potential savings to be achieved by adopting modular construction vs. field erection without knowledge of local conditions (site characteristics, labour availability).

Typically, from information on plants built, the savings can vary between 1 to 10% depending on the local situation. In any case, construction time can be reduced by several months.

To ascertain whether modular construction presents any advantages for this project, it will be necessary for a representative of Lummus' Construction Department to carry-out a survey of local conditions in Iceland particularly with regard to skilled labour availability. Only after a detailed investigation will it be possible to recommend the preferred solution.

Lummus has acquired extensive expertise in this type of construction having designed and built a number of modular plants as attested by the attached experience listing.

Lummus experience of pre-assembly and modularisation has been gained over the past 40 years. It started with skid-mounting of equipment and piping, limited by the size of units that could be transported by road or rail, for small process units for underdeveloped parts of the world where there was little construction infrastructure.

Examples of this are found in small refinery units built in the USA for Venezuela and Chile in the 1950's and a Pyrethrum Extraction Plant built in the UK and air-freighted to New Guinea for Albright and Wilson Ltd.

Since that time, the concept has grown until it is now considered normal practice to design and supply major items in pre-assembled units or modules. Such examples are cold boxes for ethylene plant chilling trains, containing brazed aluminium exchangers and all piping and instrumentation; lube and seal oil consoles for major compressors; modularised radiant and convection sections of large refinery and ethylene heaters; complete packaged hydrogen plants (one was recently supplied for Monsanto at the Seal Sands Nylon Intermediates Plant) and, at most locations where Lummus is responsible for the total grass roots complex, complete skid-mounted water treatment plants.

The current state-of-the-art is demonstrated by the offshore modules provided for North Sea oil production. These modules represent the maximum level of pre-fabrication and include a number of additional features.

Firstly, they are designed to be lifted into place with very large floating cranes and the structure has to stand the considerable forces exerted by the pad-eyes and slings. Secondly, they are normally stacked, so the structure of the lower modules is designed to carry another 1,000-1,500 ton module on top. Thirdly, they have to provide acceptable working conditions in a very hostile environment, so they are normally fully sheeted and provided with full heating and ventilating equipment.

Lummus experience of offshore modules includes the detailed engineering, procurement and construction supervision of topside facilities for the Chevron Central and Southern Platforms of the Ninian Field.

LUMMUS

PRE-ASSEMBLY

The most recent Lummus experience of pre-assembly is the award in 1977 of a multi-million dollar contract for a desalting project in Saudi Arabia for 22 separately located gas oil separation plants (GOSPS). These 22 site locations occupy an area of desert terrain 150 miles by 50 miles. The work content can be roughly divided; 40% for on-site modification of existing oil field separation equipment; 60% for the new water injection/desalting facilities.

The demands of a short schedule together with the need to minimise the site construction labour force were satisfied by modularising the similar areas of new equipment at each location and maximising the use of pre-assembled units (PAU's). Each GOSP contains 29 PAU's, making a total of 638 for all 22 sites. The project was engineered by the Lummus Hague Office, procured on a worldwide basis and the PAU's were fabricated in Japan and Italy.