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LIQUEFACTION OF COAL

DP/POL/82/002

Technical report: Process Development Unit (PDU)
Construction Progress and Coal Liquefaction
Process Technology Assessment *

Prepared for the Government of Poland
by the United Nations Industrial Development Organization (UNIDO)
acting as executing agency for the United Nations Development Programme

Based on the work of James J. Lacey,
Expert in the Construction of Process Development Units (PDU's)
and Coal Liquefaction Process Technology

United Nations Industrial Development Organization
Vienna, Austria

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RESTRICTED

December 15, 1986
English

LIQUEFACTION OF COAL
DP/POL/82/002/B/01/37
POLAND

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United Nations Industrial Development Organization
Vienna, Austria

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December 15, 1986
English

TRIP REPORT - POLAND

ABSTRACT

Project DP/POL/82/002/B/01/37
November 17-27, 1986

This report covers a trip which included ten (10) days in the Katowice, Poland area for the purpose of assessing coal liquefaction process technology and process development unit construction progress. The purpose was to assist the government of Poland in its investigations of coal liquefaction. The work was done for the Central Mining Institute and its subsidiary the Institute of Carbochemistry in Tychy-Wyry. Advice was rendered on basic technical problems of experimental units for direct coal hydrogenation. Construction progress was evaluated as regards coal grinding, slurry preparation, solids separation, and materials of construction. The report is prepared in daily journal form with an introduction, conclusions and recommendations, regarding future work. Wide ranging discussions with many Polish workers are summarized with particular emphasis on their completed 80.0 kg/hr process development unit, which was in operation with coal.

SUMMARY

This trip covered the period of November 17-27, 1986 inclusive. The period of November 17-27 was spent in the Katowice area at the Institute of Carbochemistry in Tychy-Wry. On November 27, 1986, I flew to Vienna, Austria to consult with UNIDO personnel on the coal liquefaction efforts in Poland as well as China. These consultations took place on November 28 and I left for China on November 29, 1986. The discussions at the Institute of Carbochemistry dealt with the UNDP funded project entitled, "Liquefaction of Coal", DP/POL/82/002/B/01/37. My duties were covered by two job descriptions, viz., DP/POL/82/002/11-01/32.1c and DP/POL/82/002/11-02/32.1c and dealt with coal liquefaction technology and plant construction. The objective was to assist the Polish government in these areas whereby they may use their abundant coal reserves to increase their liquid fuel supplies. Discussions concerned the construction progress on the 80 kg/hr Process Development Unit (PDU). A review was also made of the 5.0 kg/hr unit that provided design data for the 80 kg/hr PDU. The PDU was essentially complete. Mechanical start-up was completed in September 1986, and technical start-up by was scheduled for December 1, 1986. The design of the 80 kg/hr PDU was based on the bench scale results from the 5.0 kg/hr. The Polish engineers have provided for recirculation of hot separator bottoms, a severe pumping service, but required for their proposed non-catalytic operation in order to obtain adequate conversion. A recommended 100% spare was provided. When I arrived in Katowice, the 80 kg/hr PDU was operating with oil and hydrogen. It was switched to coal slurry and a successful run of 6 1/2 days, over 150 hours was made feeding coal.

TABLE OF CONTENTS

	<u>PAGE</u>
Introduction.....	1
Discussion.....	1
November 15, 1986.....	1
November 16, 1986.....	2
November 17, 1986.....	2
November 18, 1986.....	2
November 19, 1986.....	3
November 20, 1986.....	4
November 21, 1986.....	5
November 22, 1986.....	5
November 23, 1986.....	5
November 24, 1986.....	6
November 25, 1986.....	6
November 26, 1986.....	6
November 27, 1986.....	7
November 28, 1986.....	7
November 29, 1986.....	8
Conclusions.....	9
Recommendations.....	11

INTRODUCTION

The period covered in this report is November 17-27, 1986 inclusive. I left Pittsburgh on November 15 and flew to London, England arriving on November 16, 1986. After an overnight stay, I left for Poland on November 17 and remained there until November 27, in the Katowice area. During my stay in Poland, I operated under two (2) job descriptions, viz., a) DP/POL/82/002/11-01/32.1.c (Process Development Unit (PDU) Construction Expert), and b) DP/POL/82/002/11-02/32.1.c (Coal Liquefaction Process Technology Expert). The overall purpose of both job descriptions is to assist the government of Poland in their investigations pertinent to direct coal liquefaction. This work is being conducted at the Central Mining Institute in Katowice and the Institute of Carbochemistry in Tychy-Wyry. The latter is a subdivision of the former. To minimize confusion in this report, the organization in Tychy-Wyry will be referred to as the "Institute" in this report, since this is where their 80 kg/hr PDU is located.

The Polish government intends to utilize its ample coal resources to augment its limited liquid fuel supply, which is primarily imported. The present plans call for the operation of a 80 kg/hr (coal feed input) PDU to determine the optimum operating conditions for the liquefaction of several Polish coals. The program also includes the operation of a 5.0 kg/hr bench scale unit to provide back-up R&D for the PDU. In general, I advised on the technical problems associated with the operation of the PDU for direct coal liquefaction. I provided information on what was learned under various U.S. DOE funded programs such as SRC (Solvent Refined Coal), H-Coal, and EDS (Exxon Donor Solvent). The discussions centered on the 80 kg/hr (2 T/D of coal) PDU as regards to coal grinding and drying, slurry preparation and preheating, hydrogenation, solids separation and final product distillation.

To simplify the organization of this report, it has been written in a daily journal format. This type of presentation lends itself to a convenient means to express conclusions and make recommendations. The whole period was spent at the Institute of Carbochemistry in Tychy-Wyry which is in the Katowice, Poland area. The Institute is composed of about 200 people and has six divisions, viz., a) Basic Technical Research; b) Analytical Research; c) Developmental Units; d) Process Engineering; e) General Maintenance; and f) Management. Each division has about 30 people, except for Developmental Units which has approximately 50 people.

DISCUSSION

As indicated in the Introduction, this report is organized on a daily journal basis.

Day 1 - Saturday, November 15, 1986

After securing all visas (Poland and China), tickets and DOE approval, I left the U.S.A. Saturday evening for an overnight flight to Europe, stopping over in London, England.

Day 2 - Sunday, November 16, 1986

Arrived in London to change planes for Poland. Spent the day reading past trip reports and present job description. Spent the night in London.

Day 3 - Monday, November 17, 1986

Flew from London to Warsaw and was met by the Katowice personnel who provided transportation from the Warsaw airport to my hotel in Katowice, located in southern Poland about 300 kilometers from Warsaw.

Day 4 - Tuesday, November 18, 1986

This day was spent at the Institute of Carbochemistry at Tychy-Wyry which of course includes the coal liquefaction work. We talked in general about the 80 kg/hr PDU, and the apparent decreased emphasis that the U.S.A. is placing on coal liquefaction technology. I explained the DOE role as regards high risk, long range research. This indicated no lack on emphasis, only a shift from large scale pilot plants to bench scale research.

At the Institute of Carbochemistry at Tychy-Wyry, the main project is the 80 kg/hr (coal feed) unit presently in full-scale operation. This unit is a modification of their previous 50 kg/hr unit based on the Consol Synthetic Fuel (CSF) process. This modification will result in a SRC-II unit with some parts looking like H-Coal and EDS (Exxon Donor Solvent). They use the "natural" catalysts in the coal due to the lack (and high cost) of Co and Mo in Poland. They have an extensive source of bituminous (Janina) coal with about 20% ash and 3% sulfur, which when cleaned yields an acceptable feed coal containing about 8% ash and 1% sulfur. There is ample material available for a large scale coal liquefaction plant.

I met with the following people:

- o Mr. Walter Matula - Institute Director
- o Ms. J. Kulczycka - Assoc. Prof. (UNDP Project Office)
- o Mr. Adam Worsztynowicz - Division Director

We reviewed the construction of the PDU:

- a. All the basic equipment (pumps, vessels, heaters, etc.) has been permanently installed. Work is proceeding on installing instrumentation and insulation in the distillation area.
- b. The coal grinding, slurry preparation, hydrogen generation, and hydrogen compression (make-up and recycle) and reactor sections were operating. This represents significant progress over the last year since my last visit.

- c. The reaction section was operating on oil and hydrogen and with the product distillation section approximately 98% complete. All electrical equipment has been installed.
- d. Present operations with oil and hydrogen were on a recycle basis and feature conditions of 200 atmospheres (3000 psig) and 340°C in the reactor. When coal slurry is processed the temperature will be increased to 415°C. Each shift is composed of 12 operators and 4 to 5 process engineers.
- e. All construction is scheduled for completion by the end of the year. The PDU was ready for mechanical start-up by September 1986.
- f. Technical start-up is presently scheduled for December 1986.
- g. Although late delivery did seem to be a problem, these obstacles were overcome.
- h. Experimental work is continuing on the 5.0 kg/hr bench scale unit to guide the operating conditions for the 80 kg/hr PDU. The 5.0 kg/hr unit developed the design for the larger 80 kg/hr PDU. Work is continuing on product upgrading.

We spent the rest of the day discussing present DOE work and the effort at the Wilsonville plant on Two-Stage Liquefaction. I outlined the U.S. DOE past and present programs for coal liquefaction (pyrolysis, indirect and direct liquefaction). I concentrated on direct liquefaction, and how it related to the on-going Polish work being funded in part by UNDP. I briefly outlined the new work in two-stage liquefaction of coal.

Day 5 - Wednesday, November 19, 1986

The day was spent at the Central Mining Institute in Katowice. This organization is named Glowny Instytut Gornictwa, or GIG, and I met with the Deputy Director General, Dr. Antoni Goszcz to discuss the project at Tychy-Wyry. I indicated that the unit was essentially mechanically complete, with some installation of process instrumentation and vessel insulation yet to be done. We reviewed the design capacities of the various sections, where a conservative design basis was employed. There is more than adequate coal grinding, drying, and slurry preparation capacity to supply enough slurry feed for all three shifts of the planned round-the-clock PDU operation.

I indicated that the drying operation reduced the coal moisture content from 19% to 5%; however, 1% would have been better in order to reduce any possibility of foaming problems. Close attention to foaming possibilities in the production of slurry during PDU operations is in order.

We reviewed the design of the convection heater processing all feed (coal, slurry oil, make-up hydrogen and recycle gas) to the reactor. It is a conservative design proven in the early work in the German and U.S.A. coal hydro plants. This heater should work with a minimum of problems. The more recent coal liquefaction plants in the U.S.A. used radiant heaters, which are prone to coking and require close operator attention.

We reviewed the design of the pump circulating the Hot Separator Bottoms back to the Reaction Section. This is rather severe pumping service, but the application is very similar to the H-Coal pump which is used to circulate reactor contents to maintain a liquid fluidized bed. I noted that this pump was spared, as per my recommendation.

We also discussed the design recycle gas composition which will vary between 70 and 80 vol.% H₂, since the recycle gas scrubbing system involves only an oil wash. No amine scrubbing is provided for H₂S removal. The overall system should be adequate with the high purity make-up hydrogen (99.9 vol.%). If not, total reactor pressure can be increased to insure an adequate H₂ partial pressure in the reactor.

Day 6 - Thursday, November, 20, 1986

Back at the Institute in Tychy-Wyry where the 80 kg/hr PDU had been switched to processing a 25 wt% coal slurry at 5:30 pm the previous day, Wednesday, November 19, 1986. Operations were proceeding in an orderly manner. I was impressed on how well the Polish engineers and scientists work together and have integrated this project. I previously indicated that the 5.0 kg/hr unit was an excellent R&D tool and used to good advantage in the design of the 80 kg/hr unit. We spent time discussing whether the 5.0 kg/hr unit be converted to an integrated operation. I did not recommend that this be attempted, since the 5.0 kg/hr unit was too small for such a modification.

The discussions then centered around the 80 kg/hr unit. They were interested in when I could return and whether we could decide on a convenient time for both sides. I recommended September 1987. They will be able to identify any major problems at this point. A one week (5 working day) period was agreeable to both parties. I indicated that this agreement was subject to UNIDO approval.

We next discussed the mechanical aspects of the 80 kg/hr PDU. The discussion centered around the let down valves. This would be the main area of erosion while the PDU is processing coal. I recommended that these valves be taken out and thoroughly inspected between runs.

We discussed several other subjects such as:

- a) Data Acquisition - Installed in all PDU's and pilot plants in the U.S.A. to improve data gathering accuracy and

reliability. I recommended a system for the 80 kg/hr PDU to scan, alarm, and compute during operation.

- b) V/L Equilibrium Data - As this information is developed it should be closely correlated.
- c) Coal Science Meeting - The next meeting is in Holland in 1987. The Institute should attend.

Day 7 - Friday, November 21, 1986

At the Tychy-Wyry Institute, we concentrated our discussions on various aspects of the operation of the 80 kg/hr PDU. We discussed coal grinding, drying, and transfer. We discussed slurry mixing and the present batch system. Larger plants would use "wet" grinding, pulverizing the coal in the slurry oil. The possibility of using on-line mixers is also discussed in detail.

The question of the best start-up oil was discussed and I recommended the use of a heavy hydrogenated coal tar oil. They were using a lighter oil derived from petroleum and were having some problems in the slurry mixing vessel. The recommended start-up oil should have similar properties to the final product oil. As regards solid separation, I indicated that we have successfully used vacuum distillation. Present DOE work is concentrating on solvent deashing, but this technique has not been proven to the extent that vacuum distillation has.

We discussed the use of centrifugal pumps versus positive displacement pumps. The former are used for high volume, low ΔP applications while the latter are utilized for low volume, high ΔP . As a result, slurry mixing and transfer generally use centrifugal pumps and reactor feed pumps utilize the positive displacement type. Both types of pumps are suitable for streams with high (up to 50%) solids content. Recent work in pump manufacture has indicated that some high volume, high ΔP applications (e.g., amine scrubbing systems) are suitable for centrifugal pumps.

Day 8 - Saturday, November 22, 1986

At the Tychy-Wyry Institute they were still running with coal. They were planning inspection and some maintenance. The afternoon was spent with my Polish hosts visiting some local sites.

Day 9 - Sunday, November 23, 1986

No work at the Institute for me, but my hosts were kind enough to show me a little of the Polish countryside.

Day 10 - Monday, November 24, 1986

The unit at Tychy-Wyry was processing coal at the 80 kg/hr rate or about 2 T/D. No operating difficulties out of the ordinary were apparent. The reactor was operating at 200 atmosphere and 430°C. At this coal rate (2 T/D) they were using 6 T/D of slurry oil, hence feeding a 25 wt% slurry. Subsequent runs will be made at higher slurry concentrations up to 40 wt%. In addition to the combined coal (2 T/D) and slurry oil (6 T/D) they were circulating and additional 2 T/D of hot separator bottoms. The objective of this run was to complete the requirements for technical start-up and generate enough slurry oil for the next run with a coal-derived recycle oil.

We spent the afternoon reviewing the project with the Director of the Central Mining Institute, Doctor Jozef Maloszewski. He is Water Matula's supervisor and was obviously pleased with the successful run underway with coal on the 80 kg/hr PDU.

Day 11, Tuesday, November 25, 1986

Again back at the Institute in Tychy-Wyry where the PDU was still operating on coal. A very impressive performance as regards ease and duration of operation was all I could say.

We then discussed at great detail the method to be used in scaling up the results from the 80 kg/hr PDU to a full-scale commercial plant. Generally the material balance can be set with some degree of accuracy; however, the degree of process and heat integration must be improved upon to obtain favorable economics. Finally the PDU is not suitable for obtaining accurate heat balance data due to its relatively small size and its inherent high ratio of surface to volume which tends to distort the calculation of heat loss.

Although the Polish workers have most of the current coal liquefaction literature, certain key publications are simply not available in Poland. I intend to send them this material as it becomes available.

Arrangements were made for me to tour an operating coal mine in the Katowice area. We then spent the rest of the day changing into miner's equipment, descending about 700 meters (over 2,000 ft.), and walking, crawling, and stumbling to the "working face" of a long-wall mining operation. A complete demonstration was provided by the Polish coal miners on shift at the time. The tour was concluded with an inspection of the coal washing facilities.

Day 12 - Wednesday, November 26, 1986

Coal was taken out of the unit at 5:30 am and the PDU was shut down for inspection. This completed the technical start-up phase. The PDU was operated on coal for 6 1/2 days or about 156 hours. The shut

down was orderly. The plans were to inspect the unit, complete the small amount of work in the Distillation section and commence a long-term run, in the integrated operations mode on December 15, 1986.

As a final request from the Director of the Institute at Tychy-Wyry, he indicated that they wish to send several people to the U.S.A. to survey the latest developments in direct coal liquefaction. They asked for advice on the arrangements and points of contact. I recommended that they write (through UNIDO) to the PETC Director outlining in detail:

1. Names and suggested dates
2. Background of visitors
3. Suggested itinerary (Wilsonville then PETC)
4. People at PETC they wish to consult (e.g., Thomas Torkos, John Ruether).

I indicated that their contact should be with PETC, not with Wilsonville. They indicated that a letter to the PETC Director would be forthcoming and asked that the request be expedited, when it arrives. They also requested that they visit Wilsonville first, then PETC.

The Polish engineers and scientists expressed gratitude for the financial and technical help supplied by UNDP and UNIDO. A project of this magnitude relies on active cooperation of all parties involved. We reviewed the completed work on the 5.0 kg/hr bench scale unit. It indicated that the design basis of the 80 kg/hr PDU was sound. A review of the 80 kg/hr PDU operating parameters was made based on the results of the 5.0 kg/hr bench scale unit.

In reviewing the schedule, it was recommended that the Product Distillation Section be completed. It was recommended that this area be "weather-proofed" so that construction work would continue unabated during the winter months. It was observed that based on the results of the technical start-up, no major renovations are necessary.

Day 13 - Thursday, November 27, 1986

This was a travel day and I left Katowice early to get to Warsaw to catch an afternoon flight to Vienna, Austria for UNIDO consultations.

Day 14 - Friday, November 28, 1986

The day was spent in UNIDO headquarters in Vienna, Austria discussing the coal liquefaction work in Poland and China. During this time a myriad of administrative details were discussed and resolved.

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December 15, 1986
English

Day 15 - Saturday, November 29, 1986

My Polish trip was essentially over and I continued on to China. Flying from Vienna to Frankfurt, I then caught my flight to Tokyo. This day was essentially spent in transit going from Europe to Asia.

CONCLUSIONS

Considerable progress has been made in the construction of the 80 kg/hr PDU at the Institute of Carbochemistry at Tychy-Wyry, Poland. The plant is virtually complete lacking only the installation of some insulation. The Product Distillation Section needs some effort during the coming winter months. The last 5% of mechanical completion is the most difficult.

The present schedule has been met and should be critically assessed at this time next year. The attainment of full integrated operations by December 1986 followed successful mechanical start-up in early 1986 and by technical start-up in late 1986. Since these two "start-up" dates were met, the December 1986 date seems reasonable.

The budget appears adequate for this project, and it is recommended that expenditures be closely controlled; however, the purchase of spare parts is not to be ignored. The UNDP Fellowship program has greatly helped this project and should be continued. A Polish engineer, Mr. Marek S. Pawlowski, spent six (6) months at PETC to improve their access to technical literature in the field of direct coal liquefaction. I will continue as in the past to send pertinent literature directly to the Institute in Tychy-Wyry.

Another success was the 6 month fellowship for E. Jedrysik to study the state of the art in physical properties of coal liquids. Another fellowship (possibly at PETC) should be arranged for yet another Polish chemical engineer to study the results from past U.S. DOE programs such as H-Coal, EDS and SRC. This information is available at one place, the Pittsburgh Coal Technology Data Base at PETC. It has been organized for easy access and would be very valuable to the Polish coal liquefaction effort.

Construction of the 80 kg/hr PDU is essentially finished, including coal grinding, slurry preparation, hydrogen production and compression, the preheater and reaction system, and the hot separator with the hot circulation pumps. The hydrogenation section was the most critical area of the PDU. The completion of the electrical and instrumentation areas was given top priority. The section still not complete is the product distillation area. Nevertheless, all projected completion dates were attained. My experience has been that the completion of the last 5% of a construction project can consume a large amount of time and is the most frustrating portion of the construction effort.

Finally we concluded that my next trip should be in September 1987 and the visit should be arranged to include the yearly Tripartite Meeting. At this time a great deal of actual operating data on processing coal slurries should be available. At present the Polish workers are successfully developing a process for direct hydrogenation of a particular type of coal. Their long range goal is to make use of their vast coal deposits which although accessible, nevertheless contain high amounts of sulphur. Deposits in the Janina region (at 250-300 meters) have been estimated at 7 billion tons. The high-sulphur coals from these shallow mines are cheaper than most

other European coals, but cannot be burned in power plants due to pollution. Direct hydrogenation of these coals have given encouraging results which have led the Polish authorities to intensify this effort.

The plan is to continue with the R&D program on the bench-scale (5.0 kg/hr) unit and to develop the process on the 80 kg/hr PDU in the direct hydrogenation mode. Integrated operation of the PDU will yield technical data to serve as a basis for the design of a demonstration plant having a capacity of 8-20 tons/hr coal throughput.

Subject to UNIDO approval, it was recommended that I continue to assist the Polish Government in their investigations on coal liquefaction processes with a view to utilizing their coal resources to meet the liquid fuel requirements of the country. The program should continue to test at a PDU scale (80 kg/hr coal throughput) the process parameters for the effective liquefaction of Janina coals, and to carry out back-up R&D in a 5 kg/hr bench-scale unit to define the appropriate process operating parameters such as reactor temperature, hot separator temperature, feed rate, recycle oil recirculation rate and coal concentration in the feed slurry.

RECOMMENDATIONS

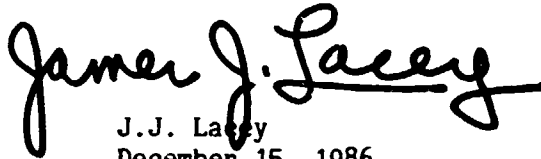
Based on my stay at the Tychy-Wyry Institute of Carbochemistry during the period of November 17-27, 1986, the following recommendations are pertinent relative to the Polish coal liquefaction effort (DP/POL/82/002/B101/37):

1. Significant progress has been made in the construction of the 80 kg/hr PDU. Concentrated efforts are still required to keep this project on schedule. The projected date for attaining full integrated operation (December 1986) is attainable. The Institute members should advise UNIDO of operating progress in detail on a monthly basis.
2. Implementation of the funding decisions made at the Tripartite Meeting (September 25, 1985) should continue particularly as regards the purchase of spare parts. Discussions on the possible purchase of a Data Acquisition System should be finalized.
3. There is still a need to insure that the members of the Institute keep abreast of the latest developments in coal liquefaction. I will continue to send pertinent material. The UNDP Fellowship program has proven valuable and should be continued.
4. Work should continue on the 5.0 kg/hr unit and design improvements incorporated in the 80 kg/hr PDU. However, the main effort must be spent on the operation of the 80 kg/hr PDU.
5. Physical property data has not hampered the design of the 80 kg/hr PDU. E. Jedrysik spent 6 months in the USA on a UNIDO Fellowship to work in this area.
6. The use of a pump to recirculate a portion of the hot separator bottoms to the inlet of the preheater is critical to the operation of the 80 kg/hr PDU. This pump and its 100% spare have been installed. This provides a means of obtaining sufficient coal conversion without costly catalysts.
7. Another Polish fellowship should be established to send a qualified chemical engineer, engaged in the operation of the 80 kg/hr PDU, to PETC in order to study the extensive Liquefaction Technology Data Base (LTDB) covering all past U.S. DOE efforts in this field. This LTDB has been organized for easy access to the key operating data for such processes as H-Coal, EDS and SRC.
8. A follow-up trip to Poland should be made in the September 1987 period to evaluate the progress on the 80 kg/hr PDU operations, and review further developmental results of the 5.0 kg/hr bench scale unit. This period was acceptable to the Polish, whereby I would spend a minimum of one week (5 working days) at the Institute in Tychy-Wyry.

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English

9. Information exchange should be continued during PDU operations. I would recommend that Polish progress reports be sent to me when they are available. I will continue to periodically send pertinent coal liquefaction literature to them.

A handwritten signature in cursive script that reads "James J. Lacey". The signature is written in black ink and is positioned above the typed name and date.

J.J. Lacey
December 15, 1986