# Natural Gas Futures and Spread Position Risk: Lessons from the Collapse of Amaranth Advisors L.L.C.

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**Abstract**

The speculative activities of hedge funds are a hot topic among market agents and authorities. In September 2006, the activities of Amaranth Advisors, a large-sized Connecticut hedge fund sent menacing ripples through the natural gas market. By September 21, 2006, Amaranth had lost roughly $4.35B over a 3-week period or one half of its assets due to its activities in natural gas futures and options in September. On September 14, alone, the fund lost $681M from its natural gas exposures. Shortly thereafter, Amaranth funds were being liquidated. This paper uses data obtained by the Senate Subcommittee on Investigations through their subpoena of Amaranth, NYMEX, ICE, and other sources to analyze exactly what caused this spectacular hedge fund failure. The paper also analyzes Amaranth's trading activities within a standard risk management framework to understand to what degree reasonable measures of risk measurement could have captured the potential for dramatic declines that occurred in September. Even by very conservative measures, Amaranth was engaging in highly risky trades which (in addition to high levels of market risk) involved significant exposure to liquidity risk – a risk factor that is notoriously difficult to manage.

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# I Introduction

In September, 2006 a large-sized hedge fund named Amaranth Advisors, L.L.C. lost $4.35B in natural gas futures trading and was forced to close their hedge fund. Although Amaranth Advisors was not exclusively an energy trading fund, the energy portion of their portfolio had slowly grown to represent 80% of the performance attribution of the fund (Source: Senate Subcommittee Exhibit #12). Their collapse was not entirely unforeseeable or unavoidable. Amaranth had amassed very large positions on both the New York Mercantile Exchange (NYMEX) and the Intercontinental Exchange (ICE) in natural gas futures, swaps, and options. The trades consisted mainly of buying and selling natural gas futures contracts with a variety of maturity dates. Their trades were very risky from both a market risk perspective and a liquidity perspective.

Since the collapse of Amaranth in September 2006, several authors have attempted to understand what positions and risk levels Amaranth was engaged in to cause such a dramatic collapse (Chincarini (2006) and Till (2006)). Chincarini (2006) used the information from newspapers, CEO statements, and actual natural gas futures data to quantify the nature of the most likely trades that were made at Amaranth. That paper hypothesized that Amaranth had engaged in a short summer, long winter natural gas trade primarily using natural gas futures. Based on these backward-engineered positions, the paper examined both the market and liquidity risk of Amaranth's positions prior to its collapse.

On June 25, 2007 the Committee of Homeland Security and Government Affairs released a document containing a detailed investigation of the Amaranth scandal entitled "Excessive Speculation in the Natural Gas Markets." The U.S. Senate Permanent Subcommittee on Investigations used its subpoena power to analyze the trading records at the New York Mercantile Exchange (NYMEX), the Intercontinental Exchange (ICE), as well as the trades of Amaranth and other traders. It also conducted numerous interviews of natural gas market participants, including natural gas traders, producers, suppliers, and hedge fund managers, as well as exchange officials, regulators, and energy market experts.

In this paper, we make extensive use of the actual Amaranth trading positions obtained under subpoena by the Senate Subcommittee and describe the trades that Amaranth actually made. We also discuss the risks associated with the trades Amaranth made and what risk managers should do to avoid these risks in the future. The rest of the paper is as follows. Section II discusses the background of the firm Amaranth Advisors, L.L.C. Section III discusses the natural gas futures market and details the basics of typical spread trades to help the reader appreciate the more complicated Amaranth trading strategies. Section IV discusses Amaranth's actual trading positions on August 31, 2006 and in other periods. Section V analyzes the market and liquidity risks inherent in Amaranth's natural gas positions. Section VI discusses lessons for regulators and risk managers and Section VII concludes.

# II Amaranth Advisors, L.L.C.

Amaranth Advisors L.L.C. was a hedge fund operating in Greenwich, CT.[1] The hedge fund launched in 2000 as a multi-strategy hedge fund, but had by 2005-2006 generated over 80% of their profits from energy trading (Source: Senate Subcommittee Exhibit #12).

## II.1 The Management

The management of Amaranth Advisors consisted of well-seasoned professionals. Below is a description of some of the key management.

1. **Nick Maounis, CEO.** Prior to Amaranth, Mr. Maounis was at Paloma from 1990-2000.[2] There he had experience managing approximately 25 traders and assistants handling a variety of arbitrage portfolios in the U.S., Japan, Europe, and Canada. During his tenure at Paloma, his group substantially outperformed both the S&P 500 and the CSFB Tremont Hedge Fund index. His group's track record included a low correlation with the S&P 500 index, returning a profit in 29 out of the 33 down months of the S&P 500 Index. From 1989-1990, Mr. Maounis was employed at Angelo, Gordon, & Co.. From 1985-1989 he was employed at Rothschild, Unterberg, and Towbin. There he served as a Senior Vice President in charge of all convertible arbitrage trading. He graduated from the University of Connecticut in 1985 with a Bachelors of Science degree.

2. **Charles Winkler, COO.** Mr. Winkler was responsible for managing all non-trading related details of the firm. He joined Amaranth in July 2001. Prior to this, from 1996-2001, he had been a Senior Managing Director and COO for Citadel Investment Group, another hedge fund.

[1] Many thanks to Dan Berkovitz for providing the information upon which much of this section is based. This section draws heavily from Exhibit #12 of the Senate Subcommittee Investigations. In addition to their Greenwich office, Amaranth had been working on expanding their operations and had offices in London, Singapore, Houston and Toronto.

[2] Paloma Partners is a well-known hedge fund.

Prior to Citadel, he was a parter with the Chicago law firm of Neal Gerber & Eisenberg. He spent 17 years at the law firm focusing on tax and corporate counseling to investment advisors and private investment firms. He graduated from Emory in 1976 with a Bachelors degree in Business Administration in Accounting and received his law degree from Northwestern University School of Law in 1979.

3. **Robert Jones, Chief Risk Officer.** Prior to Amaranth, he had worked at Goldman Sachs & Company developing proprietary arbitrage strategies and risk limited portfolio management techniques. He was also part of Goldman's equity arbitrage trading unit, where he ran a listed and OTC derivatives trading book. Robert was not a novice at risk management. In 1988, he was invited by the NYSE Chairman, John Phelan, to assist him in evaluating and addressing operational risks exposed during the 1987 crash. In 1989, he joined Paloma Entities where he managed an international derivative arbitrage portfolio. He worked with Nick Maounis for four years while at Paloma. He also led Stradivarius Capital, a firm which helped quantitatively oriented hedge funds to identify and manage sources of performance uncertainty.

4. **Artie DeRocco, Treasurer.** Mr. DeRocco was responsible for counterparty relations and maintaining all financing relationships.

5. **Michael Carrieri, Chief Compliance Officer.** Mr. Carrieri was responsible for firm compliance.

6. **Brian Hunter, Head of Energy Trading.** Mr. Hunter joined Amaranth in 2004.[3] He was hired by Mr. Maounis and Mr. Arora, a former Enron trader who had established Amaranth's energy and commodities trading desk. Prior to this, he had worked at TransCanada Corporation, a Calgary pipeline company, where he began getting a name for himself in energy trading. While there, he was able to find mispricing in energy options which helped the firm make profits. After this, Mr. Hunter moved to Wall Street to work for Deutsche Bank on the energy desk. While there, his positions in natural gas futures caused large fluctuations in profit and losses. According to a complaint he filed in a state court in New York, he personally generated $17M in profit in 2001 and $52M in profit in 2002. In 2002, he was making $1.6M in salary and by 2003 was supervising the gas trading desk. In 2003, Hunter's desk had a very positive year with $76M in profit, but then they suddenly lost $51.2M in one week. He

[3] Most of this discussion is based upon an article in the Wall Street Journal entitled "How Giant Bets on Natural Gas Sank Brash Trader." and FERC Docket No. IN07-26-000.

blamed the losses on "...an unprecedented and unforeseeable run-up in gas prices..." He also claimed that there were many problems with Deutsche Bank's electronic-trade-monitoring and risk-management software, which he said hurt traders' ability to extricate themselves from bad trades. Deutsche Bank denied such claims. By February 2004, relations between Mr. Hunter and Deutsche Bank supervisors had become so bad that they locked him out of the trading system and moved him off the desk. Mr. Hunter left Deutsche Bank in April and sued Deutsche Bank over failure to pay him a bonus and for defamation. Mr. Hunter was then hired by Nick Maounis, the CEO of Amaranth, who said that he knew of his history at Deutsche Bank but found "...nothing that made us uncomfortable." In the summer of 2005, Mr. Hunter threatened to leave Amaranth, partly because he disliked his compensation structure and did not wish to report to Mr. Arora. Mr. Maounis reacted by allowing Mr. Hunter to trade a book separate from Mr. Arora. Also, the share of his desk operating profits eventually were increased from 7.5% to 15%. Mr. Hunter made a name for himself on Wall Street when he helped Amaranth make $1B in profits in 2005. Due to his trading success in in 2005, Mr. Hunter was rumored to have been compensated between $75M and $100M. Late in 2005, Mr. Hunter was also allowed to return to his hometown of Calgary and trade from there. Eventually, his four other natural gas traders migrated from Greenwich to Calgary. These other natural gas traders on his team were Mr. Matthew Donohoe, Mr. Matthew Calhoun, Mr. Shane Lee, and Mr. Brad Basarowich. He obtained an undergraduate degree at the University of Alberta.

### II.2 The Strategies

Amaranth managed several funds. The principle fund, with $8.39B ($8,394,523,000) of capital at the end of August, 2006, was the Amaranth L.L.C. fund. This fund was structured as a multi-strategy fund that could invest in virtually any market without any position limitations. The fund's various strategies consisted of the following in no particular order:

1. **Energy Arbitrage and Other Commodities**. This category consists of a variety of so-called energy arbitrages. For example, *geographical arbitrage* consists of trading the difference of a price of a given commodity either in the same location or in different locations. *Grade arbitrage* consists of trading the difference between two related crude oil based commodities, such as the spread between WTI and Brent Crude. Trades can also be related to perceived

volatility changes of the contracts across maturity or across type of commodity. Calendar spreads are typically used to trade across maturities. Deep out-of-the-money call options were used to take advantage of price shocks to commodities. Besides energy trading, Amaranth was also involved in trades in copper. They eventually wanted crude oil to be a larger component of their trading. Within this category for 2006, performance attribution revealed that 78% of the returns were related to energy trading and the other 8% to other types of commodities. By September, 2006 these strategies used a total of 62% of the firm's capital.

2. **Convertible Bond Arbitrage**. These strategies consisted of buying a convertible bond and selling short a varying percentage of the underlying common stock that the bond is convertible into. Their portfolio was divided between US, Canada, and international bonds which included Europe and Japan. There were four portfolio managers, including Nick Maounis running convertible arbitrage, including 5 credit analysts and 3 traders. Credit risk was analyzed in-house. Their leverage in this area was 7.78 with approximately 146 positions by September. By September, 2006 these strategies had used up about 2% of the firm's capital.

3. **Merger Arbitrage**. These strategies consisted of investing in securities of companies involved in prospective mergers, acquisitions, cash tender offers, recapitalizations, and other corporate restructurings. The typical trade in this space is long the target of the acquisition and short the buyer. As of September, 2006, they had a leverage in this area of 1.26 and 72 different positions. They viewed the increasing LBO activity as very positive. For example, they had a positive view of the buyout of HCA. By September, 2006 these strategies used about 1% of the firm's capital.

4. **Credit Arbitrage**. These strategies can be divided into several sub-categories. These strategies are capital structure arbitrage, event driven arbitrage, and merger arbitrage. Some trades were in the form of buying and selling different classes of securities of the same issuer due to a perceived mispricing between the two. Typical capital structure trades may have consisted of purchasing senior debt of an issuer and selling subordinated debt of the same issuer when the subordinated debt was believed to be overpriced relative to the senior debt. Another way to exploit the mispricing would be to buy credit default swaps of the same issuer with different maturities where certain default swap spreads were expected to widen or tighten based on the perceived financial stability of the underlying company. Other variations include trading bank loans, pairs trading, credit default obligations, and credit options. As of September,

2006, 40% of the credit arbitrage portfolio had a long bias, 40% was in the form of bespoke synthetic CDOs and regular CDOs. As of September, 2006 they had a leverage in this area of 4.20 and 1,217 different positions. They viewed the tight credit spreads as unsustainable over the long run. They focused on Asia, where they believed there were more opportunities. By September, 2006 these strategies used about 17% of the firm's capital.

5. **Volatility Arbitrage**. These strategies involved purchasing or selling an option on an underlying financial instrument and selling or purchasing a varying percentage of the underlying instrument. As of September, there was a slight bias to being long volatility. They were primarily looking for cheap price volatility that they attempted to manage on a delta-neutral basis. As of September, 2006 they had a leverage in this area of 4.53 and 2,178 different positions. Due to losses in July and an increasingly challenging environment, they had reduced their exposure to this strategy as of September 2006 to about 7% of the firm's capital.

6. **Long/Short Equity**. This was a strategy adopted later by Amaranth. It involved being long and short in various securities. They launched a stand-alone fund for this strategy entitled the Amaranth Global Equities Master Fund Limited. The capital allocation of this fund was divided as follows: 35% health care, 35% technology, 15% utilities, and 15% financials. The strategy relied on both fundamental and statistical analysis to identify under- and overpriced equities. As of September, 2006 they had a leverage in this area of 2.39 and 499 different positions. As of September 2006 used 7% of the firm's capital.

7. **Statistical Arbitrage**. This was a strategy also adopted later by Amaranth. It consists of trading in equity and foreign exchange markets. Within the equity markets, the statistical arbitrage involved trading positions on the Russell 2000. Within the foreign exchange, it focused on trading the 11 most liquid currencies. They were in the process of developing an interest-rate arbitrage model. The statistical arbitrage strategy was based upon 7 models which looked for anomalies in the price correlation amongst the targeted underlying index or basket of securities. The investment horizon per trade was about one month. The statistical arbitrage book was still in the beta-phase and there were 20 programmers working on refining the algorithms and code. As of September, 2006 they had a leverage in this area of 2.84 and 4,456 different positions. As of September 2006 used 4% of the firm's capital.

Amaranth's exposure to these various strategies changed dramatically over the years prior to September, 2006. For example, at Amaranth's inception, 60% was devoted to convertible arbitrage, whereas by September, 2006 only 2% was devoted to this strategy. Also, over 86% of their performance in 2006 was due to energy and commodity related trades. In addition to this, Amaranth had no stop limits and no concentration limits, which allowed the fund to concentrate itself so much towards energy toward the end of August 2006. Also there were no leverage restrictions within the firm. Style drift was evident with this multi-strategy fund.

## II.3 Fund Structure

Amaranth Advisors L.L.C. was structured as a Delaware Limited Liability Company. The three principal funds were the Amaranth Partners L.L.C., the Amaranth Capital Partners L.L.C., and the Amaranth International Ltd. which were all multi-strategy arbitrage funds dedicated to maximizing returns on a risk-adjusted basis. The funds were part of a master-feeder structure, in which Amaranth L.L.C. had an investment objective identical to that of the funds. The strategies of these funds were described in detail in the previous section. In addition to the principal funds, there were also two smaller funds. One was the Amaranth Global Equities Master Fund Ltd., structured as a Cayman Islands exempt company. Amaranth Advisors L.L.C. was the advisor to this fund. There was also the Amaranth Securities L.L.C., a Delaware Limited Liability Company, which was registered as a broker-dealer to facilitate the stock borrow-loan business.

Amaranth's capital came from a variety of investors. About 60% came from fund-of-funds, about 7% from insurance companies, 6% from retirement and benefit programs, 6% from high net worth individuals, 5% from financial institutions, 2% from endowments, and 3% was insider capital. Insider capital was not charged management or incentive fees. Amaranth commenced operations in 2000 with approximately $200M in capital, mainly provided by Paloma. The largest investor in Amaranth by 2006 amounted to 8% of total capital. Investors could withdraw funds with the following restrictions.

1. Initial deposits had a 13 month initial lock-up with 90 days required written notice.
2. After this initial lock-up period, investors could withdraw quarterly, in January, April, July, and October with 45 days written notice and a 2.5% withdrawal fee.
3. Investors could also make annual redemption of profits with 45 days written notice.
4. Beginning in February, 2005 new investors were subject to a 2-year lock-up period on capital.

Minimum investments in Amaranth were $5M. The management fee was 1.5% and the incentive fee was 20%. A high water mark was also employed.

### II.4 Risk Management and Liquidity Management

The Chief Risk Officer of Amaranth had a goal of building a robust risk management system and process. Amaranth was unusual in terms of risk management in that it had a risk manager for each trading book that would sit with the risk takers on the trading desk. This was believed to be more effective at understanding and managing risk.[4] Most of these risk officers had advanced degrees.

The risk group produced daily position and P&L information, greek sensitivites (i.e. delta, gamma, vega, and rho), leverage reports, concentrations, premium at risk, and industry exposures. The daily risk report also contained the following.

1. Daily VaR and Stress reports. The VaR contained various confidence levels, including 1 SD at 68% and 4SD at 99.99% over a 20 day period. The stress reports included scenarios of increasing credit spreads by 50%, contracting volatility by 30% over one month and 15% for three months, 7% for six months, and 3% for twelve months, interest rate changes of 1.1 times the current yield curve. Each strategy was stressed separately, although they intended to build a more general stress test that would consolidate all positions.
2. All long and short positions were broken down. In particular, the risk report listed the top 5 and top 10 long and short positions.
3. A liquidity report that contained positions and their respective volumes for each strategy which was used to constrain the size of each strategy.

The risk lieutenants would also calculate expected losses for the individual positions. The firm had no formal stop losses or concentration limits.

Amaranth took several steps to ensure adequate liquidity for their positions. These are listed below.

1. Amaranth maintained a certain amount of risk capital to be used for anticipated margin calls on their positions. For example, in May, 2006 they had $3B or 30% of their capital in cash for these purposes. This dwindled to around $1B in the middle of September.
2. Amaranth used several prime brokers and excess borrowing power to be able to have sufficient funds if needed. The excess borrowing power with prime brokers was about 25%.

[4] One might ask whether this was indeed optimal. It could perhaps cause risk managers to become more integrated in the trading style and not be as objective in assessing risk.

3. Amaranth built their own stock loan business, Amaranth Securities L.L.C., to mitigate any potential prime broker service disruptions.
4. Amaranth used 6 prime brokers for domestic and international securities. They were Goldman Sachs, Morgan Stanley, Citigroup, Lehman Brothers, Deutsche Bank, and Merrill Lynch.
5. The prime brokerage agreements included lockups from 30-90 days for financing and margin levels. The lock-ups were subject to ISDA-like covenants including a "Keyman Clause" and NAV triggers of 30% per quarter.

# III Natural Gas Spread Trades

Amaranth's collapse was mainly due to losses in the trading of natural gas. To understand the Amaranth collapse, we need to understand the mechanics of trading natural gas futures, options, and swaps.

## III.1 Trading Natural Gas

In this section, we discuss some basic features of trading natural gas futures on the NYMEX and ICE exchanges. Traders in natural gas futures have several options. The largest exchange for trading natural gas futures is the NYMEX which has futures contracts of consecutive delivery months up to 5 years out. They also have options on all of the futures contracts, as well as spread options which payoff on the difference between futures contract prices of two different months. The initial margin requirement on futures contracts vary by type of trader (non-member customer, member customer, and clearing member and customer) and also vary by time to maturity of the contract. Contracts closer to delivery have stricter margin requirements. To give a flavor of the margin differences as a percentage of notional value, on August 31, 2006, \$12,150 was required for each October 2006 contract (Tier 1), which had a futures value of \$60,480, thus, representing about 20% of the futures notional position. The March 2007 contract had a margin requirement of \$7,425 (Tier 5) with a notional value of \$104,830 or 7.08%. The expiration of the contracts is usually a few days before the end of the prior month and there are conventions for the last trading day of each contract which can be obtained from NYMEX.

In addition to NYMEX, traders can use the ICE which is a virtually unregulated exchange, but performs very similar functions. ICE is the leading exchange for the trading of energy commodity swaps in natural gas and electricity. "The ICE natural gas swap and the NYMEX natural gas futures contract perform the same economic functions. The ICE swap contract even provides that its final settlement price will equal the final settlement price of NYMEX futures contract for the same month, which means that the final price for the two financial instruments will always be identical." (Senate Report, p. 29) Traders also can use the ICE trading screen to enter into bilateral, non-cleared transactions rather than cleared transactions. That is, OTC transactions with other parties to buy or sell natural gas. One major difference between NYMEX and ICE is that ICE has "...no legal obligation to monitor trading, no legal obligation to prevent manipulation or price distortion, and no legal obligation to ensure that trading is fair and orderly..." (Senate Report, p. 41) due to its status as an electronic trading facility. In addition, the Commodity Futures Trading Commission (CFTC) has no authority or obligation to monitor trading on ICE.

## III.2 The Natural Gas Futures Spread Trade

A popular type of trade in natural gas futures is to short one contract, while being long another contract. This type of trade has several attractive features. Firstly, the trade as a whole will have less risk to the direction of natural gas futures prices - in a sense, "hedge-like" in nature. Secondly, by shorting one contract and being long another contract, an entity will reduce the overall net position and hence allow for greater positions on the exchange without causing a trader to hit position limits.[5] Even if position limits are reached, by being short one contract and long another contract, the entity will have a better story of why they have such large positions (i.e. the position is naturally hedged) and may be allowed to engage in such positions on the exchange. Thirdly, spread positions allow for more sophisticated hedge fund like positions.

A simple example of a spread position may illustrate the point. Suppose on July 31, 2006 a trader wished to short one contract and go long another contract. Suppose the trader chose to go long the March 2007 contract and short the April 2007 contract. The closing prices on July 31, 2006 for the March and April contract were \$11.461 and \$8.851 respectively. The notional value of this position would equal \$114,610 long and \$88,510 short.[6] The position is "hedged" in the sense that if natural gas futures prices rise or fall, one position's loss will be partly offset by the other's

[5] For example, NYMEX considers net exposure limits. Thus, if a trader is long 10,000 contracts in one contract and short 10,000 contracts in another contract, the net position is 0. This makes the position more feasible with respect to NYMEX limits.

[6] Each contract of natural gas is worth 10,000 MMBtu. Natural gas futures prices are quoted in terms of 1MMBtu. Thus, each contract in natural gas futures represents a notional value of $1 \cdot P \cdot 10,000$, where $P$ represents the price of that natural gas futures contract.

gain. However, the position is focusing on a spread bet. That is, a bet that the March futures contracts will have a higher return than the April futures contracts. In the month of August, 2006, this was actually the case. By August 31, 2006 the price for March and April 2007 futures contracts was $10.843 and $8.343 respectively. Thus, if the position were closed out on August 31, 2006 by buying back March 2007 futures and selling April 2007 futures, the net profit would have been $4,700 on this simple spread position (See Table 1). The return of these positions will depend on the leverage employed. Notice that even though natural gas prices dropped, the spread position still made profits.

**[INSERT TABLE 1 ABOUT HERE]**

On July 31, 2006, these natural gas futures contracts represented the Tier 5 futures contracts on the NYMEX for margin calculation.[7] For a non-member customer, this would require an initial margin on each of the March and April contracts of $7,425. Thus, for an initial capital outlay of $14,850, the return on this investment would have been 31.6% ($\frac{4,700}{14,850}$). This is one of the advantages of leverage, lots of return for little initial capital outlay.

## III.3 The Natural Gas Spread Trade with Options

The previous section discussed one way a natural gas futures trader can engage in a calendar spread trade using natural gas futures contracts on the NYMEX. In addition to this, a trader could use NYMEX natural gas options, which are options whose value depends on the underlying natural gas futures contract. There are both call and put options and they are available for selling or purchasing.[8] Using the previous example, the trader could have made a calendar spread trade using options. One of the least risky ways to do this is to purchase a call on March 2007 futures and purchase a put on April 2007 futures. On July 31, 2006 there were many types of options available for trading. For simplicity, we will choose the closest at-the-money call and put option for each contract. On July 31, 2006, there was a call on the March 2007 contract which traded with a strike of $11.5 and a settlement price of $2.429 and a put on the April 2007 contract with a strike of $8.75 and a settlement price of $0.525. The options on the NYMEX are based upon

[7] For more details, see www.nymex.com for margin requirements. Tier 5 represents the 6th through the 16th nearby month. On July 31, 2006, March and April contracts were the 8th and 9th month respectively.

[8] Margin is required for short positions or writing options. However, for purchasing options, only the premium is required.

one natural gas futures contract. Thus, if one call and one put were purchased in this case it would result in a cost of $24,290 and $5,250 respectively. In order to make this a true spread trade based upon the difference in returns of the two contracts, we need to scale the contract so as to have an equal investment in both. For example, we might choose to buy one call option and five put options representing an investment value of $24,290 and $26,250 respectively. This is roughly the same investment value on each contract. By August 31, 2006, the prices for the call and the put option were $1.798 and $1.395 respectively. Thus, this represented a profit of $37,190 for this spread position (See Table 2). As a percentage of our capital, it represented a 73.6% return.

**[INSERT TABLE 2 ABOUT HERE]**

In addition to straight call and put options, the NYMEX also has calendar spread options available for trading. These are options on the difference in price between two natural gas futures contracts of different months. For example, an IBK07 call option is a call option on the price differential between the May 2007 natural gas futures contract and a short position in the July 2007 natural gas futures contract.

Finally, traders can trade through the NYMEX Clearport trading platform natural gas swaps and natural gas penultimate swaps which are based upon the final price of the natural gas futures contracts, but are one-fourth the size.

A trader could also do such a spread trade using the ICE. The ICE allows for trading of natural gas swaps that are based on the settlement prices of the NYMEX natural gas futures contracts.[9] The ICE swaps are for all practical purposes identical in behavior and risk to the NYMEX natural gas futures contracts. The main difference is that swaps involve one party being a seller of the swap, which means that they have a position that is short the underlying futures contract, which must be paid to the buyer of the swap on expiration. Similarly, the buyer of the swap pays the seller of the swap when the price of the underlying futures contract declines from the swap price. The ICE swaps are one-fourth the size of the underlying NYMEX futures. The ICE allows for two types of natural gas futures swaps. The ones electronically traded and cleared through their system and the ones traded off-exchange with a counter-party and then entered into their system for clearing. The P/L and functionality of these swaps is almost identical to the NYMEX natural gas futures contracts. Traders can also enter into bi-lateral trading agreements with counterparties through

[9] Although the ICE calls these instruments “swaps”, they are really just like futures contracts.

the ICE screen or directly. These are non-cleared trades and represent a small part of the overall activity in natural gas futures. ICE also has calendar strips which are based on the relative prices of different contract months. The specifications of both NYMEX natural gas futures contracts and ICE swaps are presented in Table 3.[10]

All of the positions and types of trades we discussed in this section were employed by Amaranth. In fact, Amaranth's collapse was due to a large variety of these type of trades that they made on NYMEX and ICE in both futures, swaps, and options. In the next section, we focus on the Amaranth trades in detail.

**[INSERT TABLE 3 ABOUT HERE]**

# IV Amaranth's Trading Strategy

## IV.1 The Basic Strategy

The Senate's Permanent Subcommittee on Investigations report (2007a) provided a detailed account of Amaranth's natural gas positions on a daily basis throughout 2006. Amaranth's positions in natural gas involved trades in various types of contracts, including futures, swaps, and options. Their trades also amounted to a collection of many spread trades whose return depended on the movement of natural gas futures price all the way out until 2011. It is difficult to classify a large group of trades into one simplified strategy, but for the most part, the complex combination of instruments and spread trades could be summarized as a general bet that winter natural gas prices would rise, while non-winter natural gas prices would decline, referred to as the long winter, short non-winter spread trade (Chincarini (2006, 2007a, 2007b)).

Amaranth's positions in natural gas consisted of a variety of actual instruments. The vast majority of positions were traded on the NYMEX and ICE. On the NYMEX, Amaranth held positions in outright natural gas futures contracts from October 2006 maturity to December 2011 maturity. Amaranth also had a significant amount of positions in call and put options on the underlying natural gas futures contracts with NYMEX. They also had natural gas swap contracts through the Clearport system of NYMEX. They had a combination of regular swaps and penultimate swaps,

[10]For more information on these instruments, the reader is referred to the Senate Report, as well as www.nymex.com and www.theice.com.

the latter which expire one day prior to the former, but are otherwise identical.[11] The rest of their positions consisted of natural gas swap contracts on ICE, some of which were electronically traded and cleared positions on ICE, while others were off-exchange contracts, but later cleared through ICE. Among the trades entered on ICE, some of the swap contracts were in individual contract months (e.g. October, 2006), while others were in calendar strips (e.g. November through March). Due to the difficulty of understanding Amaranth's positions when divided amongst so many types of securities, it is useful to convert all of the securities into the NYMEX futures equivalent value (NYMEX FEQ). For the swap contracts, this is quite easy to do, since the swaps are essentially the same as the NYMEX natural gas futures contract, but one-fourth the size. Thus, one swap contract is worth one-fourth of a NYMEX natural gas futures contract. The option contracts are more complicated, but can be translated by adjusting the position for the delta of the option.[12] Once these conversions have been made, we can aggregate the entire Amaranth position in terms of NYMEX natural gas futures equivalents.[13] Table 4 below shows the positions of Amaranth in the various instruments as NYMEX natural gas futures equivalents on August 31, 2006.

**[INSERT TABLE 4 ABOUT HERE]**

For example, on August 31, 2006, Amaranth had a net position of October 2006 NYMEX natural gas futures equivalent contracts of -94,441. That is, the combined position of NYMEX natural gas futures, options, and swaps and ICE swaps was equivalent to a short position in 94,441 NYMEX natural gas futures contracts. In fact, many of the outright positions on the October 2006 were short (i.e. 64,711 NYMEX natural gas futures contracts, 21,703 and 5,307 NYMEX swap contracts, and 87,625 ICE swaps), but some positions had a long exposure (i.e. 43,523 NYMEX options and 41,381 off-exchange ICE swaps). For October, ICE swap contracts represented the largest component of the trade at 33.16% of the position.

For the entire period, looking at all contract months in which they had positions, the averages are shown in the last row of Table 4. On average, 28.40% of the monthly exposures were through NYMEX natural gas futures contracts, 14.82% in NYMEX options, 34.61% in NYMEX swaps, 10.21% in ICE swaps, and the remaining 11.96% in ICE off-exchange swaps.

[11] These were created to allow traders access to an instrument that would expire one day before option expiration on natural gas futures contracts.

[12] For more on this type of concept, one is referred to any options book or any book on VaR. For example, Hull (2006), Jorion (2006), or Dowd (1999).

[13] The conversion of these positions was done by the NYMEX and the Senate Subcommittee.

Amaranth's actual positions in natural gas future equivalents on August 31, 2006 are depicted in Figure 1 and Table 5. This graph is identical to the graph produced in the appendix of the Senate Subcommittee's report. It contains the Amaranth positions on each contract month in NYMEX natural gas futures equivalents. Before the data on Amaranth's positions was publicly available, Chincarini (2006, 2007a, 2007b) postulated that Amaranth's position was a long winter, short non-winter position. Although, the figure seems to indicate this, it is worth examining the issue further.[14] For the purposes of this analysis, we follow Chincarini (2007a) and define winter contract months to be November, December, January, February, and March. All other months will be considered non-winter months.

**[INSERT FIGURE 1 ABOUT HERE]**

**[INSERT TABLE 5 ABOUT HERE]**

Table 6 presents additional measures of the August 31, 2006 position's of Amaranth in natural gas. The total dollar value of natural gas futures positions by Amaranth in winter months equalled $23,489,626,234. That is, the notional value of all winter contract months was almost $23B across all exchanges and instruments. The total dollar value of non-winter positions was -$16B (-$15,863,435,286). This is consistent with a long winter, short non-winter position. Of all the contract months out until December, 2011, 35 of those months are non-winter months, while 27 are winter months.

Another way to measure whether Amaranth's strategy was long winter and short non-winter is to find the percentage of winter months in which they had long positions versus short positions. For winter months, Amaranth had a long position 63% of the time, while for non-winter months, Amaranth had a short position 69.44% of the time. This is again consistent with a long winter, short non-winter strategy. And within the winter months, they had an equivalent of $28B ($28,812,493,334) long and $5B ($5,322,867,100) equivalent short positions. For the non-winter months, they had an equivalent $17B ($17,626,398,609) of short positions and $1.7B ($1,762,963,322) of long positions.

**[INSERT TABLE 6 ABOUT HERE]**

Thus, although not every winter contract was held long and not every non-winter month was held short, the Amaranth actual positions on August 31, 2006 seemed to be consistent with a long

[14] Although some winter months are actually shorted, the overall positions are smaller.

winter and short non-winter spread trade in natural gas using a combination of NYMEX futures, swaps, and options, as well as ICE natural gas swaps.

It's clear that prior to the events of September, Amaranth was engaged in a natural gas futures position that was long winter and short non-winter. It is not clear that this is the typical trade that they were engaged in prior to September. In order to examine the general position of Amaranth, we look at their position three months prior to August 31, 2006. The NYMEX natural gas futures equivalents of Amaranth's natural gas positions on May 31, 2006 are depicted in Figure 2 and Table 6. The total dollar value of winter month contracts was $12B ($12,576,743,060), while the non-winter months was $8B ($8,443,189,197). Of the winter month contracts, 48.7% were held long, while 70.4% of the non-winter months were held short. The total value of long positions in winter months was $17B ($17,101,267,974), while short positions were $4B ($4,524,524,914); for non-winter it was $2B ($2,782,321,097) and $11B ($11,225,510,295) respectively. Although not a perfectly consistent winter/non-winter spread trade, the general position of the trade is long winter and short non-winter on May 31, 2006.

The natural gas positions of Amaranth on other days during the summer are of a similar nature to those on May 31, 2006 and August 31, 2006 (see Table 6).

**[INSERT FIGURE 2 ABOUT HERE]**

## IV.2 The Rationale for the Strategy

In the previous section, we concluded that Amaranth's primary trading strategy consisted of a spread trade that was primarily long winter natural gas contract months and short non-winter natural gas contract months. Chincarini (2007a, 2007b) noted that such a spread trade had performed well on average since 1990. That is, a long winter, short non-winter spread trade in proportion to the open interest on NYMEX tended to do very well in September. It is not clear whether the Amaranth natural gas traders actually backtested the strategy or whether they used experience combined with their own trader instinct. If one backtests the Amaranth strategy of August 31, 2006 on past years, one finds that the strategy produced a significantly positive average return of 0.74% per month or 8.96% on an annualized basis with relatively small losses in down years (See Figure 3).

**[INSERT FIGURE 3 ABOUT HERE]**

One might naturally ask if there is some potential reason explaining this historical pattern. More specifically, one might ask if there is a justifiable reason for a trade that is long winter and short non-winter to earn an excess return. Natural gas is mainly used for home heating in the winter months. "During summer months, when supply exceeds demand, natural gas prices fall, and the excess supply is placed into underground storage reservoirs. During the winter, when demand for natural gas exceeds production and prices increase, natural gas is removed from underground storage." (Senate Report, p. 17). In many commodity markets, the storage costs of a commodity are priced into futures contracts. Theoretically, the price of a futures contract is given as $F_t = S_t e^{(c+r)(T-t)}$, where $c$ is the continously compounded storage costs of the commodity, $r$ is the opporunity cost of money or the interest rate, and $T - t$ is the time until the futures contract matures.

Thus, a storage operator might use natural gas futures to *naturally hedge* his or her exposure. That is, by selling natural gas winter contracts and buying non-winter months, the storage operator will lock-in his or her profit for storage, which in a perfectly competitive market should cover interest and storage costs. On the other side of this trade would be the *speculator* which buys winter contracts and shorts non-winter contracts providing liquidity to the natural hedgers. In exchange for taking on this risk, the speculator should receive compensation on average. This might explain the positive average return to this strategy over time. Thus, the excess returns from a long winter, short non-winter trade in September might be a compensation to speculators for supplying liquidity to natural hedgers, which consist of storage operators and natural gas producers.[15]

Although a quantitative type of trader would have probably backtested the strategy and traded this in September as some sort of statistical anomaly, it is difficult to determine if Amaranth's motive was the same. It is somewhat reassuring to find that the Amaranth strategy generated positive average returns historically. However, in my opinion, the traders were not relying on statistical techniques, but rather were using their instincts and experience in natural gas futures which was conditioned by this historical pattern. In reading through many of the instant message and email conversations between Brian Hunter and other traders, it seems that rather than some well-designed trading strategy, their trades were driven by market sentiment, weather conditions, and trader instinct.[16] For example, in one email, an Amaranth employee writes to Brian Hunter,

[15]The forward curve for natural gas futures looks like a sine wave with natural gas futures prices high in winter months and low in non-winter months. This is for a different reason which has to do with low demand for natural gas in summer months and high demand for natural gas in winter months.

[16]These documents were obtained by subpoena from the Senate Subcommittee and used in the public presentation of the Amaranth case. In particular, they were taken from Exhibit #9 of the Senate Subcommittee Investigation

*I think you should sell 15,000 red March April and buy 15,000 (or more) front Mar/Apr. My rationale is not that you should short the reds, just that you're moving risk...not increasing it. Leveraging it to the part of the curve that is undervalued and lightening up on the one that is perhaps fair value.*—Amaranth Employee, Email to Brian Hunter, July 28, 2007 (Source: Senate Subcommittee, Exhibit #9)

# V The Risks of Amaranth's Strategies

As was described in Section II.4, Amaranth had an apparently sophisticated risk management operation with 12 dedicated risk managers supporting each desk, including a Chief Risk Officer. They used daily VaR and stress reports, so one might naturally ask how they did not foresee the risks they were taking on August 31, 2006. In fact, the CEO of Amaranth stated in a conference call to investors that:

*Although the size of our natural gas positions was large, we believed, based on input from both our trading desk and the stress-testing performed by our energy risk team that the amount of risk capital ascribed to the natural gas portfolio was sufficient. In September 2006, a series of unusual and unpredictable events caused the Funds' natural gas positions (including spreads) to incur dramatic losses while the market provided no economically viable measure of exiting these positions.*—Nick Maounis, Conference Call to Investors, September 22, 2007

It could be that historical measures of natural gas volatility were insufficient to identify the types of events that occurred in September, 2006 or it could be that Amaranth simply ignored the warning signs from risk measurement systems or it might be that market risk was not the principal risk of the positions, but it was rather liquidity risk. In this section, we take the actual Amaranth positions in natural gas and attempt to construct both market risk and liquidity risk measures using only data up to August 31, 2006 to examine whether or not the risks of the Amaranth portfolio could have been obtained from basic risk measurement tools. In particular, we examine three sources of risk for Amaranth - market risk, liquidity risk, and funding risk. Market risk is the risk that occurs from the volatility of investment returns, liquidity risk measures the degree of difficulty in exiting a given trading position, and funding risk measures the extent to which they were able to meet margin calls on their natural gas positions.

documents.

## V.1 Market Risk

In order to evaluate Amaranth's market risk on August 31, 2006, simple historical VaR (value-at-risk) measures are constructed for their actual positions. We consider three ways to measure this VaR. The first method is computed by recreating the August 31, 2006 natural gas exposures of Amaranth in other years from 1990-2005 (See Table 5). Table 5 shows the weight of Amaranth's exposure to each contract month of natural gas futures. This weight is computed by taking the absolute value of the notional value of each contract and dividing it by the sum of the absolute notional value of all other contracts. For example, for the October contract month, this was equal to 10.68%. For prior years, the weight scheme was kept similar. That is, in each prior year, the weight of the October current year contract was kept at 10.68%. The corresponding returns of these positions was computed in every year from the last trading day in August to the last trading day in September. These 16 years of September returns were then used to calculate a sample average and standard deviation of the strategy in September to be used to estimate a VaR for the strategy in September.[17]

The VaR was computed as

$$\text{VaR}_t = V_t(\mu - k(\alpha)\sigma) \tag{1}$$

where $\mu$ represents the average historical return of the strategy in September, $\sigma$ represents the standard deviation of the historical September returns, $V_t$ represents the notional value of the portfolio positions, and $k(\alpha)$ represents the critical value from the normal distribution for a confidence level $(1-\alpha)$ (i.e. $k(0.025) = 1.96$ for a 97.5% confidence interval).

The second method is a modification of the first method to account for non-normally distributed returns. It is the Cornish-Fischer expansion VaR ((Cornish and Fisher (1937), Ord and Stuart (1994), and Favre and Galeano (2002)). This method adjusts the VaR calculation taking into

[17]The return calculation for the strategy is given by $r_t = \sum_{i=1}^{N} w_{i,t-1} r_{i,t} \phi_{i,t-1}$, where $w_{i,t-1}$ is the weight of contract $i$ on the last trading day of August in any given year, $r_{i,t}$ is the return of natural gas futures contract $i$ from the last trading day in August to the last trading day in September in any given year, and $\phi_i$ is an indicator variable that equals 1 if Amaranth was long in that particular futures contract and equals -1 if Amaranth was short that particular contract month, and $N$ represents the total number of contract months (e.g. 63 from October 2006 to December 2011). In some years, especially in the early 1990s, there were not as many natural gas futures positions and thus the weights were renormalized so as to be relatively the same between any two contracts. For example, on August 31, 1990 there were only 12 contracts from October 1990 to September 1991. Thus, the weight for October 1990 was -0.1697 and the weight for November 1990 was 0.14483. The relative weight was still -1.172 as in other years.

account the skewness and kurtosis of the distribution of returns. Including terms up to order -1, the formula used in this paper is:

$$k_{cf}(\alpha) = k(\alpha) + \left(\frac{k(\alpha)^2 - 1}{6}\right) m_3 + \left(\frac{k(\alpha)^3 - 3k(\alpha)}{24}\right) m_4 - \left(\frac{2k(\alpha)^3 - 5k(\alpha)}{36}\right) m_3^2 \tag{2}$$

where $k(\alpha)$ is the same as before, $m_3 = \frac{1}{T}\sum_{t=1}^{T}\left(\frac{r_t - \bar{r}}{\sigma}\right)^3$ is the skewness, $m_4 = \frac{1}{T}\sum_{t=1}^{T}\left(\frac{r_t - \bar{r}}{\sigma}\right)^4 - 3$ is the excess kurtosis, and $k_{cf}(\alpha)$ is the corresponding Cornish-Fisher critical value for the specified confidence level. The VaR calculation is the same as before except $k_{cf}(\alpha)$ is used rather than $k(\alpha)$ for the same confidence level.

The third method is to measure the most recent volatility in natural gas futures over the three months prior to August 31, 2006. Ideally, one would like to recreate the same type of positions in the past as what Amaranth had on August 31, 2006, but there is no obvious way to do this, since a whole host of different contract months are introduced. Instead, the actual positions of Amaranth from May 31, 2006 to August 31, 2006 are used and the daily returns calculated. The VaR for September on August 31, 2006 is then computed as follows:

$$\text{VaR}_t = V_t(\mu_d T - k(\alpha)\sigma_d\sqrt{T}) \tag{3}$$

where $\mu_d$ represents the daily return of the strategy over the past three months, $\sigma_d$ represents the standard deviation of daily returns over the last three months, and $T$ represents the number of trading days that Amaranth used for VaR (i.e. 20 days). The confidence levels were chosen to conform closely with the risk reports that Amaranth produced internally on a daily basis (see Section II).

**[INSERT TABLE 7 ABOUT HERE]**

Table 7 shows the potential VaR from the spread positions and different confidence intervals. Suppose we take the 99% confidence interval for use with our Method 1 VaR calculation at the end of August 2006. A notional position in the spread trade of \$10.228B would give us a VaR calculation of -\$254.95M.[18] The actual leveraged position of Amaranth had an estimated VaR of \$1.33B. This is a sizeable amount of VaR, however it is not the actual amount they lost in September. The

[18]This net asset value differs from that in Chincarini (2007b) due to a typo in the earlier paper.

actual amount they lost from August 31, 2006 to September 21, 2006 *had the positions been held constant* was around \$3.295B which is listed under the column "Actual" in the table.

Prior to that year, the worst lost in September of any year with the same sized position since the opening of natural gas trading in 1990 would have been -\$719.71M. The average return of the spread position over the prior 16 years was 0.7466% with a sample standard deviation of 1.3902 in September. Thus, if Amaranth used a simple risk measurement system as used here, they would have been chasing an average return of \$399.6M ($0.7466 \cdot \$53,524,979,536$) with a potential 99.95% VaR of -\$2.048B.

Thus, they were chasing an 4.13% return in September for a "worst-case" scenario of a loss of 21.2%.[19] This is, in itself, quite risky, but perhaps part of their philosophy. It should also be noted by looking at Figure 3 that the historical returns of such a spread trade seemed to look favorable. The strategy provided mainly positive returns with a positively skewed distribution. The largest negative return of the trade was -1.34% in 1991 on an unlevered basis.

The other methods show similar results. The Cornish-Fisher VaR is actually smaller reflecting the negative kurtosis of the sample distribution and very slight skewness.[20] The VaR based upon the last three months of Amaranth positions reflected a lower VaR than the historical calculation, but basically near the same magnitude.

It is clear from this exercise, the losses of September were not entirely explained by VaR calculations. The further losses may have come from another source of risk which they failed to manage as well; liquidity risk.

## V.2 Liquidity Risk

Liquidity is defined as the ability to sell a quantity of a security without adversely changing the price in response to your orders. Models for liquidity risk are not as common place as models for market risk. One simple precautionary measure that practitioners use to control liquidity risk is to measure the size of their trades versus the average daily trading volume of a security. A rule-of-thumb is to not own positions greater than 1/10 to 1/3 of the average daily trading volume over some specified time interval, like the last 30-days of trading.

[19]This downside percentage is for the 99.99% confidence level VaR, it would be much less for the 99% VaR at -13.8%.

[20]It should be noted that the Cornish-Fisher VaR critical values began to decrease when the critical values where extended to a 99.99% confidence interval.

Figure 4 shows Amaranth's August 31 positions as multiples of the trailing 30-day average daily trading volume in each contract for the spread position. For example, Amaranth's exposure in terms of NYMEX natural gas futures equivalents in July 2008 futures contracts represented 253 days of the average daily trading volume. Even though many of the Amaranth positions were not with NYMEX, and instead with ICE, these positions were extremely large relative to the average daily trading volume of the largest natural gas futures exchange. In some cases, the positions are hundreds of times the 30-day average daily trading volume. It is quite clear that Amaranth was taking immense risk with respect to liquidity.

[**INSERT FIGURE 4 ABOUT HERE**]

Another way of depicting Amaranth's natural gas positions is to compare them to the open interest of NYMEX natural gas futures contracts (NYMEX NGFOI). Figure 5 compares the actual Amaranth positions to the open interest of NYMEX natural gas futures. Figure 5A shows all the Amaranth positions (including ICE positions as well) as a percentage of the NYMEX NGFOI. In many contract months, this is greater than 100%.[21] Figure 5B shows only the positions on NYMEX as a percentage of NYMEX NFGOI. It is still very high and in some contracts greater than 100% as well. Figure 5C shows only Amaranth's position in NYMEX natural gas futures as a percentage of NYMEX NGFOI. Even by this very direct measure of Amaranth's positions on the NYMEX exchange, their positions were excessive representing more than 50% of the open interest in many contracts and almost 100% in some contracts. In some contracts, Amaranth had positions of nearly 100,000 contracts, which represents roughly 1 trillion cubic feet of natural gas, 23% of the amount of natural gas consumed by residential users in 2006, and 5% of the total amount of natural gas consumed in the United States in 2006 (Senate Report, p. 64).

[**INSERT FIGURE 5 ABOUT HERE**]

Thus, while market risk measures such as VaR indicate that Amaranth may have had a VaR of about -$2.048B, their liquidity risk was also very high. Thus, Amaranth was certainly being

[21]The reason that the percentage of Amaranth positions is greater than 100% is twofold. Firstly, included in this calculation are Amaranth positions on ICE, which thus is additional contracts to what NYMEX has. Secondly, the measure of Amaranth's positions included options, swaps, and other instruments that are not strictly NYMEX natural gas futures contracts, but are natural gas futures equivalents as computed by the Senate Subcommittee and NYMEX. Thus, only in Figure 5C should percentages not be greater than 100%. In Figure 5C, only Amaranth NYMEX natural gas futures positions are compared to NYMEX natural gas futures open interest.

imprudent with respect to its natural gas futures positions in terms of the size versus the market size. This may have resulted in the extra \$1246.58M losses not accounted for by simple VaR measures.[22]

In addition to these measures showing Amaranth's excessive positions in natural gas, Amaranth was continuously reprimanded by NYMEX for violating trading standards and position limits on NYMEX. The Senate Subcommittee report discusses these violations in detail (See Senate Report, pp. 90-99). On April 26, 2006 for example, Amaranth violated trading rules on the May 2006 futures contract resulting in a letter from NYMEX and a CFTC investigation. In addition to this, Amaranth exceeded NYMEX position limits virtually every month in 2006 triggering reviews of Amaranth's positions.

Of particular note was an August 8, 2006 complaint by NYMEX officials that Amaranth's position in the September 2006 contract (near-month contract) was too high at 44% of the open interest on NYMEX. Figure 6 shows that Amaranth reduced this short position by the day's close by 5,379 contracts (see the change in NYMEX contracts from the close of August 7 to the close of August 8), but they also increased their similar exposure short position on ICE by 7,778 contracts. Thus, ironically, the request by NYMEX to reduce Amaranth's positions led Amaranth to actually increase their overall September 2006 position. At the same time, they also increased their exposure to the October 2006 contract; a contract that is a close substitute to the September 2006 contract. In particular, they had increased their October 2006 position in NYMEX natural gas futures by 7,655 contracts and their equivalent position on ICE October 2006 contracts by 4,984.

[**INSERT FIGURE 6 ABOUT HERE**]

On August 9, 2006 the NYMEX called Amaranth with continued concern about the September 2006 contract and warned that October 2006 was large as well and they should not simply reduce the September exposure by shifting contracts to the October contract. In fact, by the close of business that day, Amaranth increased their October 2006 position by 17,560 positions and their ICE positions by 105.75. For September 2006, Amaranth did follow NYMEX instructions by reducing NYMEX natural gas positions by a further 24,310, but increased September ICE positions by 4,155.

[22]Here we are speaking about the total losses of \$3,295.5B that would have resulted had they held their August 31, 2006 positions until September 21, 2006. The actual Amaranth losses were even higher at \$4.35B. This discrepancy is discussed in more detail in Section VI.

On August 10, 2006 another call from NYMEX urged Amaranth to reduce the October 2006 position since it represented 63.47% of the NYMEX open interest. In response to this call, Amaranth reduced the October 2006 position by 9,216 contracts, but increased their similar October 2006 ICE position by 18,804 contracts.

By the end of this three-day session of calls from the NYMEX warning of Amaranth of its position size in September and October contracts, Amaranth had actually increased their overall positions from August 7, 2007 to August 11, 2006 in those two contracts by 16,484 (a decrease in September 2006 positions by 23,143 and an increase in October positions by 39,627).

The Senate Report highlighted one of the problems with the current system is that electronic exchanges, like ICE, are not regulated. Thus, Amaranth was able to shift their exposure and actually increase it by using ICE without the CFTC or any other regulatory body aware of the increasing risk they were taking. In fact, in an instant message conversation on April 25, 2006, Brian Hunter wrote about ICE that "...one thing that's nice is there are no expiration limits like NYMEX clearing." (Senate Report, p. 98).

Although NYMEX only uses its position limits as guidelines of whether or not to investigate an entity's position, it is interesting to note how far above these guidelines Amaranth was. The NYMEX guideline is to examine entities with an amount over 12,000 contracts in any given maturity. One can see from Figure 6 that Amaranth had exceeded this "guideline" by a substantial amount. Perhaps a quantitative rule would be better than a qualitative rule. With quantitative rules, Amaranth's positions would never have been able to be so large.

The reconstruction of the VaR of Amaranth's positions on August 31, 2006 was high, but cannot entirely explain Amaranth's losses in September, 2006 unless one designates the Amaranth collapse as a 5 standard deviation event.[23] I think Amaranth's traders and senior management were well aware of a VaR number similar to the one produced in this paper. I think that they were willing to take this amount risk given the expected return they hoped to achieve. With regards to their liquidity risk, while I believe the traders were very aware of the size of their positions, I am not sure that senior management in Greenwich really understood the extent of it. Firstly, Amaranth's risk management with regard to liquidity did not explicitly specify position limits as a percentage of volume traded or open interest on the exchanges. So risk of this type may not have been on senior management's rader in an explicit way. Secondly, Amaranth allowed Brian Hunter and his

[23]This would imply a VaR at a 99.99997% confidence level.

trading team to move to Calgary without any risk management team (FERC Report, p. 18-19). Thirdly, Amaranth was slowly increasing the size of their natural gas positions over the summer of 2006.

I think Amaranth's senior management allowed Mr. Hunter too much freedom because they had enjoyed his prior success and wanted to believe that he really was "...brilliant..."[24] and also independently "...really, really good at taking controlled and measured risk."[25] Even this statement by the CEO reveals problems with their risk management philosophy. It shouldn't be the trader that one is confident about with regards to risk management, but rather the risk manager which is monitoring that trader's risk.

In summation, I think the energy traders of Amaranth were well aware of the large size of their positions and either didn't care (i.e. the free option) or didn't realize how perilous such a position could be. I think the senior management in Greenwich knew of the market risk, but overlooked the position size by giving too much credit to Mr. Hunter, partly out of greed.

## V.3 Funding Risk

In this section, we dicuss funding risk. This is related to liquidity risk, but is focused on leverage in particular. Any leveraged position implies that the trader borrowed some of the capital to finance his position. In the case of a futures exchange, like NYMEX, a trader implicitly leverages when a futures contract is bought or sold short. For example, if a trader buys 1 contract of the October 2006 natural gas futures contract on August 31, 2006, the exchange requires him to post $12,150 of non-member customer initial margin for a notional value of $64,800. The leverage in this case with respect to the position is 5.33 ($64,800/$12,150). Theoretically, the value of the futures contract could go to 0 the next day and the exchange would be short $56,250 which it would request from the trader. If the trader didn't have this amount available, he would declare bankruptcy. Most traders will not employ a leverage so high because the risk of bankruptcy would be high.

In a more realistic setting, a trader will have many positions in natural gas futures and in addition to the initial margin required by the exchange, they will keep other cash or capital on-hand so that their fund leverage is less than that required by the exchange.

Exchanges, like NYMEX, compute margin requirements daily by valuing all positions of the

[24] Unidentified trader's email to Mr. Hunter when he was making money in July. Source: Senate Report, Exhibit #9.

[25] Public statement by CEO Maounis about Mr. Hunter.

trader to the market versus his initial margin deposit. On NYMEX, they require any profits or losses on the positions to be reflected in the customer's margin account. Thus, a complicated position like that of Amaranth will have cash flow needs every day. When the positions are profitable, some of the excess margin can be credited to Amaranth, and when negative, Amaranth will have to supply additional cash to cover the margin call.

Leverage and funding risk are very much interlinked. For example, if a trader purchases that same futures contract but keeps the remainder funds in cash (e.g. \$56,250), the trader will never have funding risk, because although the future contract was purchased on margin, the trader's fund is not levered. Suppose the trader buys 2 contracts, although he only has capital to cover 1 contract. This trader's fund now has a leverage of 2 (notional value of position / cash on-hand plus initial margin). Now there is some funding risk, although it is still low. The trader will be able to meet all margin calls until the position falls by more than 50%. Thus, a rule-of-thumb in this simple example is that a trader will face funding risk anytime the return of his levered position falls by $\frac{1}{l}$, where $l$ is the amount of fund leverage. Of course, this is only true in our simplified example, where all excess capital is held in cash. It becomes even more complicated when some of this excess capital is invested in other assets.

In Amaranth's case, the leverage of natural gas future equivalents on August 31, 2006 was 5.23 (\$53,524,979,537 / \$10,228,192,000) with respect to just their natural gas exposures. To the extent that they were investing on margin in other markets, their leverage might have been even higher. Amaranth had set aside up to \$3B of their capital in cash to meet liquidity needs according to Mr. Artie DeRocco in conversations with Nymex's Michael Christ on August 15, 2006. To the extent that only \$3B might have been available for margin calls, Amaranth's leverage could have been considered as high as 17.84 (\$53,524,979,537 / \$3,000,000,000). That would imply that even a -5.6% return on their futures position would cause them funding problems. On August 31, 2006 Amaranth's initial margin on NYMEX exceeded \$2.5B. This high margin requirement was primarily due to the notional size of Amaranth's position. In fact, if we assume that NYMEX required the maximum margin for each NYMEX natural gas equivalent, then Amaranth's positions would require \$5,306,512,760.[26] Even the actual margin requirement on that day of \$2.5B left very little room for

[26] Of course, this is unrealistically high, because it requires many assumptions. The primary assumption is that for every natural gas equivalent held, NYMEX would require the full non-member initial margin. For spread positions, consisting of two months of contracts, the initial margin requirements are much less per position at \$1000 per position. Also some of these positions are for option contracts might not require margin. Thus, this number represents an upper limit of the total margin required. Finally, this also assumes that the initial margin was calculated as if all

adverse returns for Amaranth. If we observe Figure 10 on Amaranth's daily profit-and-loss from their natural gas positions, one can see that by September 8, 2006 their total additional margin required would have been \$697M, by September 15, the additional margin required would have been \$2.287B, and by September 21, it would have been \$4.07B. Clearly, this was unsustainable as Amaranth did not have the cash to meet these margin calls. If we assume that on August 31, 2006 they had exactly \$2.5B in initial margin, by September 21, 2006 they would have required around \$6.57B of margin.[27]

What differentiates this sort of risk from other risk is that even if the strategy turned out to be profitable by month-end (which it did not), Amaranth would not have had enough funding in place to hold on to their positions until month-end. Thus, even had Amaranth's trade had been logical from a VaR perspective and a liquidity perspective, it would have not been logical or prudent from a funding risk perspective.

To give an analogy of funding risk, think of a trader that bought a government bond for \$90 that matures in 20 days and will be worth \$100 on that day for certain. If this trader is forced to close the position on any day before month's end due to funding reasons, it would yield him a negative return even if it's guaranteed to make a profit by month's end.

## VI Events in September

The price movements of natural gas futures in September 2006 were quite different than in past years. Figure 9 shows a timeline of the events in September and leading up to September. Historically, a spread trade in natural gas futures had done quite well. Figure 7 shows the average returns of different maturity futures contracts in the month of September from 1990 - 2005. The x-axis plots the contract months forward. Thus, in this particular figure, 1 represents the returns for the nearest October futures during September, 2 represents the returns for the nearest November contract in September, and so on. One can see that generally, winter month returns are higher than non-winter month returns and that natural gas prices have tended to rise on average in September for the first 36 months out. Some of the near contracts had returns as high as 5.73% on average in

positions were constructed on that particular day. To actually reconstruct the exact margin required by Amaranth on that day is not possible without further information that is not available. However, we do know from statements by NYMEX that on August 31, 2006 the actual margin requirement on that day exceeded \$2.5B.

[27]Of course, this is only approximate, as some of the natural gas equivalent positions were options. Also, this would be the total margin on NYMEX and ICE together.

September.

**[INSERT FIGURE 9 ABOUT HERE]**

**[INSERT FIGURE 7 ABOUT HERE]**

In September of 2006, the natural gas futures market behaved entirely differently than it had historically. Figure 8 shows the behavior of natural gas futures returns in September of 2006. One can see from this figure the dramatic negative returns of natural gas futures in September, which was as low as -27% for front-month contracts. One can also see that the negative returns were less for non-winter months. That is, although returns were severely negative for most natural gas futures contracts, they were worst for winter months, all the way across the maturity spectrum. For example, for the first year out, the contract months 2-6 did poorly, representing the contracts for November, 2006 - March, 2007, while in months 7-13 the negative returns are less severe representing the months April, 2007 - October, 2007. This pattern is seen for futures contracts in future years as well. This pattern would not bode well for a strategy that was long winter and short non-winter months.

**[INSERT FIGURE 8 ABOUT HERE]**

Figure 10 shows the profit and loss (P/L) of Amaranth's natural gas futures equivalent positions on a daily basis in September, 2006. Figure 10A shows the daily P/L , while Figure 10B shows the cumulative P/L starting at zero on August 31, 2006. The daily P/L is computed using Amaranth's actual daily positions from August 31, 2006 - September 15, 2006. After September 15, 2006, no data on their positions was available and the daily P/L was computed assuming Amaranth maintained their September 15, 2006 natural gas positions.

One can see that from August 31, 2006 to September 7, 2006 Amaranth had lost about $199.5M on their natural gas positions. This soon deteriorated very quickly. By he close of business on September 20, they had lost about $3.774B on their natural gas futures positions. Margin calls on these losses eventually led Amaranth to sell the energy portfolio to Citadel and J.P. Morgan with the final transfer occurring on September 21, 2006.

If one computes the losses of Amaranth's natural gas positions from August 31, 2006 - September 21, 2006 assuming the positions were not altered during the period, the losses amount to $3.295B ($3,295,239,642). The actual losses computed in Figure 10 total $4.0707B. This difference between the losses indicates that the trades that Amaranth executed between August 31, 2006 and September 15, 2006 served to increase their losses by an additional $775.5M. In fact, these additional losses were probably not accidental or random. That is, given the losses up to September 7, 2007, the Amaranth energy traders may have exercised their "free option" of limited downside liability if things went wrong by increasing the bets in response to troubled times. A correspondence between an Amaranth trader and Brian Hunter indicates a line of reasoning along this path.

*Tell me if I am wrong, but we have 3 choices here.*

*(1) shut down and start energy fund, lose 0.3 to 1.0 getting out, and have great future potential. Hiwever, if we lose that, who is going to want in on the energy fund? If h/j drops to 1.50 or worse, the deferred positions are all going to get obliterated too.*

*(2) jump back in and help this market out. Risk losing some investors due to risk profile, but manage along until we get the proper catalyst to exit positions. Start energy fund when we can later. Without the market's ability to absorb some xh or even some back length right now, this market in a world of trouble. 2 days ago things were fine, but it feels like it just tipped overboard on risk. There is comfort selling spreads, and comfort selling price right now. If you were a cash trader caught long hub gas right now, would you buy or sell January?*

*(3) Sit and wait. Let market take it's course, find natural fixed price demand.*

*There is not catalyst right now. That's the problem. You exit this size without one (ithout exiting every positions in your book), and we got a big problem. Things were fine when we were holding the risk for the market, b/c we could handle it. That risk in 30 other hands is a much more dangerous proposition.*

*Calhoun think #2*
*Rummy thinks #3*
*And I haven't decided yet.*

*All I know is I am personally 1 more bad day away from stopping out...can't afford to drop below 30 for my family.*—Amaranth Trader Shane Lee to Brian Hunter, September 7, 2006 16:54

One of the suggested choices in this email correspondance is to increase their positions (choice #2), which some were opting for. In fact, after this email correspondence, Amaranth modified their natural gas future positions over the next few days. Although it's difficult to quantify in a single number exactly what they did, the total number of absolute NYMEX natural gas equivalent contracts did increase from around 462,992 on September 7, 2006 to 508,923 on September 13, 2006. Thus, the additional losses of Amaranth in these days were partly due to increasing the actual exposure to natural gas futures contracts, partly due to modifying the positions across the maturity spectrum, and partly due to the movement of the options and other positions in the Amaranth portfolio.

## VII Lessons for Regulators and Hedge Funds

It is difficult to construct lessons after major crises, because often times the specific corrections to certain situations will only cause new crises to occur under different loopholes or conditions. Nevertheless, I think lessons from other crises have been useful. For example, after the LTCM crisis of 1998, hedge funds learned that making sure lines of credit are really lines of credit is extremely important. Hedge funds also learned that stress testing sophisticated trading systems includes the worst case scenarios, for example when the correlation of seemingly unrelated strategies goes to 1.

In the aftermath of the Amaranth collapse, there are some lessons as well. Firstly, liquidity risk is a real risk that must be accounted for by both exchanges and hedge funds, money managers, or traders. For exchanges, it means strict limits should be placed on a customer's positions. While NYMEX has soft limits, they allowed human judgement, conversations with Amaranth, and greed to soften those limits up to a point, where they did not really know the severity of the enormous positions of Amaranth. That is, not only should exchanges consider strict position limits, they should also consider quantitative rules for managing these limits, rather than ad hoc human judgement. For hedge funds, money managers, and traders the lesson has long been known — don't own too much of a market in combination with leverage. If something adverse happens in that market and the position falls and margin calls are made, selling the positions only drives prices against the position more forcing perhaps a bankruptcy. Limitations to one's position in a market will ensure enough other counterparties to a trade and keep liquidity in that market.

Secondly, transparency across exchanges in the same market may be useful. In the case of Amaranth, the NYMEX knew of Amaranth's NYMEX positions, but did not know of the other positions held with ICE. Although the CFTC oversees the NYMEX, they had no jurisidiction over ICE, since ICE is an unregulated energy trading platform. Were there a system held by the CFTC that could oversee all positions on energy platforms, the excess of Amaranth could have been spotted. By forcing Amaranth to hold much more reasonable positions, Amaranth investors would have ultimately been better off. Also, the possible manipulation by one entity of security prices would be avoided. Amaranth's selling of large positions may have caused intense volatility in natural gas prices causing natural users of natural gas (i.e. households) to pay high prices which may have been artificially high due to the excessive positions of Amaranth. In fact, Amaranth and Amaranth traders are currently being sued over the matter (FERC (2007)).

One of the steps to improve transparency in the U.S. markets is a bill introduced on September 17, 2007 by Senator Carl Levin of Michigan to regulate electronic energy trading facilities by registering with the CFTC (Levin (2007)). The bill also proposes to provide trading limits for energy traders that can be monitored by the CFTC across all energy trading platforms and exchanges, requires that large domestic traders of energy report their trades on foreign exchanges, and it defines precisely what constitutes an "energy trading facility" and an "energy commodity".

Thirdly, more standard measures of liquidity risk ought to be devised so that, as with VaR, traders, risk managers, regulators, and exchanges have a language to communicate with.

Fourthly, there are lessons for internal risk management. Rather than have risk managers join individual desks, it might be better to keep risk managers somewhat detached from the individual traders and trading desks. It might also help to follow guidelines that many large banks have of allotting only certain risk capital to certain traders and diversify across the firm, rather than have one trader like Mr. Hunter use the majority of the firm's capital and be responsible for the majority of the firm's performance. Afterall, Amaranth was not an energy trading hedge fund, it was a multi-strategy hedge fund. Along that line of thought, one might even consider a different incentive scheme for risk managers. Risk managers are not paid as well as traders. This causes their voice to be less important in the firm. And of course, risk managers' bonus also depends on firm profits. Thus, to a certain extent they will also be reluctant to reduce the firm's aggressive trading activities. They have a "free option" too. It's not clear that there is a simple way to restructure the incentives of risk managers, but it might be worth thinking about.

Fifthly, spread positions can lose money and are not "arbitrage positions", especially when the size of these positions is large.

There are critics of the new proposals for regulation in the US natural gas markets. The criticisms fall into four categories. Firstly, there is a camp that believes Amaranth's positions were not too big for the market and that setting strict positions limits will compromise "...the efficient transfer of risk in the market place." (Watkins (2007)) Secondly, some people do not wish there to be multiple regulatory agencies regulating the natural gas futures market. Thirdly, some people worry that regulation will cause business to transfer to overseas markets. Finally, some argue that the regulation will ultimately not work, because market participants will find other loopholes.

Each of these criticisms will be discussed in more detail along with my own thoughts with respect to each of them. The first criticism is that position limit constraints will prevent "...legimate speculation..." and thus make markets less efficient. Also, the critics worry that position limits and laws can become outdated. The first comment assumes the proportion of arbitrageurs is very small in the market place. To the extent that there are many speculators in natural gas, the transfer of risk can still be accomplished — it just will reduce the likelihood that the speculation is in the hands of just one large speculator. Whilst it is true that laws will become outdated, it doesn't mean they are not useful in the short-run. In addition, position limits can be made relative so that they do not become outdated quickly. For examnple, rather than have a limited specific number of contracts for each speculator, an exchange could have that number depend upon some percentage of average daily trading volume or of open interest. Also, regulation could allow exchanges and governing bodies to update position limits as market conditions change.

The second criticism is about the number of regulatory bodies in the natural gas markets. Currently, some market participants, including major investment banks, like Goldman Sachs, Morgan Stanley, Merrill Lynch, and J.P. Morgan, are trying to fight efforts of Congress to give both the FERC and the CFTC authority over the commodities markets. Their argument is that too many regulatory agencies might raise confusion and costs among market participants. While this is certainly a negative, the Levin proposal does not encourage multiple regulatory bodies. It specifies the CFTC as the only regulatory body. However, the reality is that when market participants are perceived to have acted incorrectly, many affected parties may resort to legal action as the FERC has with regards to Amaranth even if they are not explicitly assigned the role of regulator.

The third criticism is that increased regulation will lead market participants to overseas trading venues, such as Singapore. While this is always a possibility, it could be argued that the increased transparency and minimal standards of the US exchanges may draw people to the US exchanges precisely for these reasons. For example, although listing requirements on the NYSE are more stringent that those of NASDAQ, the NYSE has not gone out of business despite the rise of the NASDAQ. There will, of course, be firms that find it more desirable to go elsewhere.

The fourth criticism is that regulators "...will always be one step behind the innovating and evolving markets." (Watkins (2007)) This statement is absolutely true. However, this does not mean that regulatory constraints in cases where market failures or externalities exist are not appropriate.

The correct question is whether or not externalities and market failures potentially exist in the market for natural gas. In the end, we must answer this crucial question before deciding whether regulation is a good or a bad thing.

Without regulation, Amaranth was able to acquire enormously large positions on NYMEX and ICE that may have led to a distortion of natural gas prices which ultimately effected consumers of natural gas.[28] However, even though Amaranth's positions on NYMEX were regulated by the CFTC, they still were extremely large. So it is not clear that the regulation *per se* will solve the problem. The position limits on NYMEX were very loosely enforced and subject to interpretation by NYMEX officials. It is only at late stages of the Amaranth debacle that Amaranth moved substantial positions from NYMEX to the unregulated ICE.

Although this paper was not primarily concerned with the issue of position limits, a very crude investigation was done using the trades of Amaranth from June to September in 2006. Using data on the daily Amaranth positions in natural gas on NYMEX and the actual natural gas futures daily returns, the relationship between these two variables was measured. The first indication was to run the following regression:

$$r_{it} = \alpha + \beta \frac{\Delta Q_{it}}{OI_{it}} + \epsilon_{it} \tag{4}$$

where $r_{it}$ is the return of contract $i$ on day $t$, $\Delta Q_{it}$ is the change in Amaranth's position of contract $i$ by number of contracts on day $t$, $OI_{it}$ is the open interest of contract $i$ on day $t$ of that particular contract, and $\epsilon_{it}$ is an error term. There is an issue of simultaneity in this equation, as well as the issue of omitted variables.[29] The simultaneity issue arises because, not only might natural gas prices be effected by Amaranth's selling of positions, but since the returns are close of business to close of business, Amaranth might also respond to moving prices by selling or adjusting positions intraday. For now, we will ignore these issues and simply look at the correlations.

**[INSERT TABLE 8 ABOUT HERE]**

[28]A distinction should be made between manipulation of natural gas prices and impacting natural gas prices due to the large size of a trade. The former is illegal according to Sections 6(c), 6(d), and 9(a)(2) of the Act of the CFTC authorize the CFTC bring enforcement actions against any person who is manipulating or attempting to manipulate or has manipulated or attempted to manipulate the market prices of any commodity, in interstate commerce, or for future delivery on or subject to the rules of any registered entity. Both price manipulation and price impact are valid concerns for regulators, but one is illegal.

[29]Omitted variables cause the estimated coefficients in the regression to be biased. It is not clear ex-ante which way the bias goes. Simulataneity also results in biased and inconsistent estimates. Usually, the bias is upwards.

These simple regressions reveal no influence whatsoever of Amaranth's trades on natural gas futures returns. Even when conditioned on trades of a size of 10% of the open interest, the coefficients are all insignificant for both buys and sells except in the case of buys greater than 50% of the open interest.

Since these regressions have some issues, like omitted variables and simultaneity, another approach was taken to investigate Amaranth's influence on natural gas prices. For every trading day from June 1 to September 15, 2006, the NYMEX natural gas futures contracts were split into two buckets. One bucket contained contracts that Amaranth actually made trades in, while the other bucket contained contracts that had positive volume for the day, but that Amaranth did not trade. One way to investigate Amaranth's influence on natural gas prices is to compare the average returns of the contracts that Amaranth was buying with the other contracts were Amaranth was not buying. These average returns can be computed for various cuts of the data as before. These averages were also computed by matching the exact trading days, which only computed averages on days where Amaranth made trades in some contracts and other entities made trades in other contracts, and also simply comparing all trades that occurred. Table 9 contains the results of this investigation.

**[INSERT TABLE 9 ABOUT HERE]**

Although, no formal tests were done for the difference in the means, for Amaranth buy trades, there does not appear to be a significant difference in the mean returns. In fact, the mean returns of contracts that Amaranth did not buy were higher on average than those that they bought. There is one exception to this, both for matched trading days and without matching tradings days, trades by Amaranth of greater than 30% of the contract's open interest led to higher average returns on the buy side. This is some evidence that large trades by Amaranth pushed up prices.

On the sell side, the story appears stronger. For almost all levels of trading, the returns on contracts that Amaranth sold have higher negative returns than on contracts were Amaranth did not sell. Thus, there is some evidence that Amaranth's large positions may have influenced natural gas futures prices, but it is not extremely strong. For trades greater than 30% of the open interest, the evidence does point to Amaranth's trades influencing natural gas prices.

The Senate Report suggested that Amaranth's buying of January 2007 contracts and selling of November 2007 contracts may have led to an increase in the spread between these two contracts from January - April, 2006. Using the same methodology as before and examining trades of the

January 2007 contract in isolation from January 2006 until the end of April 2006, I find a significant coefficient of 10 for buy trades by Amaranth indicating that for every 10% of open interest that they traded they moved daily prices for that contract by about 1%. For the November, 2006 contract I find a significant coefficient of -8.23 for sells. Thus, over this period, using this crude regression technique, it seems that Amaranth's trading was correlated with the movement of these futures prices. However, when I compare the returns from contracts they traded versus those that they didn't, there doesn't seem to be any effect. Thus, the regressions might be contaminated with the problems mentioned earlier.

Regarding strict position limits, ultimately, a society must decide whether the externality imposed on consumers of natural gas and the financial market system is more or less important than the drawbacks to regulation. From the perspective of moving natural gas prices, the simple analysis presented here provides some justification for restricting the amount of trading or ownership of market participants in natural gas futures. However, a more in-depth analysis should be done, that considers lags in the effects, adjusts for the potential simultaneity issues, includes all of Amaranth's positions (not just those in natural gas on NYMEX), and considers a more sophisticated model.

## VIII Conclusion

The collapse of the hedge fund Amaranth Advisors in September of 2006 drew a flury of attention. There are several reasons why this hedge fund failure attracted such widespread media attention. Firstly, the size and speed at which Amaranth made losses. In less than 12 days, from September 8, 2006 to September 20, 2006, they had lost almost \$4B. Secondly, their losses occurred in the natural gas markets. There is some evidence that Amaranth's trading activities in the natural gas markets distorted market prices and ultimately hurt consumers of natural gas. For instance, the Municipal Gas Authority of Georgia (MGAG) complained that its hedging costs with abnormally high winter natural gas prices caused its consumers losses of \$18M during the winter of 2006-2007 (Senate Report, p. 115). Thirdly, the failure raised new concerns about risk management and leverage. In particular, it raised questions about how large a position and influence an individual entity should have over a financial market, like the natural gas futures market.

This paper dealt specifically with examining the actual positions of Amaranth in the natural gas market to understand whether conventional risk measurement tools could have estimated the large risks that caused their collapse in September 2006. The paper finds that Amaranth's VaR on August 31, 2006 was \$1.334B and \$2.048B at the 99% and 99.95% confidence level. Although large, these numbers of rather low probability events still underestimate their losses in September of \$4.35B. In fact, the paper finds that it was the management of their liquidity risk that was vastly irresponsible. Amaranth's NYMEX natural gas futures equivalent positions in certain maturity contracts exceeded 200% of the NYMEX natural gas open interest. Their ownership of NYMEX natural gas futures contracts alone was, in certain maturities, close to 100% of the open interest. When markets turn against a trader's position, futures exchanges will require additional margin to maintain those positions. Once the trader's cash on-hand and borrowing sources are exhausted (funding risk), he can only meet margin calls by selling the underlying assets. If that trader owns a large percentage of that market, he can only sell those assets by forcing the prices even lower and thus creating further losses and further margin calls. This is known as liquidity risk. A combination of liquidity and funding risk ultimately caused Amaranth's collapse.

There are several lessons from the Amaranth debacle that have to be relearned. Firstly, even if a strategy has a positive excess return with low volatility historically, with or without a theoretical justification for the strategy, that strategy can still have negative returns in the future. With leverage, these negative returns are amplified. Secondly, firms need to manage liquidity risk explicitly. The inability to sell a futures contract at or near the latest quoted price is related to one's concentration in the security. In Amaranth's case, the concentration was far too high and there were no natural counterparties when they needed to unwind the positions. Thirdly, exchanges can only adequately manage their position limits if they have disciplined rules for doing so and transparency. Currently, a bill has been introduced by Senator Carl Levin to address the second point and regulate energy trading facilities (Levin (2007)). The importance of limiting concentration comes also through the potential for price manipulation which can distort prices and have an unfair income distributional effect. It can also lead to larger uncertainties and less effective decision making by individuals. Amaranth is currently being sued by the Federal Energy Regulatory Commission (FERC) for price manipulation in specific instances. Their intent is to penalize Amaranth for unjust profits and civil penalities, in addition to seeking \$30M from Mr. Brian Hunter as well (FERC (2007)).

At the time of this paper's writing, Mr. Brian Hunter is in the process of forming a new hedge fund named Solengo Capital. His former colleagues, Shane Lee and Matthew Calhoun, are listed as portfolio managers on the prospectus.

# IX Appendix

# X Tables

Table 1: Profits from March-April Spread Trade using Futures Contracts

| Futures Contract | Price per Contract | | P/L |
|---|---|---|---|
| | 31-Jul-06 | 31-Aug-06 | |
| March-07 | \$11.46 | \$10.48 | \$9,780 |
| April-07 | \$8.85 | \$8.34 | \$(5,080) |
| Spread | | | \$4,700 |

*Note*: Natural gas futures prices are quoted for 1 mmBtu. One contract is worth 10,000 mmBtu.

Table 2: Profits from March-April Spread Trade using Option Contracts

| Futures Contract | Call & Put Price | | Number of Options | P/L |
|---|---|---|---|---|
| | 31-Jul-06 | 31-Aug-06 | | |
| March-07 | $2.43 | $1.80 | 1 | $(6,310) |
| April-07 | $0.53 | $1.40 | 5 | $43,500 |
| Spread | | | | $37,190 |

*Note*: Natural gas options trade for one contract of the respective underlying natural gas futures contract. Natural gas futures prices are quoted for 1 mmBtu. One contract is worth 10,000 mmBtu.

Table 3: NYMEX and ICE Natural Gas Contract Specifications

| | NYMEX Natural Gas Futures Contract | ICE Natural Gas Henry Hub Swap |
|---|---|---|
| Trading Unit | 10,000 MMBtu | 2,500 MMBtu |
| Price Unit | $ per MMBtu | Same as NYMEX |
| Last Trading Day | Trading terminates three business days prior to the first calendar day of the delivery month. | Same as NYMEX |
| Settlement Type | Physical | Financial |
| Final Settlement Price | Volume-weighted average of prices of trades during the last half-hour of Last Trading Day (2:00 to 2:30 PM). | Same as NYMEX Final Settlement Price on Last Trading Day |
| Delivery Location | Henry Hub, Louisiana | N/A |
| Delivery Period | First calendar day of delivery month through last calendar day of delivery month. | N/A |
| Trading Hours | Open outcry: 9:00 AM - 2:30 PM Electronic trading: 6:00 PM of the prior trading day to 5:15 PM of the trading day. | Electronic trading: 2:30 PM of the prior trading day to 2:30 PM of the trading day. |

*Note*: Source: Senate Report, p. 33.

Table 4: Natural Gas Positions of Amaranth on August 31, 2006

| Contract | | NYMEX Contracts | | | | ICE Contracts | | Total |
|---|---|---|---|---|---|---|---|---|
| | | Futures | Options | Swaps (NN) | Swaps (NP) | ICE Swaps | ICE Off-Exchange | |
| Oct-06 | | | | | | | | |
| | FEQ | -64711 | 43523 | -21703 | -5307 | -87625 | 41381 | -94441 |
| | Percent | 24.49 | 16.47 | 8.21 | 2.01 | 33.16 | 15.66 | 100 |
| Nov-06 | | | | | | | | |
| | FEQ | -336 | 6431 | 17451 | -442 | 85597 | -49453 | 59247 |
| | Percent | 0.21 | 4.03 | 10.93 | 0.28 | 53.60 | 30.96 | 100 |
| Dec-06 | | | | | | | | |
| | FEQ | -7308 | -2430 | -8154 | -449 | 28711 | -38127 | -27757 |
| | Percent | 8.58 | 2.85 | 9.57 | 0.53 | 33.71 | 44.76 | 100 |
| Average | Percent | 28.40 | 14.82 | 32.61 | 2.00 | 10.21 | 11.96 | 100 |

*Note*: On the NYMEX, Amaranth held positions in outright natural gas futures contracts from October 2006 maturity to December 2011 maturity. Amaranth also had a significant amount of positions in call and put options on the underlying natural gas futures contracts with NYMEX. They also had natural gas swap contracts through the Clearport system of NYMEX. They had a combination of regular swaps and penultimate swaps, the latter which expire one day prior to the former, but are otherwise identical. The rest of their positions consisted of natural gas swap contracts on ICE, some of which were electronically traded and cleared positions on ICE, while others were off-exchange contracts, but later cleared through ICE. Among the trades entered on ICE, some of the swap contracts were in individual contract months (e.g. October, 2006), while others were in calendar strips (e.g. November through March). All of these different types of instruments were converted to NYMEX futures equivalent value (NYMEX FEQ).

Table 5: NYMEX FEQ Positions of Amaranth on August 31, 2006

| Contract Month | NYMEX FEQ | Weight | Percent of NYMEX Open Interest | Dollar P/L (August 31, 2006 - September 21, 2006) |
|---|---|---|---|---|
| OCT.06 | -94441 | 0.1068 | -80.8 | $1,196,571,821 |
| NOV.06 | 59247 | 0.0911 | 84.1 | $(1,313,512,297) |
| DEC.06 | -27757 | 0.0518 | -54.3 | $718,082,127 |
| JAN.07 | 61825 | 0.1228 | 125.5 | $(1,698,345,675) |
| FEB.07 | -7464 | 0.0149 | -24.1 | $204,658,602 |
| MAR.07 | 58365 | 0.1144 | 73.2 | $(1,597,458,370) |
| APR.07 | -77527 | 0.1209 | -123.9 | $912,497,139 |
| MAY.07 | -140 | 0.0002 | -0.6 | $1,491,906 |
| JUN.07 | 869 | 0.0013 | 5.7 | $(9,226,529) |
| JUL.07 | -1612 | 0.0025 | -13.9 | $17,362,443 |
| AUG.07 | 406 | 0.0006 | 3.1 | $(4,408,604) |
| SEP.07 | -1128 | 0.0018 | -9.6 | $12,318,357 |
| OCT.07 | 9905 | 0.0162 | 30.8 | $(110,142,421) |
| NOV.07 | 1062 | 0.0019 | 7.3 | $(17,711,433) |
| DEC.07 | 37923 | 0.075 | 115.1 | $(793,354,118) |
| JAN.08 | 25130 | 0.0522 | 99.0 | $(570,955,577) |
| FEB.08 | -6105 | 0.0127 | -39.3 | $139,013,161 |
| MAR.08 | 3215 | 0.0065 | 11.6 | $(72,071,881) |
| APR.08 | 5567 | 0.0082 | 22.1 | $(28,502,978) |
| MAY.08 | -5356 | 0.0077 | -39.5 | $23,940,516 |
| JUN.08 | -5009 | 0.0073 | -117.4 | $22,889,968 |
| JUL.08 | -7148 | 0.0105 | -214.4 | $32,306,927 |
| AUG.08 | -6012 | 0.0089 | -179.3 | $28,376,239 |
| SEP.08 | -6145 | 0.0092 | -130.0 | $29,616,597 |
| OCT.08 | -7880 | 0.012 | -50.3 | $40,344,231 |
| NOV.08 | -5552 | 0.0094 | -106.6 | $58,127,545 |
| DEC.08 | -4601 | 0.0085 | -39.4 | $69,332,233 |
| JAN.09 | 5864 | 0.0114 | 31.2 | $(99,796,926) |
| FEB.09 | 803 | 0.0016 | 48.9 | $(13,669,329) |
| MAR.09 | 13155 | 0.0249 | 94.8 | $(218,641,446) |
| APR.09 | -12423 | 0.0171 | -82.1 | $13,913,461 |
| MAY.09 | -519 | 0.0007 | -7.7 | $243,756 |
| JUN.09 | -257 | 0.0003 | -12.6 | $146,661 |
| JUL.09 | -516 | 0.0007 | -22.9 | $345,994 |
| AUG.09 | 190 | 0.0003 | 7.2 | $(164,956) |
| SEP.09 | -1274 | 0.0018 | -37.0 | $1,427,141 |
| OCT.09 | -335 | 0.0005 | -6.3 | $475,840 |
| NOV.09 | 714 | 0.0011 | 53.9 | $(4,438,556) |
| DEC.09 | 2790 | 0.0048 | 67.9 | $(29,076,611) |
| JAN.10 | 2265 | 0.0042 | 55.7 | $(29,383,330) |
| FEB.10 | 1664 | 0.0031 | 88.3 | $(21,662,342) |
| MAR.10 | 12546 | 0.0225 | 123.7 | $(159,588,737) |
| APR.10 | -11393 | 0.0147 | -89.4 | $(25,975,483) |
| MAY.10 | 1905 | 0.0024 | 80.6 | $5,487,326 |
| JUN.10 | -461 | 0.0006 | -19.3 | $(1,281,047) |
| JUL.10 | 952 | 0.0012 | 71.8 | $2,552,490 |
| AUG.10 | 251 | 0.0003 | 12.5 | $634,490 |
| SEP.10 | 940 | 0.0012 | 44.0 | $2,190,390 |
| OCT.10 | 145 | 0.0002 | 3.5 | $295,064 |
| NOV.10 | 535 | 0.0008 | 20.2 | $(1,266,911) |
| DEC.10 | -771 | 0.0013 | -9.4 | $4,755,610 |
| JAN.11 | -55 | 0.0001 | -3.0 | $517,981 |
| FEB.11 | -233 | 0.0004 | -16.4 | $2,184,756 |
| MAR.11 | 139 | 0.0002 | 2.3 | $(1,258,372) |
| APR.11 | -3303 | 0.004 | -81.9 | $(15,621,653) |
| MAY.11 | 823 | 0.001 | 61.3 | $4,388,189 |
| JUN.11 | -29 | 0 | -3.6 | $(153,291) |
| JUL.11 | -65 | 0.0001 | -8.5 | $(345,917) |
| AUG.11 | -75 | 0.0001 | -10.6 | $(397,558) |
| SEP.11 | -74 | 0.0001 | -10.1 | $(388,634) |
| OCT.11 | -790 | 0.001 | -29.3 | $(3,932,905) |
| NOV.11 | -71 | 0.0001 | -7.0 | $(52,107) |
| DEC.11 | -227 | 0.0004 | -8.4 | $800,219 |

*Note*: Weight represents the weight of Amaranth's exposure in that particular contract as a percentage of the total absolute dollar volume of all contracts. That is, for each contract, the absolute value of Amaranth's positions are multiplied by the price for that contract on August 31, 2006 and 10,000. The percentage for each contract of each contract is the total dollar value of their position in that contract divided by the sum of the total dollar value of all of the contracts. The Dollar P/L represents the profit and loss of Amaranth in each position assuming no changes were made to the holdings. That is, it is simply Dollar P/L = NYMEX FEQ $\dot{(}P_{t+1} - P_t)$, where $P_t$ is the contracts price on August 31, 2006 and $P_{t+1}$ is the contract's price on September 21, 2006.

Table 6: Amaranth Positions in Winter and Non-Winter Months

| | Total Dollar Value | | | | | | Correct Sign (%) | |
|---|---|---|---|---|---|---|---|---|
| Trade Date | Winter-Longs | Winter-Shorts | W. Total | Non-Winter-Longs | Non-Winter-Shorts | N.W. Total | Winter | Non-Winter |
| 31-Jan-06 | 4,258,305,934 | (4,207,665,123) | 50,640,811 | 1,435,236,076 | (2,186,529,127) | (751,293,051) | 64.29 | 50.00 |
| 28-Feb-06 | 6,747,057,844 | (2,581,042,631) | 4,166,015,213 | 1,107,062,004 | (4,459,247,449) | (3,352,185,445) | 77.78 | 50.00 |
| 31-Mar-06 | 8,139,116,076 | (1,823,491,062) | 6,315,625,014 | 1,414,829,338 | (5,252,719,674) | (3,837,890,336) | 70.37 | 51.22 |
| 28-Apr-06 | 11,676,812,614 | (3,236,275,580) | 8,440,537,034 | 1,927,180,168 | (6,202,124,031) | (4,274,943,863) | 70.37 | 57.50 |
| 31-May-06 | 17,101,267,975 | (4,524,524,915) | 12,576,743,060 | 2,782,321,098 | (11,225,510,296) | (8,443,189,198) | 70.37 | 48.72 |
| 30-Jun-06 | 20,229,114,833 | (5,357,498,215) | 14,871,616,618 | 3,222,527,838 | (11,998,686,079) | (8,776,158,242) | 66.67 | 47.37 |
| 31-Jul-06 | 28,568,081,397 | (2,432,009,020) | 26,136,072,377 | 1,198,034,025 | (19,426,414,857) | (18,228,380,831) | 62.96 | 56.76 |
| 31-Aug-06 | 28,812,493,335 | (5,322,867,101) | 23,489,626,234 | 1,762,963,323 | (17,626,398,609) | (15,863,435,286) | 62.96 | 69.44 |

*Note*: For this table, winter months are defined to be November, December, January, February, and March. Non-Winter months are all other months. For each day listed, Winter-Longs represented the total dollar value of the long positions in winter months, Winter-Shorts represent the total dollar value of the short positions in winter months, W. Total represents the sum of the two, Non-Winter-Longs represents total dollar value of the long positions in non-winter months, Non-Winter-Shorts represents the total dollar value of the short positions in non-winter months, and N.W. Total represents the sum of the two. Correct Sign (%) represents the number of Winter (Non-Winter) months in which the position is long (short) regardless of size.

Table 7: Measures of VaR of Amaranth's Natural Gas Position on August 31, 2006

| | | Confidence Interval | | | | |
|---|---|---|---|---|---|---|
| | Position Size | 68% | 99% | 99.95% | Worst | Actual[a] |
| Method 1 (VaR) | | | | | | |
| No Leverage[b] | $10.228B | -65.83 | -254.95 | -391.53 | -137.53 | -629.97 |
| Leverage | $53.523B | -344.50 | -1334.18 | -2048.92 | -719.71 | -3295.50 |
| Method 2 (Cornish-Fisher VaR) | | | | | | |
| No Leverage | $10.228B | -126.44 | -246.31 | -225.14 | -137.53 | -629.97 |
| Leverage | $53.523B | -661.67 | -1288.97 | -1178.16 | -719.71 | -3295.50 |
| Method 3 (Recent Historical VaR) | | | | | | |
| No Leverage | $10.228B | -76.27 | -224.43 | -331.42 | -137.53 | -629.97 |
| Leverage | $53.523B | -399.12 | -1174.44 | -1734.37 | -719.71 | -3295.50 |

*Note*: [a] Actual losses represent the losses had Amaranth maintained the positions of August 31, 2006 through the end of trading on September 21, 2006. [b] No leverage computes the VaR based on an investment in natural gas futures equal to the value of the total assets under management by Amaranth on August 31, 2006 of $10.228B. The Leverage row represents the VaR with Amaranth's actual leverage of 5.23 on August 31, 2006. For Methods 1 and 2, the numbers for each confidence level in the table represent the VaR estimates in millions of dollars using the historical mean and volatility of the winter / non-winter spread trade of 0.7466% and 1.3902% respectively. For Method 3, the VaR estimates are based on the daily mean and standard deviation of Amaranth's natural gas positions for the prior three months. These daily values were 0.0172% and 0.2435% respectively. The "Worst" column represents the losses of the respective size fund if one uses the worst historical September loss of the spread trade using NYMEX data from 1990-2005. The "Actual" column represents the actual loss that occurred for Amaranth from August 31, 2006 to September 21, 2006 assuming no changes were made to the positions held on August 31, 2006.

Table 8: Correlations of Amaranth's Trades to Natural Gas Price Changes

| | $\hat{\alpha}$ | $\hat{\beta}$ | $\bar{R}^2$ | nobs |
|---|---|---|---|---|
| Buys | | | | |
| $\frac{\Delta Q}{OI} > 0.00$ | -0.114 | -1.49 | 0.00 | 385 |
| | (0.162) | (1.67) | | |
| $\frac{\Delta Q}{OI} > 0.10$ | -0.051 | -1.49 | -0.02 | 36 |
| | (1.01) | (3.42) | | |
| $\frac{\Delta Q}{OI} > 0.30$ | 3.99 | -8.05 | 0.12 | 10 |
| | (2.65) | (5.39) | | |
| $\frac{\Delta Q}{OI} > 0.50$ | -4.76 | 4.53 | 0.75 | 3 |
| | (1.19) | (1.71) | | |
| Sells | | | | |
| $\frac{\Delta Q}{OI} > 0.00$ | -0.108 | 3.89 | 0.01 | 418 |
| | (0.154) | (2.07) | | |
| $\frac{\Delta Q}{OI} > 0.10$ | 0.512 | 6.48 | 0.03 | 39 |
| | (0.991) | (4.33) | | |
| $\frac{\Delta Q}{OI} > 0.30$ | 0.755 | 7.20 | -0.16 | 4 |
| | (4.49) | (9.44) | | |
| $\frac{\Delta Q}{OI} > 0.50$ | NA | NA | NA | 2 |
| | () | () | | |

*Note*: The coefficient are from a regression of $r_{it} = \alpha + \beta \frac{\Delta Q_{it}}{OI_{it}} + \epsilon_{it}$, where $r_{it}$ is the return of contract $i$ on day $t$, $\Delta Q_{it}$ is the change in Amaranth's position by number of contracts on day $t$, $OI_{it}$ is the open interest on day $t$ of that particular contract, and $\epsilon_{it}$ is an error term.

Table 9: Average Returns on Contracts with or without Amaranth Trading

| | With | | | | Without | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Max | Min | nobs | Mean | Max | Min | nobs |
| Without Matching Days: Buys | | | | | | | | |
| $\frac{\Delta Q}{OI} > 0.00$ | -0.173 | 11.44 | -10.22 | 385 | -0.0095 | 14.30 | -7.18 | 4054 |
| $\frac{\Delta Q}{OI} > 0.10$ | -0.417 | 8.80 | -9.57 | 36 | -0.0095 | 14.30 | -7.18 | 4054 |
| $\frac{\Delta Q}{OI} > 0.30$ | 0.272 | 6.89 | -2.46 | 10 | -0.0095 | 14.30 | -7.18 | 4054 |
| $\frac{\Delta Q}{OI} > 0.50$ | -1.65 | -1.17 | -2.46 | 3 | -0.0095 | 14.30 | -7.18 | 4054 |
| Without Matching Days: Sells | | | | | | | | |
| $\frac{\Delta Q}{OI} > 0.00$ | -0.248 | 13.83 | -8.71 | 418 | -0.0095 | 14.30 | -7.18 | 4054 |
| $\frac{\Delta Q}{OI} > 0.10$ | -0.786 | 6.91 | -5.93 | 39 | -0.0095 | 14.30 | -7.18 | 4054 |
| $\frac{\Delta Q}{OI} > 0.30$ | -2.53 | -0.52 | -5.20 | 4 | -0.0095 | 14.30 | -7.18 | 4054 |
| $\frac{\Delta Q}{OI} > 0.50$ | -1.65 | -1.17 | -2.46 | 3 | -0.0095 | 14.30 | -7.18 | 4054 |
| Exact Matching of Days: Buys | | | | | | | | |
| $\frac{\Delta Q}{OI} > 0.00$ | -0.24 | 11.44 | -10.22 | 365 | 0.00 | 14.30 | -6.58 | 2623 |
| $\frac{\Delta Q}{OI} > 0.10$ | -0.14 | 8.80 | -9.57 | 22 | 0.10 | 14.30 | -5.75 | 755 |
| $\frac{\Delta Q}{OI} > 0.30$ | 3.27 | 6.89 | 0.84 | 4 | 1.15 | 4.73 | -1.06 | 154 |
| Exact Matching of Days: Sells | | | | | | | | |
| $\frac{\Delta Q}{OI} > 0.00$ | -0.37 | 13.83 | -8.71 | 406 | 0.00 | 14.30 | -6.58 | 2623 |
| $\frac{\Delta Q}{OI} > 0.10$ | -0.45 | 6.91 | -5.93 | 30 | 0.19 | 14.30 | -5.75 | 1007 |

*Note*: For Exact Matching of Days, the values for trades of greater than 50% of the open interest for buys and for 30% and 50% for sells are not shown, since these occurred on days where there were no trades from any other institutions on other contracts. This particular date was July 5, 2006. Numbers are presented in percentage terms. Thus, for "Exact Matching of Days: Buys" and $\frac{\Delta Q}{OI} > 0.10$ (row 10), the average daily return for contracts that Amaranth bought was -0.14%, while for those they didn't buy it was 0.10%.

# XI Figures

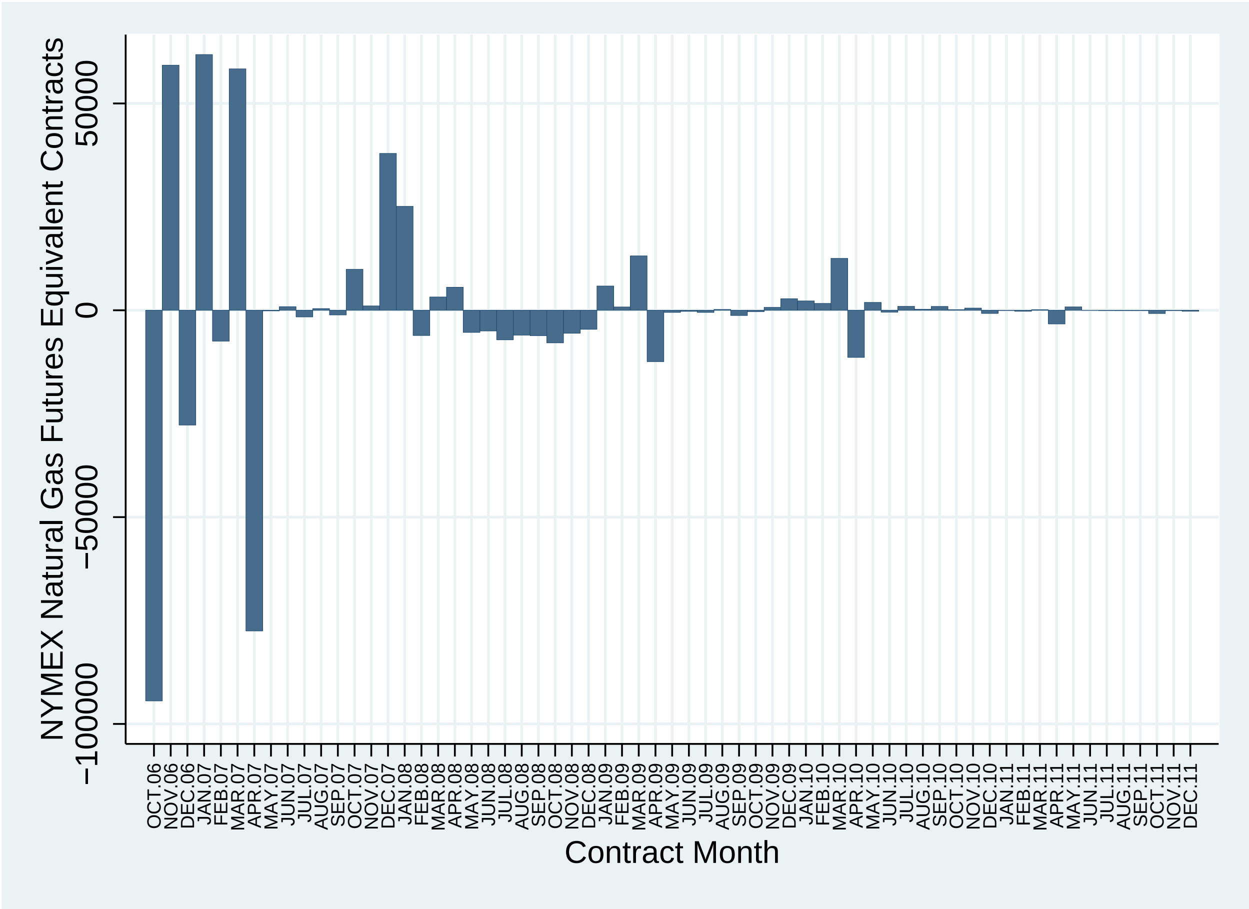


Figure 1: Amaranth NYMEX FEQ Positions on August 31, 2006

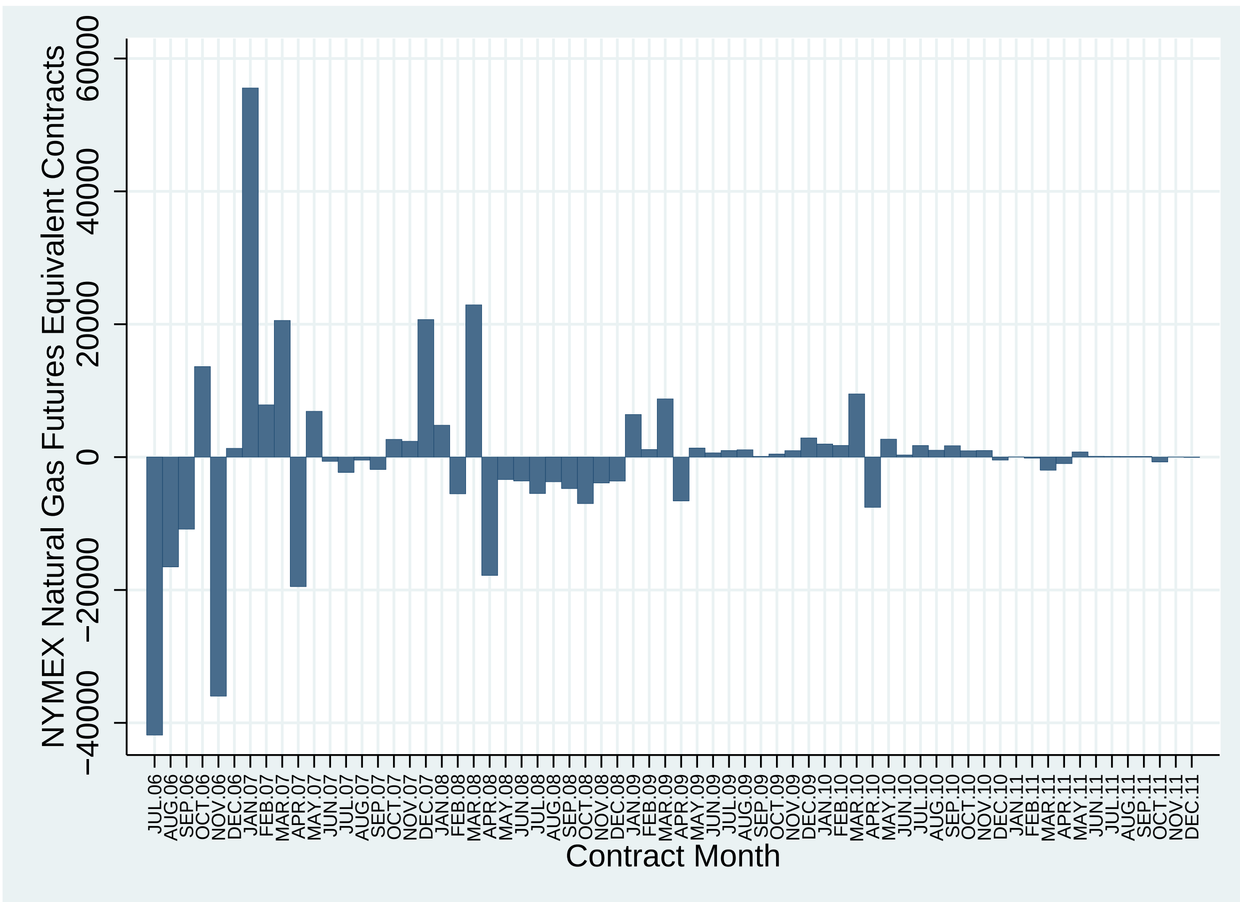


Figure 2: Amaranth NYMEX FEQ Positions on May 31, 2006

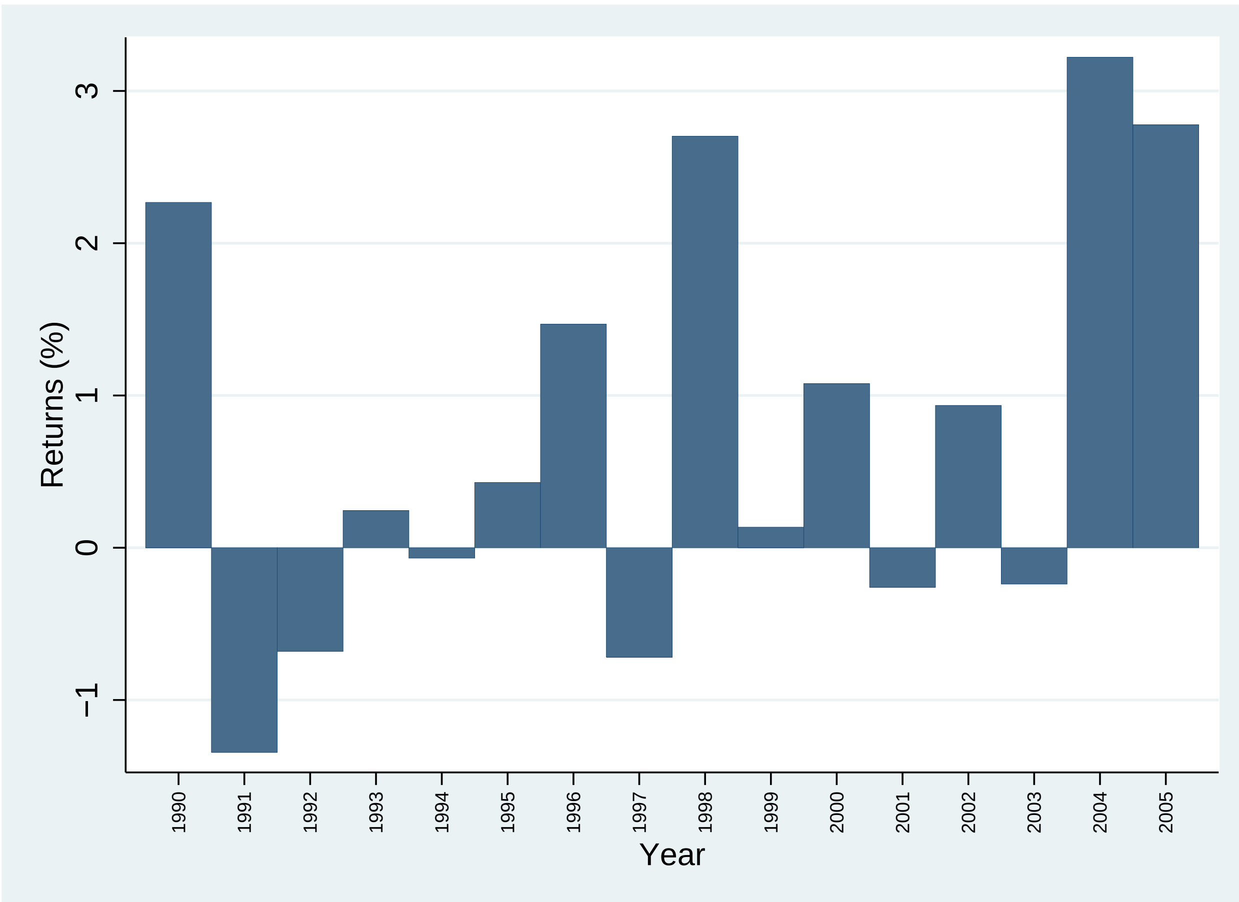


Figure 3: Historical Returns of Amaranth Positions on August 31, 2006 in September (1990-2005)

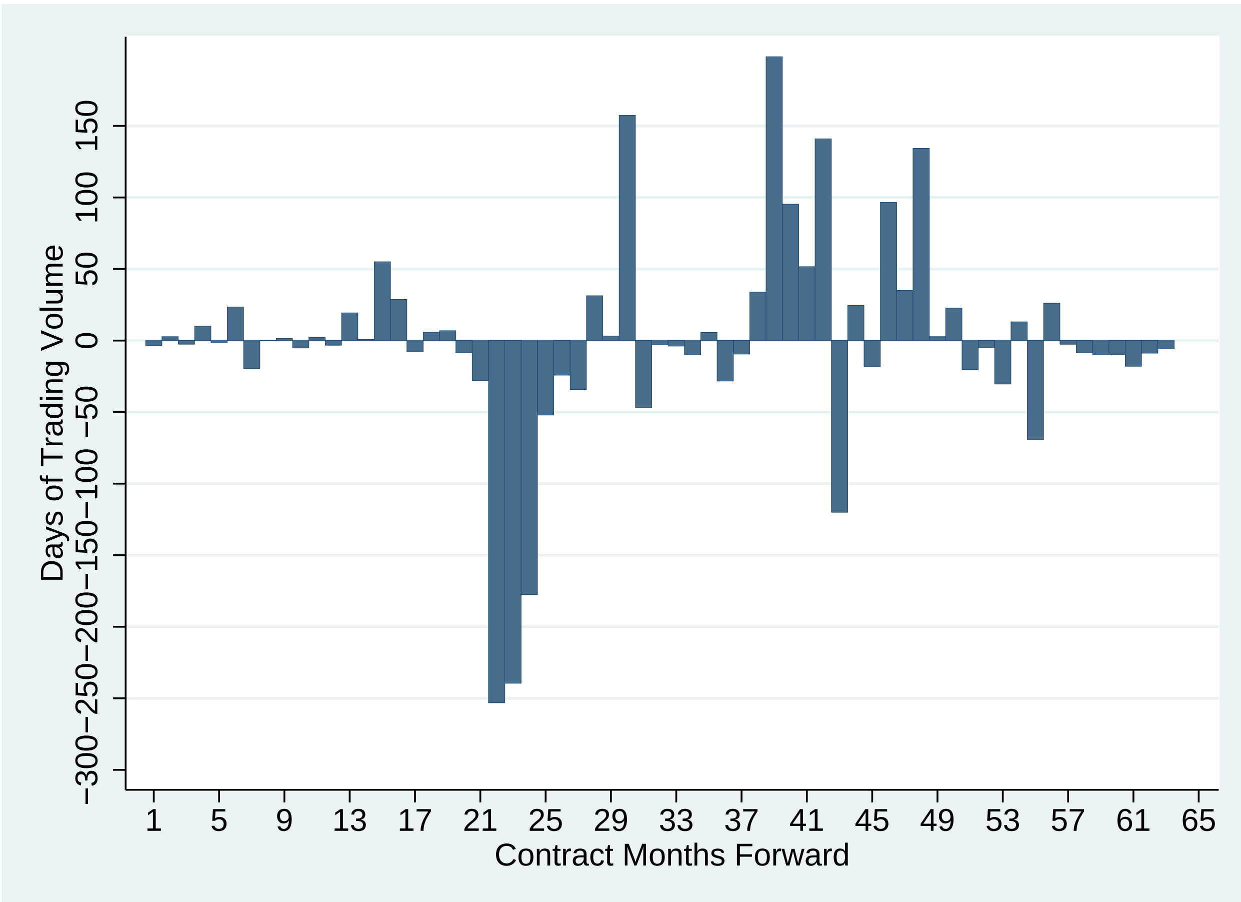


Figure 4: Amaranth's August 31, 2006 Positions as a Ratio to 30-Day Average Daily Trading Volume

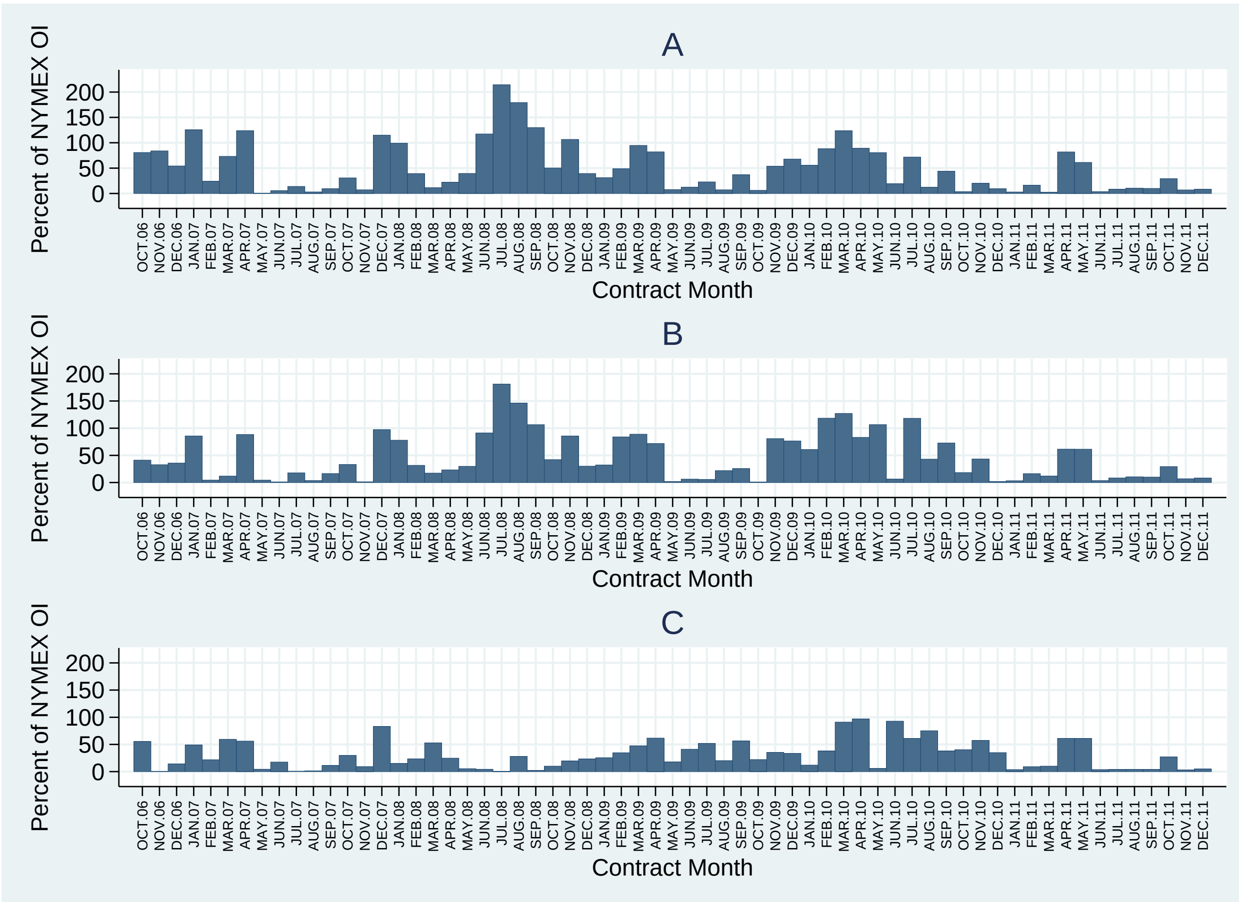


Figure 5: The Amaranth Positions as a Percentage of NYMEX Open Interest (August 31, 2006)

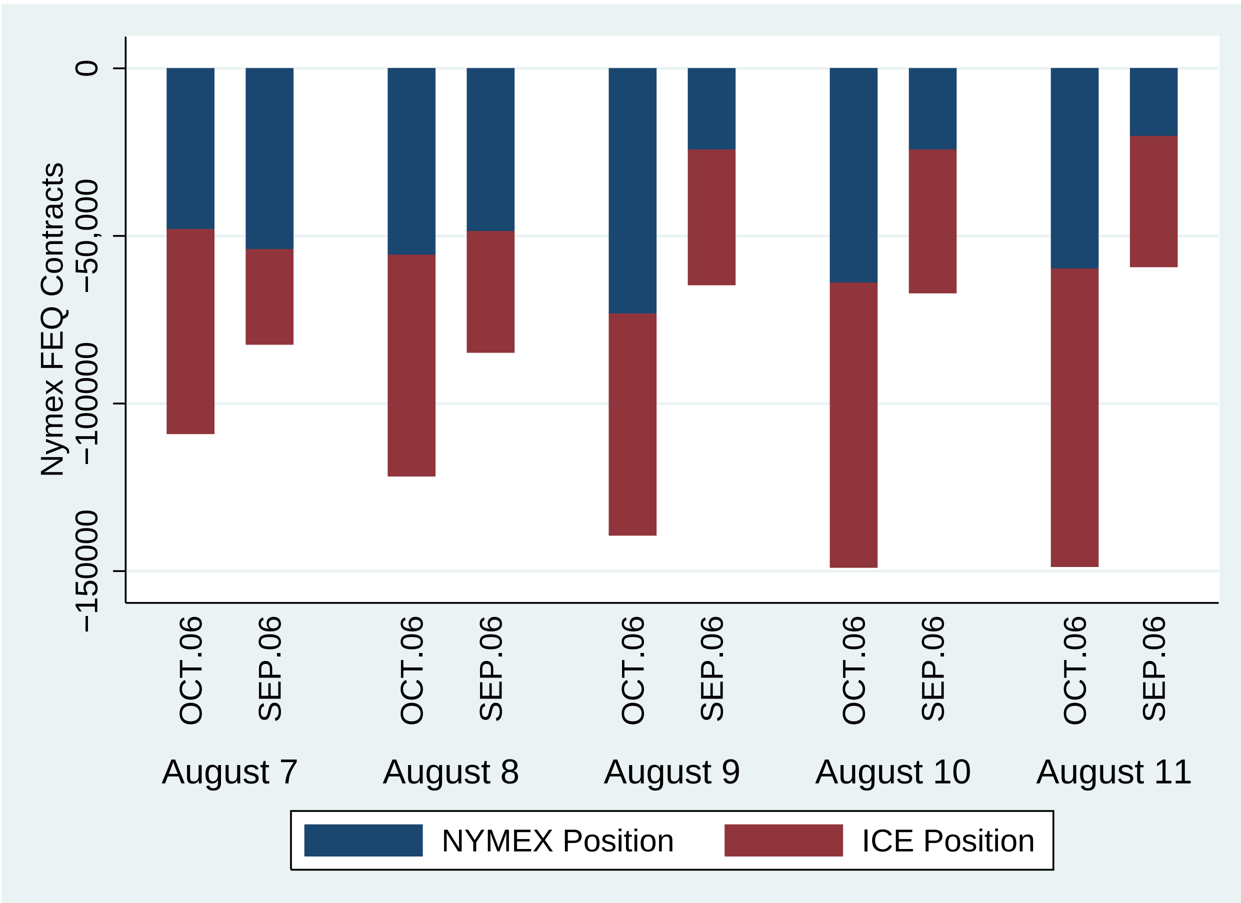


Figure 6: The Amaranth Positions in Response to NYMEX Position Limit Calls

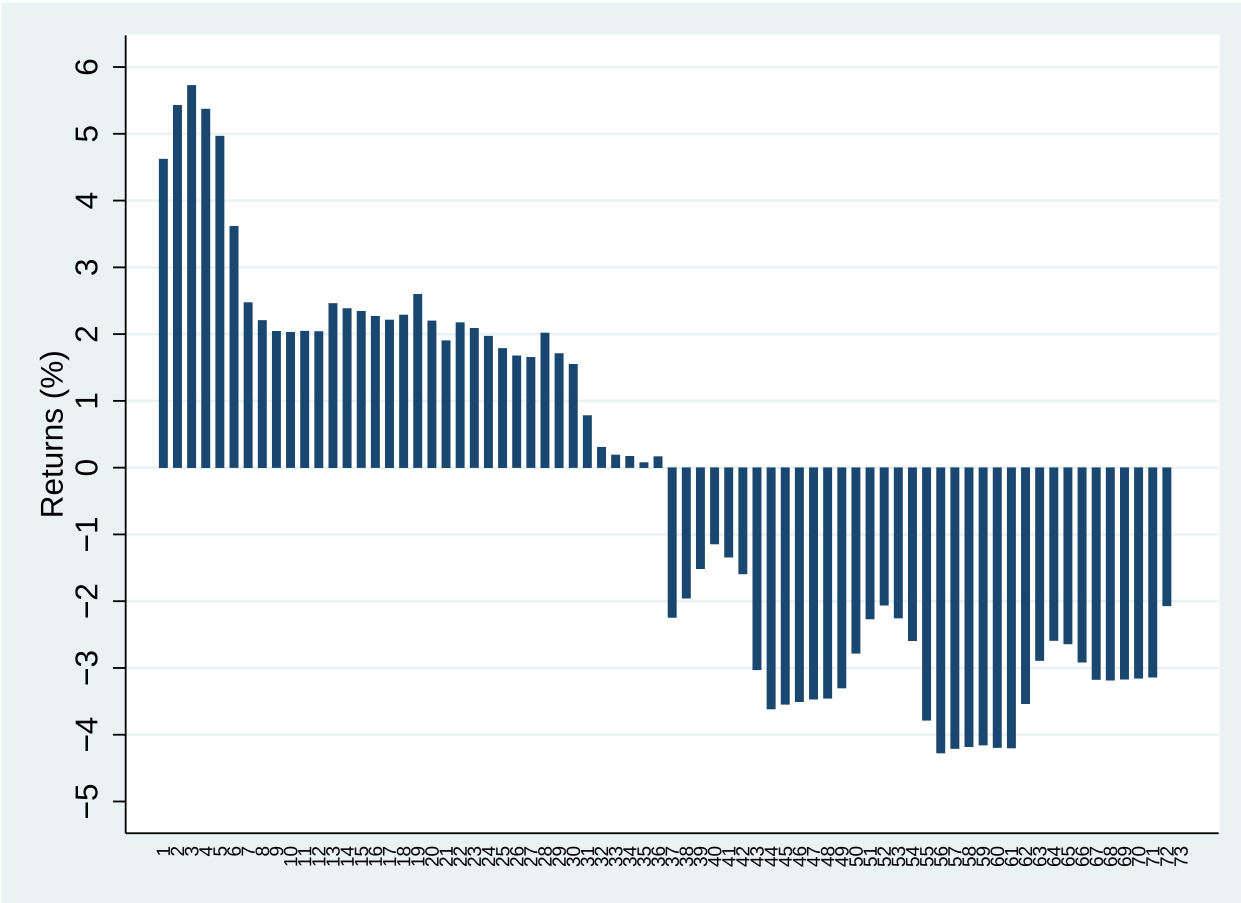


Figure 7: Historical Average Returns of Natural Gas by Contract in September (1990-2005)

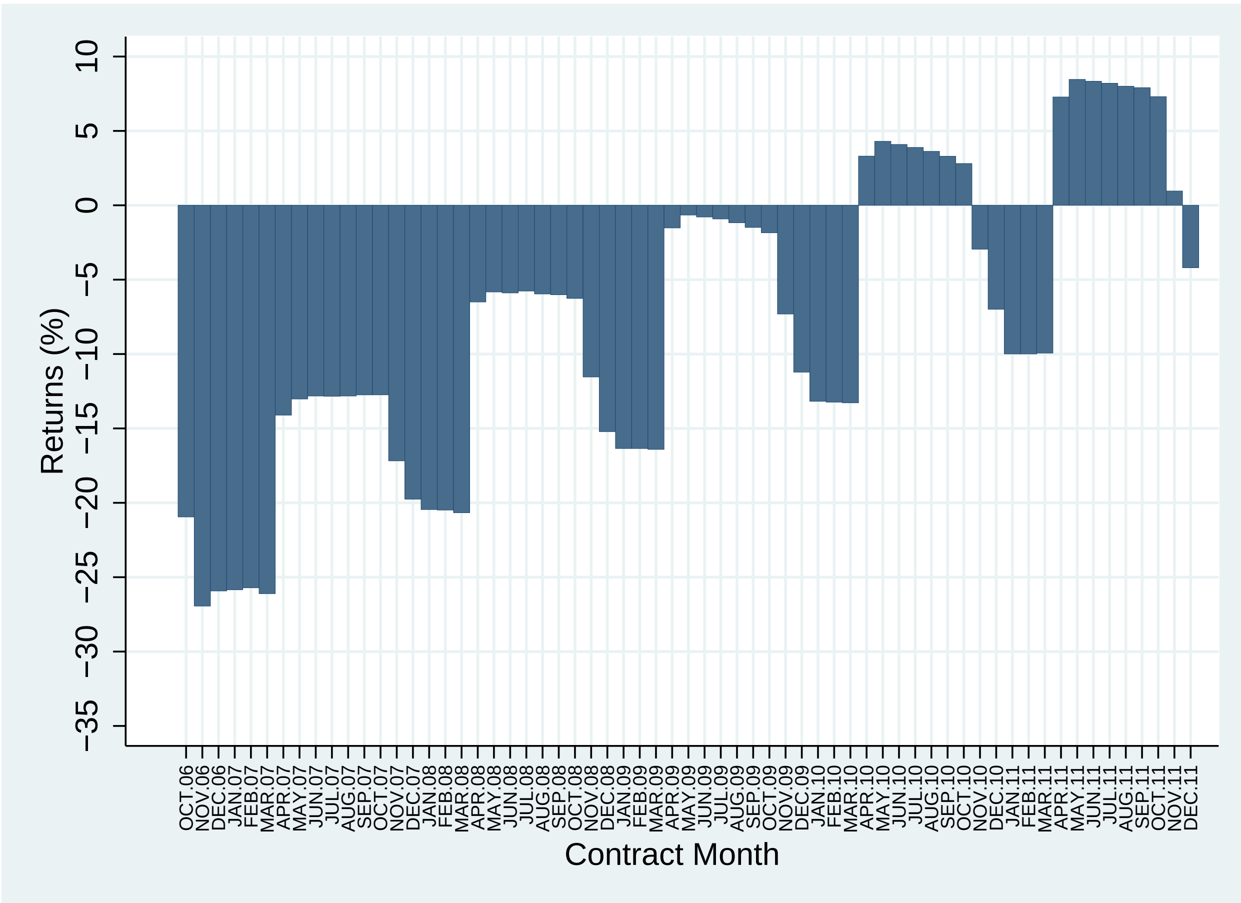


Figure 8: Natural Gas Futures Returns by Contract from August 31, 2006 - September 21, 2006

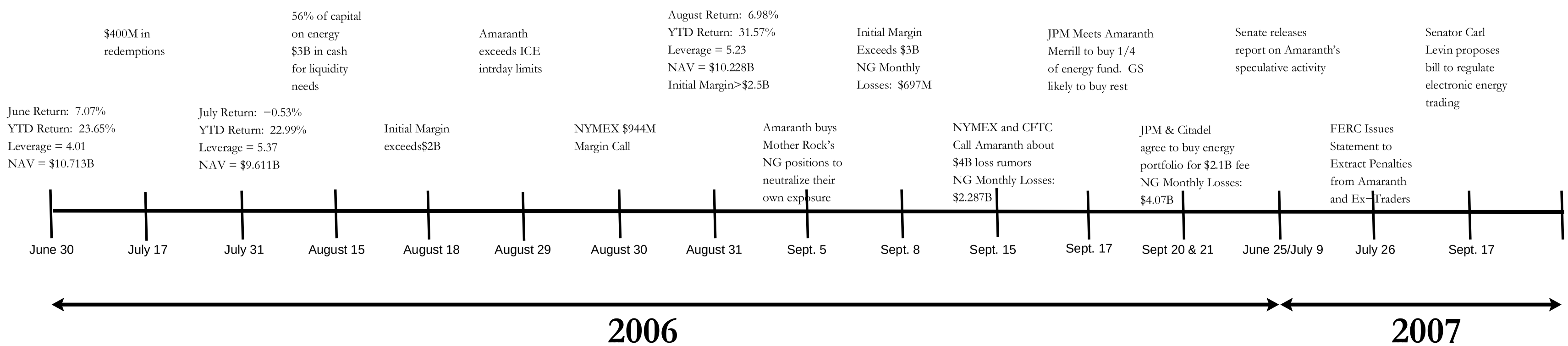


Figure 9: Timeline of the Amaranth Collapse

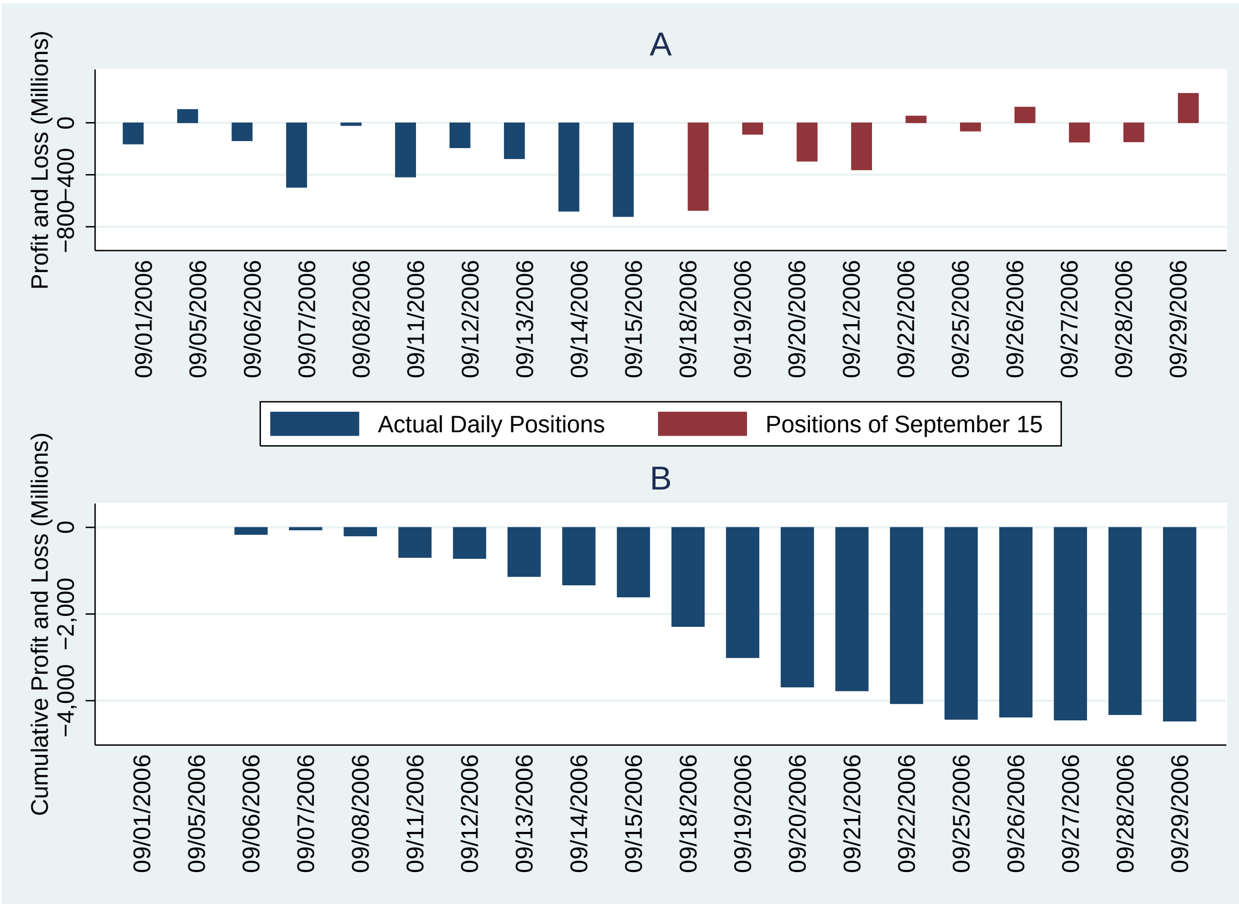


Figure 10: The Profit and Loss of Amaranth's Natural Gas Positions in September

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