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JAMAICA

IN THE COURT OF APPEAL

SUPREME COURT CIVIL APPEAL NO. 92/94

BEFORE: THE HON. MR. JUSTICE RATTRAY - PRESIDENT
THE HON. MR. JUSTICE DOWNER, J.A.
THE HON. MR. JUSTICE WOLFE, J.A.

BETWEEN	JAMAICA FLOUR MILLS LIMITED	PLAINTIFFS/APPELLANTS
A N D	WEST INDIES ALLIANCE INSURANCE COMPANY LIMITED AND OTHERS	DEFENDANTS/RESPONDENTS

Richard Mahfood QC., David Muirhead QC., Wendel Wilkins and Miss Judith Hanson instructed by Vincent Chen of Clinton Hart and Company for the appellant.

Emile George QC., W.K. Chin See QC., John Vassell and Mrs. Ingrid Mangatal-Munroe instructed by Richard Ayoub of Dunn, Cox, Orrett and Ashenheim for the respondents.

July 10-27; October 2-6; November 20-23; 27 - December 14, 1995; January 29 - February 15; 19 & 20, 1996, and March 21, 1997

RATTRAY P.:

On the 12th of September 1988, Hurricane Gilbert hit Jamaica. Hurricane force winds at Norman Manley Airport in the proximity of the Jamaica Flour Mills Plant lasted for three and a quarter hours. Storm force winds lasted for nine hours and gale force winds for sixteen and a half hours.

For the wind to be classified as a hurricane it had to attain a speed of sixty three knots or seventy five miles per hour or more. The highest recorded wind speed was at Sangster Airport on the western end of the island at 120 knots or 138 miles per hours. Further, it could not be said that this was the highest wind speed of the hurricane as the anemometer which records wind speed was completely blown away. At the Norman Manley Airport the highest recorded wind speed was 114 knots or 131 miles per hour before the anemometer malfunctioned. This Airport is in the vicinity of the Jamaica Flour Mills.

There is a range of mountains and hills behind the Jamaica Flour Mills site in an east to west direction. This configuration would have the effect of blocking and channeling the wind and would result in an increase of the wind speed to which the Flour Mills site, particularly the silos on the eastern end would be exposed. Hurricane Gilbert was the worst ever on record, not only for Jamaica, but indeed for the entire region. Furthermore, the eye of the hurricane passed over the Jamaica Flour Mills. The normal atmospheric pressure is 1013.25 millibars. The lowest central pressure associated with Hurricane Gilbert which is found in the eye of the hurricane was 960 millibars. As the pressure forces act from high to low the pressure differential results in increased pressure forces on any structure located in its path.

The above was the uncontradicted evidence of Mr. Calvin Gray, the Director of the Meteorological Division of the Ministry of Public Utilities, Transport and Energy of Jamaica.

At the time of the hurricane both silos 10 and 18 were empty. On the 25th September silo 18 was filled for the first time after the hurricane. The following day September 26, while silo 10 was being filled for the first time after the hurricane both silos collapsed. These silos were in the direct path of the hurricane, and over which the eye of the hurricane passed.

This appeal is consequent upon the dismissal by Panton J. on the 28th July 1994, of an action brought by the Jamaica Four Mills Ltd. (hereinafter referred to as "JFM") against the West Indies Alliance Insurance Company and several other Insurance Companies (hereinafter collectively referred to as "The Insurers") which carried insurance on the Flour Mills plant with respect to damage caused by the relevant perils identified in these insurance policies. One of the stated perils insured against was damage caused by a hurricane. A claim by JFM to be indemnified for the loss suffered as a result of the collapse of the silos was rejected by the Insurers who denied that the hurricane caused any such damage, and maintained that the collapse was due to their faulty design or construction. Panton J. accepted fully the contention of the Insurers, and consequently entered judgment in their favour after a trial lasting seventy-six days and in a judgment of sixty-four (64) pages. The arguments in respect of this appeal has consumed 53 days of appellate judicial time.

THE POLICIES OF INSURANCE

There were thirty-nine Insurance Companies who were defendants in the action and are the respondents in this appeal. Defendants 1 - 13 had West

Indies Alliance Insurance Company Limited as the lead insurer and are locally registered Companies. They took 70% of the risks insured. Defendants 14 - 39 are foreign incorporated Insurance Companies headed by Lloyd's of London Syndicates. They took 30% of the risk.

In so far as it may be necessary to refer to them separately I will describe them as the "W.I.A. Group" and the "Lloyd's Group".

The policies cover damages attributable to the insured risks, and extend to reimbursement for loss of profits. The policy of the W.I.A. Group insured, inter alia, against loss or damage occasioned by or in consequence of "hurricane, cyclone, tornado or wind storm including rain accompanying these perils. ..." The loss of profits policy is similarly worded in all material respects as the other policies.

Condition 4 of the W.I.A. Group policy provides:

> "The insured shall use all reasonable diligence and care to keep the premises insured or <u>maintaining</u> the property insured in a proper state of repair and if any defect therein be discovered shall cause such defect to be made good as soon as possible and shall in the meantime cause such additional precautions to be taken for the prevention of loss or damage as the circumstances may require."

The Lloyd's Group policy covers loss or damage occasioned by or through or in consequence of "hurricane and/or wind storm and/or storm. ..." It contains a clause which provides inter alia:

> "The Underwriters shall not be liable for loss or damage occasioned by or attributable to -

> (a) faulty design or construction of any property described in the policy".

The policy was extended to include as a risk insured against "loss or damage to the property insured directly caused by subsidence and collapse." The Policy further provided that:

> "In every case of loss or damage the assured must prove that no portion of the loss or damage claimed for was caused otherwise than by the perils specified above."

Further:

> "It is a condition of this policy that the insured exercises all ordinary and reasonable precautions for the maintenance and safety of the property insured."

It is to be seen that the Lloyd's Group policy was much more comprehensive in its terms than the W.I.A. Group Policy, as the specific terms provided in respect of liability relating to subsidence and collapse, as well as, the terms providing for non-liability in respect of faulty design or construction, are stated only in the Lloyd's Group policy and not in the W.I.A. Group policy. Notwithstanding this however, if the cause of the collapse is established not as a consequence of the hurricane but because of faulty design or construction then even under the W.I.A. Group policy the plaintiff could not succeed as it would have failed to establish that the cause is a peril insured against in the policy.

THE PLEADINGS

The pleadings identify clearly the position taken by the parties. The plaintiff claimed that as a consequence of the devastating effect of Hurricane Gilbert silos 10 and 18, together with other silos being part of the property insured were subjected to stresses which weakened them and such weakness persisted and was "locked-in" the structure and continued to influence the integrity thereof without being apparent and was then unrecognised, and was the proximate and effective cause of a sudden and violent rupturing of the structure which occurred on the 26th September 1988, when the silos were being filled.

Further and alternatively, against the Lloyd's Group the plaintiff claimed that the cause of the loss and damage suffered was the subsidence and collapse of the silos, an insured peril under the Lloyd's Group policy. The damages in relation to loss including loss of profits were particularised. Little if any emphasis was placed in this allegation of "subsidence and collapse" and although I can find no evidence of its abandonment my judgment is without consideration of this pleading.

On the other hand the defence is equally specific. It denies that the forces created by Hurricane Gilbert weakened the premises or were locked into the structure or influenced the integrity thereof or that the forces of Hurricane Gilbert created any stresses which were the proximate or effective cause of the rupturing of the structure. The defence further goes on further to plead specifically that:

> "The proximate or effective cause of the rupturing of the structure was faulty design and detailing and deficiency in construction."

In the alternative also the defendants maintain that the plaintiff failed:

> "... to take reasonable precautions for the maintenance and safety of the silos or to carry out any or any reasonable or adequate inspection of the said silos after the said hurricane in breach of Condition 4 of the Special Perils extension to Policy No. C1067 and Condition No. 5 of Policy No. 551 FAFR 147."

Additionally:

> "Whether before or after the said hurricane, the plaintiff failed to carry out any or any reasonable or adequate inspection of the said silos in breach of the aforesaid conditions."

<u>THE FLOUR MILLS SITE AND PLANT</u>

There are twenty-six silos constructed on the Flour Mills site for the purpose of storing grain, which when required is emptied out of the silos to be used for the milling of wheat flour The silos are constructed on a concrete slab with dimensions of 2 feet thick, 135 feet long by 54 feet wide. Silos 10 and 18 are situated on the south easterly end of the slab. At that end the slab is 10 feet from the edge of a 45 degree slope. The height of each silo is 131 feet 6 inches. The two silos are part of what is known as the "A" bank of silos. They were constructed and have been in full service since 1967. Above silo No. 10

there is a construction referred to as a "head-house" which is 76 feet 6 inches high and which is supported by four reinforced columns down to the foundations. At the time of the hurricane all the silos were filled with the exception of silos 10 and 18 which were empty. These two silos are adjacent to each other and connected by a dividing partition wall and a junction between the wall of the bins, referred to as the "haunch". It was this haunch which split on 26th September 1988 resulting in the collapse of the silos.

THE ISSUES

The central issue which the Court had to determine and which is evident from the pleadings is whether the collapse of the silos was caused by the forces of Hurricane Gilbert or whether the proximate or effective cause of the rupturing of the structure was faulty design and detailing and deficiency in construction. A subsidiary issue since it was mentioned in the pleadings is whether the plaintiff failed properly to maintain the silos and in its duty to inspect and that this failure caused the collapse of the silos. Put another way the question to be answered is what is the proximate or effective cause of the collapse of the silos?

MY APPROACH

Critical to a review of the Learned Trial Judge's determination in the action must be:

(a) an evaluation of the content and quality of the evidence mostly technical advanced by both parties at the trial;

(b) an identification of the obligations imposed on the respective parties by the policies of Insurance;

(c) the legal and evidential burdens which each party must satisfy;

(d) a consideration of the judgment of Panton J. to determine whether his conclusions can be supported on the facts and on the law.

THE SUBSIDIARY ISSUE

I would like to get the subsidiary issue out of the way. The learned trial judge made no finding as to the inadequacy of maintenance or the lack of inspection. He would have found it extremely difficult to do so adversely in the face of the evidence of Mr. John Ruland, the Managing Director of JFM, himself a Civil Engineer, that the milling facility was well maintained. His detailed evidence of maintenance procedures, the method of filling and emptying and the cycle used in this regard, the existence of a Maintenance Department, a technical service agreement with Pillsbury Company Engineering

Department and three foreign contractors "who we and the Pillsbury Company had used numerous times for installation and repair", the inspection of the facility immediately after the hurricane and before the collapse - all this, unrebutted and indeed unchallenged when he gave his evidence left no room for the success of any allegation that the policy conditions in relation to maintenance and inspection had not been met by JFM.

THE CENTRAL ISSUE -

THE EVIDENCE - THE PLAINTIFF'S CASE

The plaintiff had from very early after the collapse posited a view which would lead to a conclusion, that the effect of the hurricane was to cause pressures to be exerted on the soil beneath the slab upon which the silos were constructed. These pressures so generated produced a differential tilt between the south-eastern and the south-western section of the slab, as well as torsion which resulted in greater subsidence at the south-eastern end of the slab on which silos 10 and 18 which collapsed had been constructed. These pressures were locked-in and so weakened the structures that on the first application of loading after the hurricane the structures fell.

How did the plaintiff seek to discharge the burden of proof to establish on a balance of probabilities that the proximate and effective cause of the collapse of silos 10 and 18 was the force unleashed by Hurricane Gilbert on the 12th September 1988?

THE PLAINTIFF'S INVESTIGATIONS

After the collapse of the silos, the plaintiffs/appellants commissioned Zetlin Argo Structural Investigations Inc. a firm qualified to carry out that sort of engineering assessment to investigate and report upon the cause of the collapse. The work was done under the direction of Dr. Leo Zetlin, the President of the Organisation and Mr. Kazimierez Cader. Unfortunately Dr.

Zetlin died seven and a half weeks before the commencement of the trial but after a report referred to as the Zetlin Argo Report had been made of their joint findings.

That Report in respect of the component of wind engineering relied upon an examination done and conclusions arrived at by a Dr. Emil Simiu an engineer qualified in that field. However, it was discovered that Dr. Simiu an employee of the Federal Government of the United States of America was not permitted to give evidence in a foreign jurisdiction and so could not come to Jamaica to be a witness in the case. The appellant therefore commissioned Professor Peter Sparks who carried out his independent investigation and assessment in the place of Dr. Simiu so as to be able to give evidence with respect to the wind effect of the hurricane on the Flour Mills structures.

MR. CALVIN GRAY

The evidence of Mr. Calvin Gray, the Director of the Meteorological Division of the Ministry of Public Utilities and Transport whose qualifications and experience in the field remain unchallenged, is direct evidence of a specialist eye-witness to Hurricane Gilbert from his vantage point of observation at the Norman Manley Airport in close proximity to the JFM plant. He provided too, the recorded evidence of the speed and direction of the winds up to the time the anemometer malfunctioned at Norman Manley Airport and the one situated at Sangster International Airport was blown away. I have already referred to a part of his evidence at the commencement of this judgment.

The hurricane influenced weather patterns over the island between the 10th and the 15th September 1988. The wind forces recorded were from the 11th to the 13th of September. The wind was out of the north, north-west, at an average speed of sixteen knots gusting to thirty knots. He explained that a gust was like a sudden blow - "you feel this increased force and it almost dies off as rapidly." If a gust lasts for more than sixty seconds it is classified as a wind, "so you have three second gust, ten second gust, fifteen second gust." Gusts in the range of thirty-four to forty-seven knots are referred to as of "gale force". Winds in this range are referred to "as gale force winds". Winds in the region of forty-eight to sixty-three knots are classified as storm force winds. Above sixty-three knots they become hurricane winds. If they last less than sixty-seconds they are hurricane force gusts. Mr. Gray testified that from the 11th to the 13th September:

> "Hurricane force winds at Norman Manley Airport lasted for three and a quarter hours. Storm force winds lasted for nine hours, and gale force winds sixteen and a half hours."

At Norman Manley Airport on the 12th September the highest winds recorded were 114 knots per hour that is 131 miles per hour. However as the anemometer which measures winds speeds at the Airport malfunctioned afterwards, it cannot be said that these were the highest winds generated by the hurricane at the Airport.

The eye of the hurricane, that is, its centre passed over the JFM plant. Its diameter was about fifteen miles. The eye represents an area of calm wind and the lowest central pressure. After the eye passed it moved south of the main mountain range which runs east/west across the island. It was able to maintain its power and also able to re-generate and again pick up its wind speed immediately on exiting the island over the western end. After the passage of the eye the winds now came from the south east having originally approached from the north because of the counter clock wise flow of hurricanes. The winds gusted up to one hundred and twenty knots at Sangster Airport being the last recorded value before the anemometer was blown away. Mr. Gray said:

> "It would not be correct to say that the highest wind associated with Hurricane Gilbert was one hundred and twenty knots ... that is the last recorded figure before the equipment was lost."

Cautiously, and conservatively, Mr. Gray gave his opinion that an additional wind speed in the order of ten knots resulted over the eastern end of the Island. JFM, like Norman Manley Airport is situated on the eastern end of the Island.

The blocking referred to earlier caused by the range of mountains and hills could also result in creating eddies and vortices - "we could in fact end up with smaller systems in which the intensity of the wind is much greater." Obstruction and blocking can spawn wind speeds or tornadoes ending up at "over one hundred miles per hour although the basic wind speeds associated with that system were only in the order of say fifty knots." The wind recognises an object at a distance of fifteen times the height of the object and having recognised the object:

> "It can go over that object or go around either side and will in general revert to its normal trajectory at a distance five times the height of the object. If we have a barrier which is say ten meters tall the wind coming along would recognise this barrier from one hundred and fifty meters away and its trajectory would be altered to either go over or come around or to go around. The silos in general, would be exposed to both channeling and vortices - since we are looking at the hurricane and all the winds coming from the north at one time before the eye passed and then from the south after it passed then certainly the entire structure and indeed the silos and especially those on the eastern end because of the location, ... would lead to channeling at one time and at the other instance would lead to blocking. This is with respect to the wind speed and wind direction.
>
> There were three major features associated with the hurricane - Wind, pressure, rain fall. Hurricane Gilbert was a large wind storm. The maximum twenty-four hours rain fall recorded at Manley for Gilbert was of the order of eight inches in a twenty-four hour period and for all practical purposes we would not classify this as extreme rain fall. In combination however with other factors the damaging effect would just be the same. In terms of wind speed the hurricane was the worst not just for Jamaica but for the entire region. With respect to pressure this is a most damaging component of any hurricane. Pressure forces act from high pressure

> to low pressure and at the centre of the hurricane you have the lowest pressure in the order of nine hundred and sixty-seven millibars with respect to Hurricane Gilbert. So when Gilbert came along this would have given rise to a sudden change in pressure as you move from your normal atmospheric pressure to the central pressure associated with that system. The result of this difference in pressure is that since pressure forces act from high to low the pressure differential must result in increased pressure forces on any structure located in its path."

Mr. Gray gave the example that if you are travelling in an aircraft the pressure inside the aircraft is much higher than the pressure that is outside. That is why if you have damage to an aircraft whilst in flight suction would result. The silos in general would be exposed to both channeling and vortices - "certainly the entire structure and indeed the silos and especially those on the eastern end because of the location."

Mr. Gray attempted to give an example of what had happened to a tank west of the Flour Mills during the hurricane arising out of differential pressures. This evidence was ruled to be inadmissible. In my view this was relevant evidence which should have been allowed in subject to cross-examination, and its exclusion was a judicial error. Mr. Gray's evidence was very important in support of the plaintiff's case since unrebutted as it was, it established that unusual pressures were set up in relation to the two silos situated at the eastern end of the plant which collapsed and that these pressures would have been transmitted to the soil. The likely or probable effect of this in relation to the collapse of the silos was a factor pertinent to the determination of the central issue.

The trial judge although referring briefly to Mr. Gray's evidence gave no indication how this evidence was of assistance to him one way or the other in making his determination. His reference was only by way of narrative. Hurricane Gilbert had done extensive damage to the island of Jamaica. An Article (Ex. 44) by Miles Lawrence, a Meteorologist, at the National Hurricane Centre in Coral Gables, Florida entitled "The Weather of 1988 - Return of the Hurricanes" states damage estimates in Jamaica from Hurricane Gilbert at $2 billion.

PROFESSOR PETER SPARKS

Professor Sparks established his credentials with respect to his engineering qualifications and work done by him on the response of buildings to wind and earthquake and the measurement of the response of buildings to various forms of dynamic loads. This included how pressures are generated on buildings subject to the force of hurricanes. His expertise and experience is in an area known as "wind engineering." In his career he had been commissioned to investigate many hurricanes. He made an aerial examination in a helicopter of the conditions in the vicinity of the Flour Mills site. He examined also the relevant Meteorological Reports. He procured the original anemometer trace of the hurricane for detailed information on the hurricane, the information from Sangster Airport to verify the track of the hurricane, and all available photographs of the hurricane as it was first making land fall in Jamaica. He consulted also an Article from the Journal of Wind Engineering and Industrial Dynamics by Tunissen, a Canadian, which dealt with wind movements on a hill in Canada regarding the speed up that could occur around the hill. The closeness of the Flour Mills to the Norman Manley Airport would ensure that the conditions at both places would differ only because of the aspect of the terrain and topography. His opinion was that conservatively, the speed of the winds at the Flour Mills during the hurricane would have been 15% higher at the Mills than at Norman Manley Airport. The presence of Long Mountain would have increased the speed around the site. He described from the charts, records and the anemometer trace the wind speed as "bouncing around" and changing a lot - "speeding up and down so it's not a steady wind and it's not a steady direction." The Flour Mills would respond to the varying wind forces as if being hit by a "fluctuating load" - "the wind load would come up and go down" and produce a certain amount of rotation. It would have an effect on the way the soil responds. The soil is sensitive to the way in which it is loaded. He converted the wind speed to pressures and forces acting on the silos and the head-house. There is a relationship between wind speed and pressures. If you double wind speed you would have four times the pressure. It is squared. When asked to compare the winds and forces affecting the structure from the north in the first phase of the hurricane with the wind and forces affecting the structure from the south, he explained that in the first half:

> "... the winds were coming closer to normal to the bank of silos for winds from a northerly direction. In the second half after the eye of the storm had passed over the winds were coming approximately parallel to the bank of silos and so the wind effect is limited passing the forces this end of the bank."

"This end" was identified as the south eastern end. It is to be recalled that the two affected silos were at the south eastern end of the bank which was the end mainly exposed to the hurricane winds on their first passage over the plant.

In coming to his conclusion on the distribution of the wind pressures on the soil, Professor Sparks used a distribution formula which before the time he used it was not a formula known to him. Much has been made in the presentation of the case at the trial, in the judgment of the Court and before us on the fact that Professor Sparks had not known the formula before, derisively referred to by Counsel for the defendants/respondents and the trial judge as "the unknown formula". This pejorative dismissal of the validity of the formula caused the focus of the Court to wander away from the real question with respect to the use of the formula. This was not whether Professor Sparks knew the formula before but whether it was a known formula in engineering valid for the purpose for which it was used, and therefore properly adopted by Professor Sparks. I will deal with this aspect later.

Apart from visiting and inspecting the site, he consulted with Mr. Calvin Gray, the Jamaica Government Meteorologist, obtained the original anemometer trace of the hurricane, verified the track of the hurricane, procured a satellite photograph of the hurricane which gave supporting evidence as to the size of the eye. He used an ordinance survey map of the Kingston area to confirm the wind distribution in relation to the topography. He also reviewed Dr. Simiu's Report. As far as the hurricane was concerned conditions at Norman Manley Airport and at the Flour Mills would differ essentially only because of approaching terrain and topography. The presence of Long Mountain which was 1400 feet high would have displaced a volume of air which would have gone around it and would have increased the speed around the silos. The wind is bouncing around during the time the storm is passing as observed from the trace. "It appears to have gone from 270 degrees round to about 360 degrees if you observe that trace carefully". It was "speeding up and down so it is not a steady wind and it is not a steady direction." The Flour Mills would respond to varying wind forces as if being hit by a fluctuating load. "... the wind load would come up and down." He compared the application of the fluctuating wind load on the Flour Mills structures to the driving of a pile into the ground "so the structure like the pile doesn't respond, it doesn't change its characteristic, but the soil does, the soil is sensitive to the way it is loaded." The wind load tends to produce a certain amount of rotation on the building. "The movement would be very small because the building is very stiff." He described the effect of what was happening but the precise response of the soil was a matter for a specialist on soils, an expertise he did not claim to have.

He converted the winds speed to pressures and forces acting on the silos and head-house using his own independent approach.

Much has been made of the fact that he did not follow the approach of Zetlin Argo or Dr. Simiu. What is important is a determination of the integrity of his evidence - the only viva voce wind expert called. His approach was:

> "I took the load on the longitudinal direction of the silos and in the transversed direction of the silo, and I investigated the effect of the wind coming in various directions. I included the asymmetry of the loading caused by the head house and its effect on the foundations. Zetlin Argo and Simiu did not include the longitudinal effect, I think that was a conservative approach." [See p. 1991].

And further:

> "This is a force which was not included, which should have been included and I believe they placed more importance on the torque on the bank of silos than I would have done."

He calculated the wind load and arrived at the following:

(S.W.) Sigma 1, plus 2.3 kips per square inch.

(N.W.) Sigma 2, minus 2.76 kips per square inch.

(N.E.) Sigma 3, minus 3.5 kips per square inch.

> (S.E.) Sigma 4, plus 3.81 kips per square inch.
> [p. 1993]

The silo was not in the wake of Long Mountain. The wind approached along the side of the Long Mountain and was therefore much higher than was suggested in a Report by a Professor Lawson, who was present during the trial on behalf of the defendants, but who was not called to give evidence.

Professor Sparks defended the use of a fifteen minute mean instead of an average hourly wind speed to determine the loading caused by the hurricane winds since the wind was gusting.

> "... if we take an hourly average from that chart you would get a totally different value; it is purely a fictional hourly average, a fictional item. All we need is a stable meteorological pressure of wind conditions, and in a hurricane which is moving rather fast the 15-minute mean is that property."

With regard to the shielding effect of buildings in the vicinity of the silo, Professor Sparks was adamant from his inspection and from photographs he had taken that there was nothing between the northerly wind and the silos. He discounted any shielding factor in respect of a low building in the vicinity of the silos, as the wind forces near the ground are slower near the ground and have less effect. You could put a building at the bottom and it would not have much of a shielding effect in relation to the wind on the silos. Because of the existence of other local forces the minimal shielding effect of a low building would not affect the overall wind forces.

The Torque

Professor Sparks stated that with the wind from the north "the mean torque you would expect to be in an anti-clockwise direction." Zetlin Argo had applied the torque in a clockwise direction. Professor Sparks explained:

> " ... that we are talking about a particular equation which has been pointed out to me which deals with torsional forces on the silos. There is another torsional effect due to the wind on the headhouse which goes in the opposite direction."

He believed that the "forces on the silos would probably be felt by the foundation the whole structure is connected to the foundation and would probably respond to these fluctuations."

Furthermore:

> "... the load on the headhouse has a significant effect upon the load you apply to the foundation," and "... in regard to the stresses induced in the soil by the momènts which are applied, it has a very important effect."

Professor Sparks agreed with Dr. Simiu's approach in not taking into account any shielding effect of the mill building. He stated [p. 2119]:

> "I think the essence of the question here was whether or not a reduction should have been taken because this building, this mill building was occupying one corner of the site and therefore might provide some shelter in that corner and my answer to that is because it is in the corner and near the ground, it makes very little difference to overall forces on the structure."

With respect to the shielding effect reduction Professor Sparks at the end of a day's cross-examination ventured the opinion that it would be about ten percent. The following morning he requested permission to correct that estimate and stated [pp. 2139-40]:

> "I was asked at the end of the day what reduction I thought there would be in the force exerted on the silo and I said off the top of my head without any calculation, I estimated ten percent. ...
>
> What I failed to do in the heat of the moment was to remember that the wind was not coming perpendicular to the face of the silos, and so the figure that was in my head was one that I expected to happen. ...
>
> ***HIS LORDSHIP:*** So the ten percent was wrong?
>
> ***A:*** It was too high, much too high. I would estimate no more than three percent because the wind leaks around the side of the building - or perhaps I should say, would leak around the side of the building and create very little pressure ...
>
> ... the presence of the building in fact would tend to trap the air in the corner. So the additional effect is not to reduce the overall load on the building but in fact to increase it."

I specifically refer to this evidence because the learned trial judge used Professor Sparks' re-assessment as a reason for rejecting him as a witness of truth.

Professor Sparks' evidence related to the overall forces on the structure. He maintained that Dr. Zetlin made two errors.

1. The application of the torque in the wrong direction.

> 2. "Yes and he failed also to consider force in the longitudinal direction which had a tremendous effect on this."

In cross-examination Dr. Zetlin's figures were put to Professor Sparks and he agreed that if those figures were correct and the torque was applied in an anti-clockwise direction as it should have been greater pressures would have been produced in the south-west than in the south-east. Any comfort for the respondents in this answer should have dissipated when it is noted that Professor Sparks did not accept Dr. Zetlin's figures as correct.

The silos were rigid in relation to wind. It depended on the foundation whether they are rigid in relation to soil.

<u>THE 'UNKNOWN' FORMULA</u>

In cross-examination on the Zetlin Argo Report Professor Sparks was asked:

> "Whether a pure torque about a vertical axis can influence vertical stresses in the soil?"

He pointed out that Zetlin Argo:

> "Did not strictly use the torque to calculate the soil pressures. What they did was to use the torque as a guide to the distribution of the effect of moment about a horizontal axis."

He explained that if the silo acts as a rigid body the movement of that vertical axis does not influence the vertical stresses in the soil. However, while the silo is rigid in relation to wind "it depends on the foundation whether it is rigid in relation to soil." The evidence in relation to the soil was given by Dr. Oweis who established its flexibility.

The distribution formula used by Zetlin Argo resulting in the exertion of vertical pressure on the soil had not been known before by Professor Sparks and he had not checked it in any work.

He explained his use of the formula as follows:

> "I used this equation as a means of estimating the effect of the flexibility of the foundation on the redistributing moments that were applied to the foundations. The applicability of this equation depends upon the flexibility of the foundation."
> [p. 2245 - Vol. 10].

The fact is that Professor Sparks' evidence discloses clearly that his mandate as a wind expert was to calculate the wind load to which the structure was subjected. It was the soil expert, Dr. Oweis who applied the load to the soil to determine the effect, and he gave the evidence which established the flexibility of the foundation and which would make the applicability of the formula appropriate.

THE CONFIGURATION OF THE SILOS

Professor Sparks was asked about the configuration of the silos. He stated that with regard to overall forces the bank of silos could be treated as "a rectangular plan body with sharp edges."

As he later said:

> "The important thing, M'Lord, is that this is not a rectangular box with a curvature but it has all these little bits and pieces, but I don't want to say it is a

rectangular cross section with a curvature, it clearly isn't."

When further pressed about this shape of the building resulting in a reduction of wind force on it he said [at p. 2227]:

> ***"A***: That curvature like this, then it would in fact flow around here but in fact it is caught in this corner. So this re-entrant corner is a very, very important feature. In fact it probably means that we have been under-estimating the forces rather than over-estimating the forces."

The silos are not a rectangular shape with rounded corners. In determining the loads he based it upon a rectangular block with sharp edges and, "I realise now that in fact I underestimated the load because of that". I have already stated the load as calculated by Professor Sparks.

The head-house although a small part of the superstructure has an important effect on the load because of its position. It is right up "in the air and it has a tremendous moment about the foundation." The wind is not shielded and has an effect on the head-house. In determining the effect of the wind on the foundation Professor Sparks discounted the forces on the bank of the silos for winds coming in a longitudinal direction. Most of the hammering would come from the head-house, which induces stresses in the soil by the moments which have been applied. A pounding effect is a better designation than a hammering effect.

What then did Professor Sparks' evidence establish?:

1. That the pounding effect of the winds generated by Hurricane Gilbert would produce a certain

amount of rotation on the bank of silos and have an effect on the way the soil responded.

2. The effect would be greater on the south-eastern end on the first passage of the hurricane from the north on the silos than after the eye had passed and the winds returned to the south.

3. There was very little if any shielding effect of the lower buildings in the vicinity.

4. The shape of the silos did not result in a decrease of the wind forces applied to them by the hurricane.

5. He used a distribution formula which Dr. Zetlin had used, and though not known to him before would be applicable dependent upon the flexibility of the foundation.

6. He arrived at specific pressures on the bank of silos which he stated to the Court.

DR. ISSA OWEIS

The credentials of Dr. Issa Oweis as an expert on soils and the behaviour of soils under pressure were not challenged. His mandate was to evaluate the settlements of the soil at the silo site before Hurricane Gilbert and after the hurricane. He directly supervised test borings and measurement of water levels and the retrieval of soil samples for testing. The stability of the slope was tested and no movement was found. He described the nature of the soil found and stated:

> "So that as far as describing the soil is concerned we input all these parameters into a two dimensional finite element nonlinear model and you apply the load given by the structural expert and you basically calculate the formation or settlement."

The soil test would determine how the soil would behave "with increasing strength or with increased loading." He testified that he carried out a non-linear analysis which showed that under the hurricane loading substantial differential settlement would occur. He rejected the use of a linear approach:

> "Because of the nature of the loading which is high load especially during the hurricane and also the proximity of the foundation of the silos to the edge of a steep slope which is ... about 45 degrees."

The slope which was stable was slightly south of the eastern side of the silo, and the edge of the foundation mat was within ten (10) feet from the edge of the slope.

He concluded that without a non-linear approach "no realistic assessment of the settlement could be considered rational." He calculated settlement based on the dead load, that is the weight of the structure plus live load the weight of the grain and this included the hurricane load which "as you can see, the hurricane load theoretically would produce compression on the south-east and tension or uplift on the north side." Because of the non-linear nature of the soil the unload, that is the rebound, was very small. You have settlement due to the historic dead load plus live loads, then all the load caused by the hurricane. This he modelled to the 45° slope.

> "... we proceeded with the premise that the unloading the soil would not rebound or would rebound very, very little indeed, and that is why the historic settlement would not have changed after the hurricane; ..."

Taking dead load plus 100% live load he found settlement at the south-west corner of the mat 4.2 inches which jumped to 5.3 inches due to the hurricane. At the south-east corner it was 4.2 inches before the hurricane and it jumped to 7.2 inches after the hurricane. Settlement in the north-east and north-west remained at 2.93 inches before and after the hurricane. The differential settlements or the difference in settlements between the respective points were as follows:

> "Before the hurricane between south-east and south-west corners zero differential.
>
> Between north-east and north-west zero differential. After the hurricane the differential settlement between north-east and north-west remains zero but between south-east and south-west created a differential settlement of 1.72 inches."

Dr. Oweis was referred to the much maligned "unknown formula" which Professor Sparks had used and he gave evidence as follows:

> ***"Q:*** What is your view about that formula?
>
> ***A:*** This is a very common formula used in foundation engineering. In fact I cannot think of any foundation book that does not have the formula for soil pressure under eccentric loading. It is represented in various texts in one form or another, it may not be the same one, the same format but the same formula is there.
>
> ***Q:*** What is your view about the applicability of the formula in the circumstances of the case ... we are now investigating?
>
> ***A:*** The formula is really an axiom in calculating soil pressure, so I use it all the time. I have to agree with it."

He prepared a document showing the derivation of the formula - [Exhibit 59 in Vol. 50]. He read the transcript of evidence given by Professor Sparks and did a calculation of his settlement that would result from the pressures testified by Professor Sparks. He then prepared a comparison of the settlement from Dr. Zetlin's figures which was testified to by Mr. Cader and Professor Sparks' figures "using the same soil profile, the same parameters but only will change the pressure from those given by Dr. Zetlin to us and those outlined in Dr. Sparks' testimony. The results, as you can see, are very close to each other and are for all practical purposes are the same." [Exhibit 60 Volume 51]. This settlement comparison shows:

Point 1 ie S.W. Zetlin 5.33" Sparks 5.70".

Point 2 ie N.W. Zetlin 2.93" Sparks 2.93".

Point 3 ie N.E. Zetlin 2.94" Sparks 3.00".

Point 4 ie S.E. Zetlin 7.02" Sparks 7.21".

In his judgment the learned trial judge did his comparison of the soil pressures as calculated by Professor Sparks vis-a-vis those calculated by Zetlin Argo and concluded that they "produced significantly different figures." What is important is the settlement caused by the application of the figures.

Dr. Oweis was cross-examined on Reports with respect to the soil prepared by Engineering Geology Limited, a Company engaged by the defendants/respondents for this purpose and another Company in that field called Strucom, none of whose representatives were called to give evidence. They had used a linear analysis approach. Dr. Oweis rejected this approach:

> "I believe the linear approach is irrelevant."

With reference to a later 1993 Report prepared by Engineering Geology Limited using a non-linear analysis he found the results disappointing because "it did not fit into the physical situation." He commented:

> "How could the silo bank move north when the load eccentricity is to the south. Physically it is difficult for me to accept that."

When it was put to him from one of the Reports that:

> "... at some time in the loading history of the silos a loading condition may have existed that would have caused settlements equal to those predicted for the average loading plus the loading effects of hurricane Gilbert."

He replied:

> ***"A***: I would say that it is possible that the silos or the foundation of the silos may have experienced a pressure above the average dead plus live load, however for the foundation to experience an excess pressure during the operation equivalent to 3.77 kips per square foot is not possible and for this to happen Gilbert should have occurred before."

With respect to his calculations Dr. Oweis was asked:

"HIS LORDSHIP: These calculations indicate the tilt?

A: Yes. These calculations indicate that before the Hurricane Gilbert because of the presence of the slope the settlements are larger along the south side as opposed to the north side. It does not make a lot of sense at least even for a

> non-engineer because the presence of the slope in my view, my opinion is that the slope provides a softer soil in a nutshell because there are shifts near the slope.
>
> Our soil calculation indicate that during Hurricane Gilbert immediately after the hurricane using the loads that were prepared by Mr. Cader, and Dr. Zetlin that also the additional settlement to the south and therefore, conditions would get worse according to our calculations."

Dr. Oweis explained that as a Geo-technical Engineer he was interested in pressures on the soil to calculate his settlements:

> "So I took what Dr. Sparks had calculated - he said Mr. Cader is wrong, so I took Dr. Sparks' pressures and did my settlement and I presented the results in my testimony."

However, in other calculations he used both Dr. Zetlin's figures as presented by Mr. Cader and those of Professor Sparks:

> "... and we calculated the settlement using the same soil profile; the same parameters but only we changed the pressure from those given by Dr. Zetlin to us and those outlined in Dr. Sparks' testimony. The results, as you can see, are very close to each other and for all practical purposes are the same. [See Ex. 50 Vol. 51].

His mission was to compute settlements:

> "My presentation to you is that the foundation has been subjected to soil pressures in the past, the soil has settled under the soil pressures."

He calculated the settlements on the four corners of the concrete mat on which the silos stood. The mat was 135 feet by 45 feet. Because of the non-linear nature of the soil at the JFM even a less severe load than that which caused the historic footprint imposed upon the soil could cause additional settlement because the soil had already weakened. His task was to assess the settlement based upon the pressures which had been given to him. Dr. Oweis insisted that the slope was 45°. Mr. Minor was to maintain that it was about 30°. The slope was calculated from a plan prepared by technical persons (the builders of the plant Mel Jarvis Construction Company of Kansas, U.S.A.) after the building of the silos and was confirmed by Dr. Oweis on a visual inspection. He continued to maintain that the historic loading is the proper weight to use in the settlement analysis, that is historic average dead load plus the live load of the facility. The result of his non-linear analysis was that under the hurricane loading substantial differential settlements did occur.

He quite separately took E.G.L.'s pressure in their non-linear analysis as presented in Exhibit 48 and:

> "I divided them by the spring constants proposed by EGL back in 1989. If you go through this exercise these are settlements that you would get: 8.176 inches at the south east corner, 3.03 inches at the north east corner, 1.8 inches at the north west corner, and 5.52 inches under the south west corner." [pp. 3338-9]

It had been suggested that a tunnel in that vicinity would have created a situation where there would be less settlement. Dr. Oweis refuted this. He was asked his opinion in conclusion as to the effect which the rigidity of the tunnel would have on the amount of settlement and after giving reasons in relation to test he had done he stated [p. 3255]:

> "So the effect of the tunnel in my view would be insignificant for estimating settlement before and after Hurricane Gilbert for two reasons:
>
> Number one, it is located under the neutral axis, and the second reason, it is not really that rigid."

And further:

> "It is supported on soil that is similar to the rest of the silo foundation: it is not any stiffer so there is no rock or rigid support underneath that tunnel."

With regard to the 45° slope he stated:

> "It is very important to model the slope with the drawing we have showing a slope of 45° one and one ... we divided the slope into layers then elements then we apply the load top of the slope at the given depth."

Dr. Oweis disagreed with the conclusions of the Engineering Geology Limited Reports except in one respect on which he commented as follows:

> "So regardless of the numerical accuracy of these predictions at least they are consistent with the physical situation. It does predict tilt to the soil which you will expect and it does predict that it is tilted to the east which is also consistent with the physical situation."

Dr. Oweis had personally examined all the soil samples "and we developed what we believe is a realistic soil profile for the analysis."

Dr. Oweis' evidence therefore established:

1. Because of the nature of the soil which was flexible a non-linear analysis was appropriate

as against a linear analysis.

2. The hurricane force winds created a differential settlement of 1.72" in the south-east.

3. The foundation engineering validity of the formula used by Dr. Sparks for soil pressure under eccentric loading.

4. That using Dr. Zetlin's figures as given by Mr. Cader and Professor Sparks' figures the results for all practical purposes are the same.

MR. JOHN RULAND

I have already commented on the evidence of Mr. Ruland as it related to the maintenance of the plant.

The Managing Director of the JFM is a Civil Engineer. He had worked for years in the construction and installation of milling facilities in various countries of the world including the United States of America and Canada. He described the procedure for the loading of the silos. Grain is delivered in barges or ships to a jetty owned by Shell Company Limited which extends into the harbour. JFM had installed belt conveying equipment and discharging equipment on the jetty and after the discharge of grains from the ship or barge it is conveyed by conveyor belt into the silos for storage. At around the time of the collapse grain arrived approximately every two to three weeks. Mr. Ruland described the loading pattern as follows [p. 3761]:

> "So when the grain is discharged form the tripper into the collection device, what is normally done is that you load one side or the other, you load the south bank,

> north bank; north bank, south bank, and you come back down the belt doing that operation. If there is a silo that is empty that can take grain you put it on the north and you move down and put one on the south. You take the outside bins first and load it for the full extent of the tripper."

And later [p. 3762]:

"HIS LORDSHIP: Let me see if I understand you. Isn't it loading north and south, north and south in the initial stages?

A: Yes."

The grain is unloaded essentially using the same procedure. The practice is "we load the outside first, the centre bin last and we discharge the outside bins first and the centre bins we discharge last." The general rule is that you try to load the facility as uniform as possible:

"Q: What is the general effect of first loadings taking place in the uniform manner that you have described?

A: Well, the reason for doing it would be to control the settlement.

HIS LORDSHIP: Is it to get uniform settlement of the facility?

A: Right."

The wheat discharged from the silos was conveyed to the pit on the east end of the 'A' silo bank, lifted by elevator to the headhouse and directed either to the 'A' mill processing or 'B' mill processing facility to be milled into flour. Silos 10 and 18 are on the 'A' bank of silos.

Mr. Ruland was at JFM on the day of Hurricane Gilbert and experienced it at first hand. Next day 13th September 1988 he made a complete inspection of the facilities which lasted about four hours, specifically looking for damage to the property structurally and water damage as a result of the rain. He described the damage he saw. He observed no water coming from the silos. He stated:

> "We looked for structural damage other than what I observed on the roof of the engineering shop to the warehouse and the broken windows, we observed no other structural damage to the building."

As a result of a radio telephone call about 6:30 a.m. on the 26th September 1988, we proceeded immediately to the plant to discover there had been an accident on the site and three employees were missing. The Fire Department, the Jamaica Defence Force and the Rockfort police were there involved in rescue operations and crowd control. In the course of the day said Mr. Ruland, we discovered that there had been a failure somewhere at joints 10 and 18, the control room located beneath silo 18 had collapsed and trapped three employees underneath the weight of the grain and concrete. It was later discovered that the three employees had been killed.

At the time of the accident wheat was being unloaded from a vessel into silo 10. Silo 18 had been loaded the previous day, 25th September. At the time of Hurricane Gilbert both silos 10 and 18 were empty. At the time of the accident silo 10 was being loaded for the first time after Hurricane Gilbert. Both silos collapsed making all the production facilities inoperable. Pillsbury Company Engineering Department, with whom JFM had a technical services agreement, and three contractors, whom they had used on numerous occasions for installation and repair work, were brought to Jamaica to assess what would be required to rebuild and bring back the facility into service as early as possible. Through the structural engineer of Pillsbury, Zetlin Argo was identified as a consulting firm of engineers that could give a competent analysis of the facility and investigate the cause of the accident.

During Mr. Ruland's time at JFM there had been seismic episodes in Jamaica that had been felt at the mills. On every occasion when this occurred Mr. McKoy, an engineer, "who has done structural and contracting work for us at the Flour Mills ... would be called either by our maintenance engineer or the operations director to conduct an examination of the facility to look for damage." This was done in late May and early September of 1988. Mr. Ruland believed it was on the 1st September. After the hurricane Mr. McKoy was also called in and had accompanied Mr. Ruland when the inspection had at that time been done. He made a report to the operations manager and effected repairs at the plant following the hurricane. Mr. Ruland gave evidence of the existence of an engineering department of some twenty-odd employees with a maintenance engineer who had the responsibility for general repairs, maintenance of the facilities and equipment. There is an engineering shop with a shop manager. Both maintenance engineer and the manager report to an operations director who is a graduate engineer. There are general safety rules. "The design and installation of the equipment follows international code of practice that has to do with the installation and maintenance of the equipment." Safety and safety-precautions in the operations of JFM are "the primary responsibility of both the engineering staff and the operating staff." Mr. Ruland described a head-house construction on the top of the bins at the eastern end. It has four columns, one on each corner of the head-house, they were constructed from the silo foundation mat and went all the way to the bottom "of the top of the silos" which were "actually the bottom of the columns that supported the head-house itself which rested on top."

Production capacity was partially restored in early December 1988 and full capacity by the end of December 1988. The demolished silos 10 and 18 were never rebuilt.

Mr. Ruland agreed that the pattern of loading which he described was only partly followed on certain days between the 11th and 25th September. He explained that at that particular time, two weeks after the hurricane, because of the hurricane Jamaica Commodity Trading Company, a Government agency, [pp. 3940-1]:

> " ... had requested that we discharge a cargo of corn for them since the unloading facilities at Wherry Wharf had been damaged, so we agreed that, prior to the receipt of the wheat vessel, we would take that corn into the system and then unload it as quickly as we could. I gave evidence earlier that we have a load-in or load-out system for discharging corn, that is on the south side of the A bank of elevators adjacent to Windward Road; those three bins are set up specifically to receive corn. So when we discharged the

corn we relocated the wheat in position so that we could put the majority of the corn in those bins so we wouldn't have to move it again, and we could - except there was part of it that was in one bin on the north side. I was questioned on that movement in cross-examination. It was exceptional because of Gilbert, the request by JCTC that we put the corn in position so that we would not have to relocate it.

HIS LORDSHIP: What was the exception?

A. In that the north south operation wasn't followed as we would normally do because in order to put the corn in position for load-out from the silos and still receive room for the wheat we had to put the corn on the south side in two of the bins that could only be used; so that the ability to go north-south was restricted by those bins that were tied up with corn."

Mr. Ruland was never asked as to whether on his inspection after the hurricane, and that of Mr. McKoy, he found any cracking in the haunch. It was never suggested to him that there was a crack in the haunch so strongly relied upon by the plaintiff, or that his maintenance procedures were inadequate or faulty and his inspection less than thorough.

MR. KAMIZIEREZ CADER

Mr. Cader visited Jamaica between October 12 and 14 for the purpose as commissioned by JFM of investigating the cause of the collapse of the silos. He inspected the silo bank, noted the failure site, which was a separation between the partition and the exterior walls through the haunch connecting silos 10 and 18:

> "The joint of the two exterior curved walls of bin No. 10 and bin No. 18 meet in the haunch which was larger than any other haunch in the exterior joint. It was due to the headhouse support sitting directly above the critical joint."

He formed a preliminary opinion that the cause of the collapse was Hurricane Gilbert. Subsequent investigations which concluded a safety factor of 1.4 in the weakest point based on the 1966 American Code requirements were calculated "on the strength of tested material taken from the vicinity of the critical joint."He also investigated the load due to normal operations. The original design in keeping with the knowledge at the time the silos were built did not take into account dynamic forces created when the grain in the silo was being discharged. However, the collapse occurred not when grain was being discharged but when the silo was being loaded. The dynamic load created during loading is very small. Mr. Cader gave the view that:

> "... in this type of structure the deficiency in design for construction should lead to a failure in a very early stage of use. Other factors which could weaken the strength of the structure were chemical deterioration as well as extensive wear of the concrete."

His investigation detected none of these. Very early Mr. Cader posited the view that in the investigation of the cause of failure of a structure already built "the best way to calculate safety factor is to test it ... all parameters like geometrical shape, property of materials is known."

In designing a building a safety factor is introduced to cover unknown parameters prior to construction:

> "We design and we are not sure until twenty eight days after the concrete is poured what strength does it have."

Mr. Cader was therefore carrying out his investigations in respect of the safety of the silos and their capacity to carry out safely and effectively the function for which they were built, that is the storage and discharge of grain and he proceeded by testing the actual strength of the structure and determining the worst operational load to which it would be subjected, rather than by investigating the design.

He described the bank of silos with:

> "A headhouse sitting on top of the eastern portion of the silo bank ... supported by four concrete columns within the bank structures."

The dimension of the haunch, which failed was 1 ft. 6 ins. All other haunches between the silos were 6 inches wide.

The compressive strength of the concrete prescribed in the drawings for the structure was 3000 psi. Checking the components of the structure connected to the area where the collapse occurred Mr. Cader jointly with Dr. Zetlin concluded that:

> "It is our opinion that the original 66, 67 design provided adequate strength to the bins to resist the load to which the bins were intended to be subjected according to the 66, 67 requirements."

This was corroborated by the fact that:

> "The bins behaved safely for over 20 years under the imposition of the severest load that existed in that period."

Mr. Cader jointly met with Dr. Zetlin, and carried out investigations which led them to conclude that the 1967 construction could contribute to the collapse only if there was:

> 1. low strength of concrete and of the reinforcement so as to "create a sufficient low factor of safety to cause a collapse;
>
> 2. insufficient bond strength concrete at the ends of the reinforcing bars or insufficient lap length between the reinforcing bars, so as either to pull bars out of the concrete or fail to transmit tension between lapped bars."

Their investigation and analyses demonstrated adequate factors of safety in both respects.

They then turned their attention to the effect of Hurricane Gilbert.

Investigation and inspection of the surviving bins confirmed that there was no deterioration resulting in weakening of the concrete or steel in the structure of the bins.

In my view it is most improbable that the only deficient materials would be found in the structure of bins 10 and 18 if defective materials were a contributory cause of the collapse since all the other silos remained intact and had like silos 10 and 18 safely carried the operational load.

Tests were carried out on structural materials taken from bins 10 and 18 and inspection of the debris was carried out.

The five steps taken by Mr. Cader and Dr. Zetlin in calculating the cause of failure were in respect of:

1. the horizontal load created by Hurricane Gilbert;
2. the soil pressures including that load;
3. soil settlement due to dead load, live load and Hurricane Gilbert load;
4. the internal stresses caused by the differential settlement;
5. a computer analysis of the three dimensional model of the eastern end of the silo bank.

The evidence with respect to 1, 2 and 3 is provided by Professor Sparks and Dr. Oweis, the wind and soil experts, respectively. The computer run showed:

> "At the east end we have a 6' 6" of tilt. At the west end tilt was calculated at 2.72."

These figures also corroborate the measured tilt by Wiss Janney Eistner.

The conclusion arrived at was as follows:

> "This computer analysis represents the state of stress after Hurricane Gilbert. The effect of the hurricane remains in the structure deformation. Foundation settlement due to excessive external force of Hurricane Gilbert caused deformation (tilt) of the silo bank. The deformation generated severe tensile forces particularly in the partition between silos #10 and #18."
>
> Thus are the internal stresses identified.

Mr. Cader's criticism and disagreement with the approach of Mr. Minor the chief witness for the defendants/respondents who was called inter alia to disprove Mr. Cader's thesis was twofold:

1. Mr. Minor used linear strings to model non-linear soil.

2. In his computer investigations Mr. Minor incorrectly tied the exterior walls to the roof with the result that "the whole bank of silos rotated as a rigid body creating uniform tilt of 13.8 inches."

Mr. Cader's inspection of the silos after the collapse in 1988 showed no evidence of concrete deterioration. In relation to the concrete from the haunch he said:

> "The break of the concrete indicated the well compacted material and the strengths which could be expected about which was specified 3000 pounds per square inch (psi) which would indicate the strength of concrete in order of specified 3000 pounds per square inch. When concrete breaks and the stone which is integral part of the concrete breaks through the stone or gravel this indicates the strength of the concrete."

Mr. Cader pointed out that Mr. Minor had said [Exhibit 28 page 79]:

> "The amount of reinforcement provided was adequate, it was based on manual calculation provided."

Mr. Cader always insisted that you have to deal with the existing structure in order to calculate the safety factor not how it should have been designed in 1966. The partition wall between silos 10 and 18 was a 6 inch wall.

In respect of the detailing of the reinforcement in the critical joint, had he designed the structures he would not have done the detailing in the way in which it was done. He would have provided the required overlap in the joint. That however did not contribute to the failure:

> "We had calculated the strength of the foundation in the Report, Phase 2 and 3 in all critical cross-sections and we found the safety factor was appreciable."

Hurricane Gilbert had a wind load 83% bigger than that required by the 1966 Jamaica Building Code. The Building Code has a specification of 96,713 kips feet. Gilbert had 178,000 kips feet.

What was the position in respect to the loading of the silos on the day of Hurricane Gilbert? Mr. Cader states that almost every bin was filled with grain except the eastern end. The effect of the hurricane would be limited on the western end of silo bank where the bins were loaded. It would be exaggerated on the eastern end where the silos were empty and thus very vulnerable to wind load.

It was Mr. Cader's view that:

> "Engineering history shows that structures which served their purpose safely for twenty years or so do not collapse suddenly unless:
>
> (i) there was a sudden change in the service function of the structure;

> (ii) there was chemical deterioration of the concrete and/or of the reinforcement;
>
> (iii) the structure was subjected to unpredictable external forces;
>
> (iv) occurrence of unpredictable violent acts of nature."

He further stated:

> "If it is sufficient safety factor you would not expect failure even after a hundred years of cyclical loading. It is a matter of stress stage."

Mr. Cader's testing programme was prepared to determine:

1. yield stress, ultimate strength and ductability of the reinforcing steel;

2. compressive strength of concrete;

3. tensile strength of concrete.

All test samples were taken in the vicinity of the collapsed joint between bins 10 and 18.

What was the quality of the concrete in the haunch? Some concrete taken from the site of collapse had delaminations and honeycombing, but it is concrete quality from the haunch that is important.

Mr. Cader maintained that:

> "We should distinguish the two groups from the cores which were taken from the debris. The two pieces of debris as shown on figure 1 and figure 2 were taken from the exterior curved wall which was smashed after it opened due to the collapse, so we tried our best to get those concrete samples from the vicinity of the joint between bins 10 and 18. We did not succeed

with that because many of them were cracked due to the collapse."

However Mr. Cader maintained:

"... our inspection of the crack which went through the haunch did not detect in any part of the joint the honey-comb condition of concrete.

Q: Mr. Cader, are you saying that there was no honeycomb in the haunch?

A: Yes.

Q: You checked it yourself?

A: As far as I could, yes.

Q: As far as you could?

A: Right.

Q: Have you ever said that in any report before?

A: No."

This evidence drew from the Learned Trial Judge in his judgment the illogical conclusion that since the absence of honeycomb in the concrete in the haunch was not mentioned by Mr. Cader in any report then there was in fact honeycomb in the concrete in the haunch. Mr. Cader had further stated:

"I hadn't seen any honeycomb on the face of the haunch crack at the partition; that is the place inspected."

The test cores of the site of the material taken from the site produced average strengths of concrete tested as 2,921 psi.

In dealing with the design requirement of the code Mr. Cader was asked:

> "***Q***: To make a true assessment of the design situation should you have limited yourself to the design requirements of the code?
>
> ***A:*** If the project was sent to me prior to construction I would do so. After the collapse to establish the safety factor I could not neglect the concrete tensile strength."

The safety factor in determining the strength of the structure is "the simple relation between the strength and the expected forces due to normal loading."

Mr. Cader was shown a photograph which indicated rusting and pointed out that the rusting shown on that photograph is a reinforcement of the eastern curved wall. He was also shown a coloration which was suggested to him showed grain on the inside of the crack which indicated that it was an old crack. He does not agree as he said:

> "It's a residual of the grain which was falling down when the collapse occurred. ... We had massive grain falling down and part of it just happens to stick to the rough surface, that is my understanding of it."

It will be important when we come to Mr. Minor's evidence to see the circumstances under which the photographs were taken and how they were taken to determine what conclusions we can reasonably draw as to certain aspect of the photographs.

Mr. Cader saw no evidence of concrete deterioration during his inspection after the collapse.

In Exhibit 29 page 78 Mr. Minor had stated:

> "The amount of reinforcement provided was adequate, it was based on the manual calculations provided."

Mr. Minor had stated in relation to the fact that the day before the collapse one silo was filled but the other was empty that:

> "Since the unbalanced load on the partition wall is at a maximum when one silo is empty and the other full Zetlin's argument about the weakening effect of the hurricane is not credible. The unbalanced load on the partition wall between silos 10 and 18 was greater the day before the accident than when the failure occurred."

Mr. Cader however stated:

> "We investigated very carefully the loading pattern, the loading process during September 1, and we did not find any greater load than we introduced, the corn of 98 tons loaded and unloaded the day before or two days before."

In my view any analysis which includes dynamic effect of unloading in determining the cause of collapse is not appropriate as the silo was not being unloaded on the day of collapse and so there was no dynamic effect at that time.

Mr. Cader agreed that the design was not perfect, but what was relevant was the strength of the structure not accuracy of the design - "we looked at the existing structure."

In calculating the strength of the existing structure Mr. Cader looked at the theory of concrete, the theory of reinforced concrete and also the theory of structure.

The defendants/respondents proposition is that if a building does not faithfully follow the requirements of the Code for design and it collapses however long after it is constructed then the collapse must be due to faulty design. Mr. Cader challenges this. He is saying that you must still test the building for its strength to determine whether its collapse was due to its inability to deal with the loads it was constructed to carry in its day to day usage and operation or whether the cause of the collapse is some external force generated by an unusual peril against which the owners of the building have insured it.

It was agreed by Mr. Cader that the really important factors of safety are:

(a) the tensile strength of concrete, and

(b) the bond strength between the steel and the concrete.

The factor of safety against cracking at the section where the crack took place was 2.3:

> "We calculated in tension. The crack occurred, this is agreed and we had no other approach, the section of the partition six inches wide.
>
> When concrete crack the steel becomes the major component dealing with tension."

Mr. Cader checked "the structure strength against the original 1966 load requirements, and the second factor was that the structure collapsed being exposed only to static pressure."

The learned trial judge was critical of Mr. Cader because he used his engineering judgment at times. This is a judgment made and expressed in an area where the witness is qualified to do so by virtue of training and experience. If there is evidence which throws doubt on that judgment or if there is a preferable contrary opinion the Court may reject it. However, the Court should not reject engineering judgment given by an expert merely because it is engineering judgment. It is a legitimate source in decision-making by a person qualified to do so.

Where did the crack take place?

Mr. Cader answered:

> ***"A:*** It cracked through the haunch about 10 to 12 inches.
>
> ***Q:*** Mr. Cader, didn't it manoeuvre, it wasn't a straight line was it?
>
> ***A:*** It wasn't, it was very various width.
>
> ***Q:*** Some 8 inches, some 10 inches, and so on?
>
> ***A:*** I would say some areas w ere 8 inches, some were more than 12 inches.
>
> ***Q:*** Some were 8 inches. It was the zone of failure, this whole area?
>
> ***A:*** Yes, we agreed on it."

Thus one of the certainties of this case is the exact locus and dimension of the crack which caused the collapse. It is the strength of that haunch which is relevant to a determination of the cause of collapse.

Mr. Cader says that the haunch had safely resisted for years a much larger force than the 7.9 kips applied at the time it collapsed, therefore the design could not be the cause of the collapse. He checked the strength of the joint (haunch) against the static pressure. The design was not perfect. He said:

> "I would not design a structure like that frankly."

There was no dynamic pressure on the day of the collapse:

> "We investigated the silo due to the static pressure as per 66 code as well as the cause of collapse was investigated as the day of the collapse load."

7.09 kips was the largest force imposed on the partition between bins 10 and 18 on September 26, 1988 by the grain due to loading. The junction was safely subjected in former years to a force on the partition of 17.04 kips. In cross-examination it was suggested that that figure should have been 13.23 kips. In my opinion it really does not matter as to whether the force to which it was subjected at an earlier time was 17.04 kips or 13.23 kips as against 7.09 kips the largest force imposed on the day of the collapse. The critical crack took place very close to the jack rod. Some of the steel bars did not go around the jacking rod. However, all the bars did reach the jacking rod. Stresses decrease as you go further into the haunch.

Mr. Cader had said that in certain conditions cracks will move towards the areas of greatest localized stress but this did not apply to the haunch:

> "Because ... the haunch is getting wider so rapidly the stresses dissipate."

He rejected any suggestion that a crack occurring on the 8" or 9" section of the haunch would move towards the 14" section where the bar ends.

Mr. Cader also rejected any suggestion that a crack in the concrete would lead eventually to progressive failure. As long as the reinforcement was sufficient the crack would remain in the concrete. If there is a bond failure caused by forces there will be a break immediately:

> "The crack which is initiated when it goes through the reinforcement immediately transfers the tensile forces into the steel reinforcement and the widening or the crack doesn't change ... until we reach beyond bond strength."

Bond failure is when the bar slips from the concrete.

From Mr. Minor's photographs it appeared that a number of bars did not go around the jacking rods. However, from the photographs it was very likely that all the bars at least touched the jacking rods from the inside. Bars do go into the haunch.

There was a measured tilt (Wiss Janney) discovered by a verticality test after Gilbert:

> "As far as our information were concerning the wind load prior to Gilbert we did not find any similar horizontal forces to be applied to the structure so we did not expect differential tilt prior to Gilbert."

Mr. Cader admitted that the torque was applied in the wrong direction. If the torque had been applied in the correct direction the figures would have shown greater subsidence in the south-west, but two errors were made by him:

> "... which both cancelled itself as it was presented by Professor Sparks, so in this logic I admit the numbers are correct, but as far as the Gilbert load is concerned we can't summarise this as the final number."

He admits the error concerning the torque, but:

> "Another component which I mentioned before is the longitudinal forces which we did not take into account at first at the moment when we calculated the soil pressures. It happens to be that dropping the torque the mean torque and fluctuating torque from the consideration, adding the only torque due to geometry that the hurricane is generating we have the final soil pressure which was presented by Professor Sparks very close to those numbers presented in this report."
>
> [The Report referred to is Mr. Cader's Report].

Many suggestions were made to Mr. Cader concerning hypothetical conditions in terms of a variety of loading patterns which could cause settlements at one end or another of the silo bank. Mr. Cader's reply was that:

> "Knowing the standard operations procedure to load one silo we did not look at it from this perspective."

Mr. Cader did not find it reasonable to use the worst loading patterns when in fact there was no evidence to support that these loading patterns had indeed been used and there was evidence as to what the normal loading pattern was. Indeed Mr. Ruland, the Managing Director of JFM gave this evidence.

Mr. Cader using computer runs concluded that the stress concentration resulting from the differential tilt would be at the joint between bins 10 and 18 which was the area of failure.

There has been much comment and indeed highlighted by the learned trial Judge in his judgment that the computer runs by Mr. Cader were "stage-managed" in order to establish that there was deformation and differential settlement. What was not grasped from Mr. Cader's exhaustive and no doubt exhausting cross-examination was that:

> "It was clear that I was trying to find a deformation that complied with the differential settlement, it was not hidden ... it was quite an accurate direction which I was going by using the computer analysis ... it was the method iteration."

Mr. Cader had earlier explained the iteration process:

> "This is a method where you approach the problem by trying different conditions of the structure to find out the final deformation in our case ... when there

> are too many variables which is almost impossible to resolve mathematically we use the method by calculating step by step looking if the numbers are getting closer."

The word "stage-managed" was introduced by Mr. George QC, Counsel for the defendants/respondents and having earlier introduced it in reference to Mr. Cader's calculations using the method of iteration Mr. George asked:

> ***"Q:*** And the eight pages that follow are stage-managed to say that there has been settlement?
>
> ***A:*** Yes."

It is to be noted and it is clear by a reading of the record as to Mr. Cader's use of words that English was not his native language. The evidence is that he is from Poland. The learned trial judge instead of making a determination as to whether the process of iteration was a recognised and acceptable process in the engineering profession seized upon Mr. George's emotive word "stage-managed" and clearly misunderstood the purpose and methodology of Mr. Cader's computer runs.

Since the Learned Trial Judge states that Mr. Cader "agrees that when one compares the calculations for nodes 21 and 25 there is an inclination of the settlement towards the west, it is interesting to see the context in which this agreement is arrived at.

Asked if the computer output is 0.48 inches at node 25 which is at bin 24 is 0.48 inches Mr. Cader agreed. He was then asked by Mr. George Q.C.:

"***Q:*** But node 25 is to the west of node 21?

A: Yes, sir.

Q: So the inclination there of the settlement there is more towards the west than to the east?

A: No, sir.

Q: And on the southern boundary?

A: No, we discussed this situation which should be taken as relative rotation of the eastern section to the west section. So the rotation of node 21 is higher due to the smaller distance having almost the same vertical settlement than the section through the nodes 3 and 25.

HIS LORDSHIP: The question as I understand it is that there is an inclination of the settlement towards the west when you compare the calculations for nodes 21 and 25?

A: Yes, I agree with that.

HIS LORDSHIP: You are not disagreeing with that?

A: I am not disagreeing with that, I am just qualifying the use of that with the reality to ...

HIS LORDSHIP: You are just trying to say there is hardly any difference?

A: Yes.

HIS LORDSHIP: But there is an inclination of .002?

MR. CADER: 0.001.

MR. GEORGE: ***Q:*** But, Mr. Cader, it certainly doesn't show it going towards the south east.

	A:	It doesn't show it if you look at those two numbers only but from the bigger picture ...
MR. GEORGE :		We will come to that.
MR. MAHFOOD:		Please, please, let him finish.
MR. GEORGE :	***Q:***	And if you look at those two numbers alone you see ...
MR. MAHFOOD:		Let him finish his answer.
MR. GEORGE :		M'Lord, I did not ask the witness to argue with me.
MR. MAHFOOD:		It is not an argument.
MR. GEORGE :		It is an argument. I said to the witness, 'but these two figures do not show an inclination towards south east', all he can is answer me is, yes, but to tell me about it does that.
MR. MAHFOOD:		M'Lord, I would like to be heard on this. It is a typical evidence, taking numbers and misusing them.
HIS LORDSHIP:		This doesn't really require any further explanation by the witness."

All this was very technical evidence and in my view Mr. Cader should have been permitted to make any explanation which he thought necessary in order to clarify his answer; particularly as it was important enough to be referred to by the Trial Judge in his judgment.

Mr. Cader was given Professor Sparks' soils pressures, and he pointed out it was for the wind from 30° to the silo bins. Asked whether his figures widely differed from Professor Sparks' he replied:

> "From the total yes, but when you look at the components we are in the same ball-park figures."

The building was more flexible than at the time it was built because over the years natural cracking makes the building more flexible. His engineering judgment was his engineering knowledge and experience. The forces generated by the head-house either the operating forces or dead load or wind load are transmitted through the four columns of the head-house which are reinforced and created to transfer the virtual loads to the foundation.

Mr. Cader's evidence therefore concluded in support of the plaintiff/appellant that the cause of the collapse of the silos was the forces unleashed by Hurricane Gilbert which he described in detail to the Court.

THE WITNESSES FOR THE DEFENDANT

MR. BASIL MINOR

The brunt of the defendants' responsibility was borne by Mr. Basil Minor, a Civil Engineer who had working experience in the United Kingdom, in Malta and on the Continent of Africa. R. B. Hawkins, an Engineering Firm in the United Kingdom, well-known for their specialization in arson and explosion cases had been contacted on behalf of the defendants/respondents to investigate the collapse of the silos when it was thought that the collapse might have been due to some explosion. They recruited the assistance of Mr. Minor as a structural engineer. When it was clear that an explosion was not involved R. B. Hawkins early dropped out of the picture and Norman and Dawbarn, another Engineering Firm joined the investigation in January 1989. The Norman and Dawbarn Report was written by a Mr. Peter Pugh, but an appendix written by Mr. Minor stated:

> "... due to the stresses caused by operating the silos, by filling them with grain, the bars in the junction of the haunch between the outer wall and partition of silos 10 and 18 were over-stressed. The concrete cracked, there was insufficient length of bar across the crack to hold the silo together, and the silo as a result failed." [p. 3982]

Mr. Minor has not diverted from that conclusion as his evidence discloses. The purpose of the silo is to hold the grain for a period to be then discharged when required for milling. This happens regularly over the years. The grain exerts pressures on the walls of the silos and on the floors. The loads carry a high proportion of the grain and are pushed downwards both because of self-weight and the weight of the grain. There is horizontal tension created on the walls. A Formula known as Jannsens Formula gives a good representation of the state of stress of granular materials when a silo is being filled or the grain is stationary. It had more recently been discovered that this pressure is greater when the silo is being emptied. The JFM silos were designed before this discovery was made. Two concrete specimens taken from the site of the collapse on being tested indicated the absence of a lot of salt, the presence of which could have led to the corrosion of the steel reinforcement, and also the absence of any excessive carbonation given the age of the silos, which would have made the concrete more acidic and less alkaline. The quality of the steel was in excess of that required by the drawings. As no steel was broken in the collapse the quality of the steel had nothing to do with the collapse. In his opinion the silos collapsed because the bins are subject to loading and unloading over the years:

> "The crack perhaps might have been there from the very beginning - or perhaps the crack occurred in the first filling or second filling, small cracks - slowly open under each successive filling and emptying. ...
>
> This progressive cracking caused by tension forces and compressive stresses in the silos grows larger and larger until eventually we come to a point where there is too much crack and one is relying no longer on the stresses being distributed both by the concrete and steel reinforcement but all the stress must be taken by the reinforcement."

Whether or not the silo then stays up,

> "... is determined by the strength of the bars; whether the bars themselves are properly bonded into the concrete in order that they can transfer stress from one reinforcing bar to another reinforcing bar. If there are not enough bars the stresses in the bars would be too high and the bars would break. If there are enough bars on the other hand, we have got enough bond, then the bars would slip and each time it's loaded the bars would slip, and each time the other bin is loaded those bars from one side of tension would now go into pressure and then would perhaps push back in there, and each time it is pulled out and has to be pushed back in - but although it is being pulled out the force of pulling causes hoop tension which are always higher than the force of pushing, because pulling and pushing, those bars are bending, but overriding that is pulling which is due purely to hoop tension; so each time the cycle goes it pulls a bit

more till finally there is no more anchorage left and everything will slip.

MR. GEORGE: Q: The whole thing will un-zip?

A: The whole thing will un-zip from the bottom to the top." [pp. 3991-2]

It is to be noted that the steel reinforcing bars in the silos did not break.

When Mr. Minor visited the site after the collapse he could not get up close to it as he would have liked because of the fear of further collapse which seemed likely because of concrete and steel hanging from the wreckage. Being a near-sighted person he borrowed and used a pair of binoculars to get a better view so as to take in more details to be able to make a judgment. Mr. Minor was trying to determine the mechanism of collapse why the initial failure had taken place and other contributory factors. He saw no evidence of differential settlement. He looked to see:

1. The quality of the concrete.
2. How the reinforcements were placed.
3. Whether the walls had the dimensions as shown in the drawings.

He took photographs. At the site of the collapse "there seemed to be very little protrusion of the reinforcing bars out of the concrete." He saw a great many layers of bars but he photographed a record of the first sixty. He wished to determine "whether each of the two bars in any layer might or might not have been hooked around the virtual jack rod bar". It took him two to two and a half hours because:

> "There is a difficulty when you are looking at something if you are standing still you can't tell where it is in three dimensions, so one has to move side to side to see whether it moves relative to other things; in order to get the third dimension that helps. So it took quite a long time to do this because I kept on moving my position to see where each bar was." [p. 4000]

He produced a table which he had made in respect of the layers of steel bars. He admitted in answer to a question:

> ***"Q:*** Could you have made any mistake in producing this table?
>
> ***A:*** I might have counted the same bar twice, I might have left a bar out, but it would be difficult to make gross errors because one merely looks at a time on two, three or four bars. There would be an angle inclination to where you are standing and you would know that you had seen those two or three bars, so I don't think I would have made any gross errors. I may have missed one or two bars or counted the same one twice." [p. 4001]

In interpreting the photograph he assumed that any bar that is straightened to a certain extent went around the jacking rod and that any bar that is at right angle or is still embedded over the concrete did not go around the jacking rod. The significance of whether the bars were or were not around the jacking rod was that this would determine "whether the construction was in accordance with the design or not ..." He found that 50% of the bars were definitely not around the jacking rod and that was very poor construction. He viewed the scene about two weeks after they had collapsed. He gave his opinion that in some areas where the design called for one bar to be on the safe side he would have put two bars. He saw evidence of rusting bars which indicated that in certain areas the steel did not have sufficient concrete cover. This evidence was from the photographs he had taken. One particular photograph is examined by Mr. Minor - photograph 36:

> "... you will see two bars that came away from the outer wall of silo 10; you can also see the camera has gone closer - the end of the partition between silos 10 and 18." [p. 4020]

Mr. Minor did not take this photograph himself and is only interpreting it. It was taken by Mr. Pugh.

I cite the evidence since Mr. Minor relies heavily on it for his conclusion :

"MR. GEORGE: ***Q:*** Now, can you explain the significance of what you see in photograph 36 for us?

MR. MINOR: ***A:*** If we look at the indentation particularly the top of the location where the bar was you will see that the concrete - the indentation has a slightly rusty colour, and you will see if you wind the reinforcing bar back onto its indentation, you will see that it is particularly rusty at the point where it would have been if one winds it back where the actual crack occurred. So that rusted portion on that bar would have been, if one wound it back onto the wall at the point where the crack actually occurred. Same is true of the other bar, the second bar, you will see the rust at the same location on that bar, and if one goes down and look at the distinctive shape of these concrete

you will see that there is a crack between it and the remainder of the outer wall, and that crack shows up with a rusty colouring. In fact, you will see another bar just above that is rusty at that point. That indicates that there had been a crack in the wall there for sufficiently long a time for the bars to have rusted. Not only that, the crack must have been wide enough to have allowed the entry of water into the concrete. Therefore, as I only came to the site - this photograph was taken eight days after the collapse - clearly that crack had been there before the collapse, a significant time before the collapse. Maybe a year, maybe two years, maybe five years. The degree of rusting is not - consistent with two or three weeks."
[pp. 4021-2]

Concerning photograph 32 his evidence is:

"A: There are three points of interest in this photograph. One is that the width of the cracked zone varies, being quite narrow, being wide, but a large number of the hooks clearly are still embedded in the concrete, and thirdly, there is grain on surfaces at that point. Some of the grain is clearly crushed, others, the grain appears to be a bit more grain, I don't think you will see any full sized grain, but it's broken and totally crushed grain on that surface.

Q: What would that indicate, would it indicate anything to you as to how it got there?

A: For grain to have got there you notice that much of the crack has no grain in it at all. You will notice most of the surface of the wall has no grain material on it. In fact most of the vertical surfaces had no grain. It indicates that something must have pushed that grain onto that surface in order for it to be there on that surface.

MR. GEORGE: Q: How would that happen?

> ***A:*** Well, if there had been a crack at the time when the grain in there was sufficiently high up for the grain to get into crack, if the crack then closes when the other bin is being filled, then the pressure exerted when the crack closes by filling the other one would have impacted that grain onto those surfaces." [p. 4022-3]

The photograph he said disclosed areas in the silos of concrete of honeycombing.

He later evaluated Dr. Zetlin's Reports which had been prepared in conjunction with Mr. Cader and the Ward Report which was prepared by Ward and Oweis. His evaluation of Dr. Zetlin's Report "dealt with winds coming from the north." In fact the winds came from the north-west:

> ***"Q:*** And this point of view remained until Dr. Sparks gave evidence, isn't that so?
>
> ***A:*** Yes, it is a misunderstanding on my part I must say." [p. 4035]

Dr. Zetlin's diagrams did show the winds coming from the north-west. In dealing with wind loads and whether the wind came from the north or north-west Mr. Minor said [p. 4037]:

> "The forces that might be expected due to the wind will be much the same given the same wind load velocity irrespective of the direction, but the point of application of those forces will vary as the direction of the wind itself varies."

It must be recalled that Mr. Minor's expertise is not wind engineering.

He went on to deal with the question of suctions. At this point Counsel for the plaintiff/appellant Mr. Mahfood QC challenged Mr. Minor's qualifications and experience to give expert evidence on the effect of winds and the Learned Trial Judge said that the evidence would have to be considered for weight later.

The judgment does not identify that he did so. Mr. George QC appearing for the defendants/respondents said that if the necessity arose the defendants/respondents would call a wind expert. Indeed Professor F. D. Lawson, a wind expert commissioned on behalf of the defendants/respondents and present in Court was never called. In my view Mr. Minor was not qualified to give evidence on wind effect and pressures and therefore his evidence in this regard should not be preferred to the evidence of Professor Sparks and Mr. Calvin Gray. His evidence on wind consisted really of an interpretation of a Report by Mr. Lawson in an area outside Mr. Minor's expertise. Its admission was dubious and its weight, if any, negligible.

His extensive comments on the computer runs by Zetlin Argo and their validity must also be considered in the same light. Mr. Minor is likewise not an expert on soils, although diffidence did not restrain him from exhaustive commentary and views in this important area:

> ***"Q:*** So you did your own computer model?
>
> ***A:*** We did our own computer model."

On examination it is seen that the computer analyses were done by Norman and Dawbarn/Strucom and Mr. Mahfood QC did point this out during the evidence to the learned trial judge. Mr. Minor's evidence therefore as to wind effect, differential settlement, settlements generally, the effect of the head-house, the computer runs distortion, linear/non-linear soils, the real locus of the higher stress during the hurricane, is in my view very much second hand, constructed on hearsay and of very little assistance because it carries negligible weight when placed in the scale as against the evidence of the specialist wind expert Professor Sparks and the specialist soil expert Dr. Oweis. It is in this light that his conclusion on the computer models Norman and Dawbarn/Strucom must be assessed:

> "Yes, it convinced me of two things: one is that it would be exceedingly difficult if not impossible to get a differential settlement of an inch and a quarter in the manner shown in the Zetlin Argo Report. And further, had there been a settlement, whatever its value, the higher stresses would occur elsewhere in the silos to the point which collapsed two weeks later." [p. 4084]

Mr. Minor did some calculations to determine the order of magnitude of stresses which he would find in the silo due to grain, wind, hurricane, earthquake. For the reasons I have already given we can discount his evidence on wind and hurricane and also omit earthquake since no one suggested that the collapse was caused by seismic activity.

Mr. Minor calculated using average values for the density of wheat - 24° considered by him as typical in a range of 15° to 35° - and applying

Jannsens Formula: “The state of pressure in grain when at rest or being filled” - and concluded that the tensile force in the walls between silos 10 and 18 was 99 lbs. per square inch. He therefore expected cracking to be initiated. The design drawings showed crushing strength of concrete of 3000 lbs. per square inch which allows the compressive strength of 1000 lbs. per square inch and the “allowable” tensile stress in the concrete as accepted by the engineering knowledge of the 60s of 10% of 1000 or 100 lbs. per square inch. This typical loading is up to the maximum permissible stress.

Here we note one of the main differences between Mr. Cader and Mr. Minor. Mr. Cader maintained consistently that in determining the cause of collapse it is necessary to investigate the strength of the structure as constructed and existing at the time of collapse and not the design requirements.

Mr. Minor looked at tensile strength in the concrete when one silo is full and the adjacent silo empty and came up with a stress value of 684 lbs. per square inch. In his view the concrete would have cracked “long before we got anywhere near 684.” He considered the effect of these stresses in relation to the 6 inch partition wall. There is no dispute as to where the failure site was situated. It was in the haunch, which was not 6 inches thick but was in fact eighteen inches thick. Then Mr. Minor makes a remarkable statement in view of the fact that he was attempting to establish that cracks were caused by stresses:

> "... in any case the concrete might have been born with cracks in them."

Referring to loading conditions at the time of the collapse he stated:

> "I find that the tensile stress due to moment and hoop tension was quite low under those loading conditions and therefore under those conditions ... the amount of reinforcement provided was adequate. ... it was adequate in terms of the amount not for its location or for the way it was actually put in the structure." [pp. 4102-3] .

. He was unhappy with the way the steel was laid both as shown in the drawings and as seen on the site in the photographs and his long distance view. There was no overlap of the bars which is needed in order to transfer safely stress from one bar to the next. The design did not call for it, and in Mr. Minor's view was in this respect deficient.

He said:

> "... all I had left with was the anchorage of a few hooks across a crack which had pre-existed before the collapse." [p. 4104]

An important question to be determined in the case was whether the crack in the haunch was an old crack existing before the collapse which progressively grew until the reinforcement in the haunch could hold it together no longer resulting in the collapse. That was Mr. Minor's thesis.

The bar should extend beyond the crack into the path that holds the two bits together:

> "On one side the bar is in the whole of the partition, I saw 9' 6" of bar but on the other side of that there was just a hook, there was no length of bar in many instances. In fact, the hook did not extend as far as the crack so all that was left was the hook; that is all that was left in some cases to hold the structure together." [p. 4106]

He calculated a factor of safety of 1.1 and with this factor of safety collapse is possible at any time. A good design assumes that concrete has no tensile value and would have assumed a crack. There was no sign of any distress in the silo due to a vertical load. He saw nothing in the other silos which would be attributed to wind load or grain load.

What then, I ask, was the difference in construction between silos 10 and 18 and the other silos and the factors which caused these two silos to collapse? The haunch and the head-house sitting on top of silos 10 and 18, the pounding effect of the hurricane on the head-house, the non-linear nature of the soil, the differential settlement all eventually leading to the cracking of the haunch and the collapse of the silos on the first loading after the hurricane. That seems to me to be the reasonable answer on the balance of probabilities.

Mr. Minor was not diffident in wandering into the area of soils and in criticism of the Report of Drs. Ward and Oweis. My remarks on his level of experience in relation to wind force and effect would equally relate to his lack of experience on soils. His discounting therefore of the evidence of pressures caused by the hurricane must be viewed in that light. In so far too as he gave views on the Ward/Oweis Reports on soils and the Engineering Geology Limited and Strucom soil Reports prepared on behalf of the defendants/respondents (the authors of which never gave any viva voce evidence) the weight of these views must be minimised in relation to their evidential value.

Mr. Minor did not have any information as to the amount of grain in each silo in the bank of silos at the time of the hurricane. His information was only in regard to the amount of grain in the four silos at the eastern end - silos, 3, 10, 18, 25, of which 10, 18 and 25 were empty at the time of the hurricane.

He carried out several computer runs and concluded at p. 4274:

> "The various studies carried out continue to indicate that even under extreme wind loads or substantial foundation distortion the critical tensile force that caused collapse of the silos is due to loading the bins with grain. Choosing other values for foundation stiffness or other directions for the wind forces are also going to have minimal effects although conditions can no doubt be found which will increase rather than decrease the stresses in the critical joint."

The Hawkins/Strucom/Minor computer runs had one obvious critical flaw. Mr. Minor quite wrongly tied the exterior circular walls of the silo to the roof. The effect of this was:

(a) the foundation mat was treated like a rigid body;

(b) there was no differential settlement and no differential tilt,

(c) there was no distortion of the silos which distortion the plaintiff/appellant had maintained had caused the stress in the critical joint.

Mr. Minor admitted that the computer model attaching the roof to the walls created a more rigid structure than the actual silo bank at JFM:

> "Our computer model might be in the order of 50% too rigid."

He stated that:

> "Because of the time and the way the Court sits, having made this mistake of fixing the roof I cannot go now and redo my computer run, so I am stuck with the structure which has a certain stiffness." [p. 5572]

Mr. Minor further admitted [pp. 4331, 4333] that he was unable to prove from the loading of the silos at the time of the hurricane that the load:

> "... is either the same or perhaps slightly higher in the south-west than in the south-east. ... So I have to remain with my statement that I do not know whether it was higher in the east or the west."

He used an inclinometer to measure the slope which was stated as 45° on the Mel Jarvis drawing which Dr. Oweis had used in combination with his assessment:

> "... we didn't get on the slope itself, we went and parked in the road below the slope. ... we got readings at 30 degrees at the west end and 27 degrees at the east end." [p. 4353]

The "unknown" formula is "used for determining pressure due to eccentric loading and not for torsion" So what Mr. Minor is certain of is that Dr. Zetlin is wrong, Dr. Simiu is wrong, and Professor Sparks is wrong in the use of the formula. However the formula now graduates from being "unknown" to one that is known for deriving pressure due to eccentric loading, in fact for the distribution of pressure. It is to be noted that Mr. Minor has not established any expertise in this particular area. He however agrees with the approach of Professor Sparks that the wind load "is a north westerly wind and would blow on the silo bank both to the south and the east." His departure is in respect of the use of the distribution formula. Mr. Minor however did make one concession [p.4331]:

> "... obviously, if you have a headhouse at the eastern end you would expect the pressures to be higher than they are in the western end."

He however then proceeds to embark on a theory as to why they were not.

In the welter of evidence which Mr. Minor produced on the question of settlement of soils Mr. Mahfood QC for the plaintiff/appellant asked the question [p. 4493]:

> ***"Q:*** On a point of clarification, is this evidence being tendered by Mr. Minor as a soil expert or a structural engineer?
>
> ***HIS LORDSHIP:*** I think we dealt with that some time last week, that in the end it would be a question of assessing his ability to give the evidence that he is giving."

An examination of the judgment does not disclose whether the Court ever made the promised and necessary assessment.

Mr. Minor's criticism of the design is stated as follows:

1. Like Mr. Cader he believes that there should be overlap of the reinforcing bars, as the proper way of transferring loads from one reinforcing bar to the other. The design however had some hooks around the vertical bar.
2. The Code requires every three sets to be staggered and in the design only two sets are staggered.

He quoted the provision in the British Standard Code of Practice as follows:

> "(1) General - Laps in bars in any member should be staggered."

Mr. Minor when asked directly:

> **"Q:** ... how do you say the collapse of the structure came about?"

replied as follows:

" A: The structure was inadequately provided with reinforcement insofar as the location, of the amount ...

HIS LORDSHIP: Insofar as the -?

A: The location of the reinforcement probably the amount of reinforcement as well. This under-provision of reinforcement resulted in cracking occurring at discrete points in the walls.
[Emphasis mine]

MR. GEORGE: Q: Yes.

MR. MINOR A: Due to the manner in which grain is taken out of the silos, for example, you might get high stresses occurring in the walls at some height of say 20 feet above the bottom, so because of particularly high stresses that particular wall cracks and because it cracks, the crack gets to any width, the wall would flex a little bit and the load would drop just marginally, so the inherent strength still left in the wall after it is cracked matches forces that are now on the wall. That crack might be only over a length of four or five inches the first time at one side of the wall. Now when the other silo is perhaps empty at some future date one perhaps get an over pressure - over stress again and crack might then turn the other side of the wall; it might be only two or three inches long, and because the nature of grain tends to be very similar it tends to produce the same colour type, it doesn't mean the grain is always the same, sometimes it is different. If you look at the grain inventory you will see that they have had two or three different types of grain in the silos at any one time. For this first grain we are talking about, it produced these high stresses at the height of 20 feet or so. If you had a slightly different grain it might produce these high pressures at a height at the middle of that high pressure, say 25 feet, so now instead of cracking 20 feet a new crack might start at 25 feet or perhaps it might not because the design at 25 feet above might be good, they might put all the reinforcement around the jacking bar. So perhaps at this point it might not crack but with a different wheat, with a different area at different times then perhaps the crack occurs somewhere else and slowly over these years these little cracks - and each time the grain is slightly different that point of high pressure might move up or down at some point about 20 to 30 feet from the bottom and slowly these cracks in effect might start touching each other, and when cracks touch each other the forces now have to go further around, they either have to take the steel now, the steel that goes through. The steel now is through the crack and the steel, each time it's loaded has now bond with the concrete.

I don't know how to describe this but I could perhaps try. If the bar isn't held in the concrete and the bar pulls, and it is being pulled by the load that is there, it sets up very high stresses in the concrete around the bar, and particularly high at where the face of the crack is, but as the bar goes further into the concrete mass the stress between the bar and the concrete produces.

Although there may be an average stress, a high peak stress occurs right at the face of the crack. So what happens is that the bar tends to slip very marginally at the face of the crack and then the average bond takes hold and the rest of the bars stay there, but the next time it's loaded that high stress is no longer on the face of this crack, that high stress is now a quarter of an inch into the concrete because that is where the high stress would now have to take place because the bar already slipped in the first place. So each time that bar is stressed this slip goes further into concrete. It may slip by a very, very small amount but over the years that slippage slowly becomes more and more until the bond is totally broken between the bars and concrete and the thing gives way. [Emphasis mine]

MR. GEORGE: ***Q:*** When it snaps it's large?

MR. MINOR: ***A:*** Well, once you get a large - let's say ten or twelve feet of wall going, the stresses cannot longer flow around the damaged portion, the whole thing then goes, and because all the bars, one above the other, they are not staggered, and because there is no overlap it just goes straight through like a zip, and the zip analogy is Dr. Zetlin's analogy, it is not mine.

MR. GEORGE: ***Q***: And does this have to happen within any limited space of time?

A: No, this could take one year, it could take 20 years, it could take 200 years." [pp. 4568-4572]

Mr. Minor was asked whether in his experience he had known of any silo or bank of silos unzipping as had occurred at JFM?:

"A: In my personal opinion, I have had failing silos but not unzipping in this manner."

It is to be noted that in his theory of causation Mr. Minor does not ascribe any blame to lack of maintenance.

His Lordship made a wise comment:

> "Mr. Cader said he would not have done so and so, it does not follow it was badly done."

I adopt his Lordship's words.

Neither in my view does it follow that the way it was done caused or contributed to the collapse. Describing a scenario of failure which could take one year, five years, or two hundred years in my view defies the balance of probabilities required as a standard of proof.

Mr. Cader had given evidence that the main reason why the bars are hooked around the jacking rod is to stabilize the reinforcing grid during slip forming. I cannot recall a challenge to this.

The principle of "locked-in" stress is not a fiction. Mr. Minor himself in examination-in chief says [p. 4698]:

> ***"Q:*** When the wind stops blowing what happens to the stresses due to the wind?
>
> ***A:*** The stresses due to the wind disappear unless there was some form of locked in stress, but any effect other than locked in stress will disappear with the wind."

And Later [p. 4699]:

> "They could be locked in for two reasons: one is due to differential settlement as has been suggested and the other is a suggestion about a bit of grain and sand falling into some crack."

An early suggestion of Mr. Minor therefore that "locked-in" stress is a creation of Dr. Zetlin fizzles.

Mr. Minor admits that a field survey shows a tilt in the silos:

> "Well, someone has done a survey which shows there is a tilt; it shows the top is not vertically above the bottom and without any knowledge otherwise I would have accept that; but that it is caused by settlement, that I can't be sure of, and whether that settlement occurred in the twenty years before Gilbert, during Gilbert, or in the two weeks after Gilbert, that again I don't know." [p. 4728]

Asked whether he agreed with the statement in the Ward/Oweis Report:

> "That the only reason for the differential tilt between the silo bins is a difference in differential settlement, west to east and north to south?"

Mr. Minor replied:

> ***"A*** No, as I said earlier this morning, it could have been built that way.
>
> ***Q:*** Could have been?
>
> ***A:*** It could have been built in that way and whether the settlement had anything to do with the tilt or not I do not know." [p 4734]

There is of course no evidence that it was built that way.

The acceptable factor of safety was 1.75 which was not a figure on which Mr. Cader and himself differed.

Mr. Minor agreed with a statement [Exhibit 7] put to him:

> "A structural unit will seldom fail because of a single defect or a mistake in the statistical analysis. Rather, it must be assumed that the failure is caused by a number of structural deficiencies.
>
> The safety factor of N = 1.75 provided in most reinforced concrete specifications gives enough reserve strength for small mistakes or faulty construction methods. If the safety factor is reduced however, the over pressure during emptying of bins or the shifting of underlying soil or the failure of a pile formulation may lead to complete failure of the grain silo." [p. 4842]

The Report by Jenike and Johanson was put to Mr. Minor as to the probable failure scenario. They had reviewed sketches provided by R B. Hawkins. Again Mr. Minor duly read and interpreted the Report for the Court since none of the makers of the Report was called. They set out what they referred to as design deficiencies and stated [p. 4850]:

> "'In addition these design deficiencies we have been told of a construction problem in which the hooks for one set of bars in the partition wall did not reach the jack rods'."

Mr. Minor's comments on this is interesting [pp. 4850-1]:

> "I think they got it slightly wrong because they say only one side was the problem; they say this resulted in one face of partition wall being left unreinforced at a point which was expected to take both tension and flexure. This is not quite correct, but then they only had numbers of sketches. They assumed that the deficiency was on one side only."

Jenike and Johanson were asked by the respondents specifically to look at design, and "to assist in analysing the causes of failure and provide expert witness testimony of the trial" [p. 4860].

Mr. Minor conceded [p. 4861]:

> "They have greater experience and expertise than me in the field of materials handling which is silos and conveyors, chutes, etc., for industry and there are other great expertise in the field of silos in particular."

Mr. Minor really only presented their Reports with his comments.

There was no lap spice. Mr. Minor says the measured tilt was 6½ inches maximum in a height of about 125-130 feet. [p. 4876]

It is to be noted that there is no evidence of any crack in the haunch seen on the inspection which was made by Mr. Ruland after Gilbert. Indeed when he gave his evidence he was never asked about it. There was no evidence of progressive cracking.

This is important since Mr. Minor had said [p. 4890]:

> "Now silos 10 and 18 were empty on the day of the hurricane and they remained empty till a couple of days before the collapse. So it would be quite easy to see because no grain was in the silos whether or not crack occurred."

Since neither side carried out a wind tunnel test we are not assisted by any speculation as to what a wind tunnel test may or may not have established, and a determination has therefore to be made on the evidence that exists.

Mr. Minor commented on Professor Sparks' evidence although he said he did not have Professor Sparks' calculations. Since they were handed to Counsel for the defendants/respondents it seems a little strange for Mr. Minor who has commented on every possible document prepared by someone else was not given Professor Sparks' calculations for his comments. However, the Learned Trial Judge remarked [p. 4902]:

> "The position is that the witness is saying that he does not have those calculations and unless there is evidence indicating that those calculations were

> produced to the witness I am prepared at this point to say that I see no reason to doubt the witness' evidence on that point at this stage."

Mr. Minor prepared diagrams as to how the "steel was actually found to be at the failure zone." [p. 4933]:

> "All I am trying to show in the first four diagrams is how the steel was actually to be found at the failure zone and haunch when I inspected it after it collapsed."

It is to be recalled that his method of inspection was by binoculars and looking at photographs.

Mr. Minor embarked upon an exercise of how he would have designed the silos as against how they were designed.

There was no Code of Practice for silos until 1977, prior to that the relevant Code was that relating to buildings generally.

Mr. Minor said:

> "I have been unable to find a mechanism by which the forces that were exerted - obviously were exerted by the hurricane could have been retained within the structure." [p. 4969]

This however obviously contradicts what he said earlier that (1) differential settlement could cause this and (2) sand in the crack. However Mr. Minor insisted that the silos collapsed because their time had come.

"In accordance" he said [pp. 4971-2]:

"with the equations that I have used, and in accordance with the requirements of the Code it could have failed on the first day, but it didn't.

MR. MAHFOOD: ***Q:*** So as a result of the equations you used is it your opinion that failure could have occurred on the first day of operation?

A: According to the equations it could have occurred on the first day, yes. There is no doubt about that."

He further stated [p. 4973]:

"A: The position is that the equations are not accurate enough to foresee on which day it will happen. The equations tell me it could happen the first day or after two hundred years; that is all I know. The time is not within those equations."

A bond can exist which has the weakness to fail in one day or the strength will last two hundred years. He came to his conclusion in relation to causation quite early and ruled out the hurricane.

His evidence continued. With a safety factor of 1.017 with a static load the silo survived over twenty years. With dynamic load the safety factor would be a lot less. A structure is always stronger than its factor of safety, because the factor of safety does not establish the actual strength of the silo. Using typical grain load the internal forces that were imposed between September 25 when bin 18 was filled and September 26 when bin was partially filled would be 7.09 kips. Hoop tension calculation by both Mr. Minor and Zetlin Argo was 8.82 kips for cyclical grain. He is not an expert on wheat. The failure occurred on the first full load loading of silo 10 after

Gilbert. He does not agree that if a structural function is safe under a force of 8.82 kips, it must be safe under a smaller force of 7.82 kips. The collapse was progressive. In September 1988 the structure was falling apart. A general sign of differential settlement is diagonal cracking. He saw vertical and horizontal, but not diagonal cracking. The silo is a rigid body.

It will be recalled that Dr. Oweis the soil expert speaking of the rigid state of the silos pointed out that because of the non-linear nature of the soil the silos were sensitive as to soil. Mr. Minor agrees that differential settlement causes differential tilt. On the question of whether differential settlement causes high stresses he stated:

1. that trying to twist the structure does not produce particularly high stress;
2. because of the stiffness of the structure there is no way of applying enough load in order to induce it to twist.

The point is that he had not considered the non-linear nature of the soil and it will be recalled that his advisors Strucom/E.G.L. had treated the soil as linear which Dr. Oweis pointed out was wrong.

Mr. Minor criticised Zetlin Argo's computer runs because there is no wind component. However, it will be remembered that these runs were done in relation to the day of collapse when no wind existed.

He maintained that there was little steel crossing the crack and therefore not sufficient bond. The silo did not crack for the first time on September 26. Photographs he produced he said show dust on the surface of the crack which indicated the crack had been there for a long time. The question was whether it was dust which had been in a crack existing before the day of collapse. It has been contended by the plaintiffs/appellants that this was the dust or grain which lodged on the internal surface of the silo at the time of the collapse. He also said there was rust on the steel as shown on the photographs, as well as some other material which looked like dust and some like crushed grain [pp. 5027-8]:

Mr. Minor said [p. 5029]:

> "There was a little crack that slowly grew and when it got to a certain stage it was too big for the structure and it collapsed."

Mr. Ruland who inspected after the hurricane was never asked if he saw any crack in the silo when his inspection was made.

The concrete cover for the reinforcements was less than what it should have been and this to Mr. Minor was an example of poor construction. Mr. Mahfood QC asked [pp. 5031-2]:

> ***"Q:*** In your opinion did that poor construction have anything to do with the cause of failure?
>
> ***A:*** No, it is another bit of poor construction.
>
> ***Q:*** This reinforcement shows rusting?

> ***A:*** It does. If you are going to ask detailed questions, I only have black and white copies, but from memory it does show rust.
>
> ***Q:*** That rusting that you have referred to, Mr. Minor, is that not rusting in a particular area of the exterior circular wall?
>
> ***A:*** Yes, I would not expect much rusting on the interior wall because there wouldn't be any water there to cause rust.
>
> ***Q:*** So this rusting had nothing to do with the haunch?
>
> ***A:*** I didn't say it has.
>
> ***Q:*** Why did you bring it up?
>
> ***A:*** It is an example of poor construction.
>
> ...
>
> ***A:*** Well, put it this way: Mr. Cader suggested that grain arrived on those surfaces as the walls separated, collapsed. I am suggesting it was there before; that is the suggestion."

Mr. Minor at [p. 5032]:

> "I suggest these photographs were taken for a purpose and that purpose was to look at the failure joint. The day we went there we could not get any closer because of the dangerous state of the building."

Mr. Minor was referred to photograph 23, a column of Mill Building A:

> "***Q:*** Do you see there something that looks like crushed grain or dust?
>
> ***A:*** You mean on these inclined surfaces?
>
> ***Q:*** Yes.
>
> ***A:*** It is not crushed, it is whole grain.
>
> ...

Q: Does that tend to suggest an old crack?

A: This is not a vertical surface.

Q: But it is grain, dust and grain that would have been lodged when the silos collapsed.

A: That is grain which lodged when the silos collapsed."
[pp. 5034-5]

What was the nature of the crack in the haunch? An original photograph of the haunch was showed to Mr. Minor [Exhibit 18A - pp. 5039-40]:

"Q: Do you see looking straight in the face, Mr. Minor, the haunch?

MR. MINOR: ***A:*** The upper or lower photograph?

Q: It is a photograph of the haunch - sorry, the top one.

A: Yes, I see the haunch.

Q: Do you see the steel bar coming down to the right of the haunch as you look at the picture?

A: Yes.

Q: And that is the jacking rod, is it not, which was released from the haunch at the time of failure?

A: That is correct.

Q: And doesn't this photograph show quite clearly, Mr. Minor that the crack is coming down in a straight line at the jacking bar?

A: It is coming down, not necessarily in a straight line; it depends on what you call a straight line.

Q: What do you call a straight line?

A: A straight line to me is perfectly straight but if you are going to say it is straight, it wavers from that straight line, it wavers from it by up to four inches.

MR. MAHFOOD: Q: So your testimony is that it is not perfectly straight?.

A: If I knew why you wanted it straight or not straight I could say whether straightness had any value to what is being said.

Q: You are not prepared to answer the question unless you know the reason?

A: Because there is straight and there is straight and if you are saying it is straight, the geometrical definition of straight is the shortest distance between two points. This is not straight by that definition. If you are asking, is it approximately straight: it wavers around - between six, eight, ten and twelve inches."

Mr. Minor's theory of the cause of failure was an old crack in the haunch which grew larger and larger and eventually caused the collapse. [pp. 5042-3] He was referred to photograph 36:

"Q You made two comments there: there was rust and there was an old crack?

A: Correct.

Q: Isn't the crack that you are referring to in the circular wall?

A: It is at the junction of the haunch with the outside wall.

Q: And that is a place where everybody expects cracks?

A: Except, if I remember rightly, Zetlin Argo had a factor of safety of over one against cracking.

	Q:	The crack that you have drawn attention to, Mr. Minor, what was the purpose of drawing attention to it?
MR. MINOR:	***A:***	Perhaps it was to show that it cracked.
	Q:	It cracked at the junction of the circular wall?
MR. GEORGE:		Let the witness finish his answer.
	A:	Zetlin Argo had produced factors of safety to prove it hadn't cracked; that is why I drew it to attention.
	Q:	So you drew it to our attention not to imply that this proved that there was an old crack in the haunch - that was not your purpose?
	A:	The purpose was to show that the structure had cracked."

Cracking of course is irrelevant if it does not refer to the acknowledged failure site. Mr. Minor had explained that honeycomb could be formed when steel was running beside formwork and because of the stiffness of the concrete it could not get across the steel to the formwork and thus created honeycomb. He admitted that there is no steel very close to formwork in the haunch. The point to be determined is whether there was honeycomb in the haunch. There is no evidence to establish that there was.

The difference of investigatory approach between Mr. Minor and Mr. Cader is clear in relation to how respectively they proceed to determine the cause of the collapse of a structure The following exposes Mr. Minor's approach [p. 5054]:

> ***"Q:*** In doing your initial structural analysis did you rely on tests of the concrete and the steel, or did you rely on assumptions from Building Codes design criteria?
>
> ***A:*** And the drawings."

Mr. Cader's approach was the testing of the component parts of the structure that is the concrete and steel. The difference in approach emerges in this piece of evidence [pp. 5056-7]:

> ***"Q:*** Let us go back to the question of the difference between the design approach and the investigation of cause of failure approach. In design, for example, Mr. Minor, the Code and the Building Codes tell you that when you are dealing with reinforced concrete you assume that concrete has tensile strength?
>
> ***A:*** That is correct.
>
> ***Q:*** Now when you come to analysing the cause of failure you agree, do you not, it is important to know the actual tensile strength of the concrete.
>
> ***MR. MINOR:*** ***A:*** Not necessarily, no."

Mr. Minor's experience also came under scrutiny [pp. 5057-8]:

> ***"Q:*** Mr. Minor, have you had any experience in doing an investigation into cause of failure of a major structure?
>
> ***A:*** I do it three or four times a year but they are not major structures generally.
>
> ***MR. MAHFOOD:*** ***Q:*** Is it your practice, for example, Mr. Minor, when you are dealing with a structure in which one of the main materials is concrete, it is your practice to do it without testing the strength of the concrete?

MR. MINOR: ***A:*** No, Mr. Mahfood, it depends on whether it is necessary to do so or not. Most of the investigations we do have to do with someone ringing and saying, Look, I want to buy such and such a property, will you survey it for me. One might find cracks and you have to tell them whether the crack is important or not important. Now to go and destroy this building by cutting a piece of concrete is really beside the point. What he wants to know is whether the crack is likely to get worse or not get worse. Sometimes I may have to take out a wall or destroy a building or I might write the report unfortunately, without doing this I cannot answer the question."

Mr. Minor was asked if he was aware that the core tests done by Wiss Janney showed tensile stress of the concrete at 325 psi [p. 5066]:

> ***"A:*** I am also aware that Dr. Mitchell and Dr. Cook report shows that at collapse it was a mere 73 psi."

In respect of the Wiss Janney test he stated [p. 5067]:

> ***"A:*** Well, there are two things wrong of course, with the core test in this particular condition. One is that the core tests are single tests, they are not cyclical; they are not repetitive, they are once and for all. Secondly, they do not have reinforcement in them to cause high local stresses. Thirdly, the Wiss Janney test was produced under laboratory conditions - sorry, it was not? So I was wrong in saying that."

Of course the test by Dr. Mitchell was produced under laboratory conditions. Mr. Minor said that he [p. 5068]:

> "... would have little regard to tensile test particularly as a measure of the strength, the quality of concrete because I would not put any reliance on any factor of safety, I would not calculate any factor

> of safety based on concrete in tension whether it collapsed or not collapsed. Whether it was design or investigation I would not take the strength of concrete in tension under any circumstances whatsoever."

In respect of cracking [pp. 5073-4]:

> ***"Q*** ... are you suggesting - you may not be - but are you suggesting in this phrase here that there is something sinister in the concrete cracking?
>
> ***A:*** No, it cracks all the time.
>
> ***Q:*** That is the normal way reinforced concrete works?

MR. MINOR: ***A:*** Of course."

Mr. Minor had given evidence of a crack in the 6 inch partition between the walls of silos 10 and 18. It is to be borne in mind that the haunch and the 6 inch portion though contiguous are separate parts of the structures [pp. 5078-9]:

> ***"Q:*** And you, Mr. Minor, were analysing the structure to show that a crack occurred at the six inch cross section?
>
> ***A:*** Yes, that is right.
>
> ***Q:*** So the crack you have identified and the crack that your calculations were based on was a crack at the six inch cross section?
>
> ***A:*** Yes, sir.
>
> ***Q:*** You did no calculations to show a crack deep in the haunch at the ten inch cross section or the eight inch cross section?
>
> ***A:*** No.

HIS LORDSHIP: Is it section or cross section?

A: Cross section I think, M'lord, it is just an abbreviation.

Q: Do you agree, Mr. Minor, that at the six inch partition where you calculated a crack the reinforcement was sufficient to safely deal with the tensile forces?

MR. MINOR: ***A:*** Under that particular loading condition and only that particular loading condition.

MR. MAHFOOD: ***Q:*** So Mr. Minor, your calculation as based upon the loading in your calculations shows that where the six inch crack occurred the reinforcement was sufficient to deal with the stress?

A: Indeed."

Page 5082:

"***Q:*** ... what is the distance from the six inch calculated crack to the hook which went around the jacking rod?

MR. MINOR: ***A***: It is nine inches.

Q: And isn't it a fact, Mr. Minor, that in calculating the bond strength you used strength of a standard hook which was not used and ignored the nine inch of steel?

A: But of course I did. I thought I had explained that. The fact is that failure was not at the six inch section. Once it had cracked I had to consider the amount of steel beyond the actual crack.

Q: You transported your crack right across the haunch your crack walked right across the haunch?

A: Yes, it did."

Mr. Minor said that the crack that caused the fracture was very close to the jacking rod. The crack was not at the six inch section. This lack of specificity in Mr. Minor's evidence emerges from the piece of cross-examination [p. 5098]:

"MR. MAHFOOD: Q: Applying that general principle, do you not agree in relation to this particular haunch that failed, since it widened rapidly the build up of stress in the haunch would be very low until you reach the point of anchorage?

A: I though I suggested that as the stress was emanating from the inside concrete outwards or partially, you have two sets of stresses: one due to pure tension and you have one due to bond effect due to anchorage and you have the third one due to bending moment. Now the exact loci of maximum stresses when you add those three maximum stresses together is quite complex; and if you add to that the fact that there may be cracks, there may be honeycombing in the joints, I can't predict where the crack may be.

The other problem is maybe the concrete is made up of discrete units such as aggregate stones, the cracks would tend to go around the aggregate rather than through the middle and the crack will tend to be on one side or the other of the stones; therefore the path of crack is not necessarily a precise straight line."

Mr. Minor produced Exhibit 40 a chart that he had made which showed the development of the crack in the haunch. It had different stages. On the first load stage a crack appears at the load 3.015 in the partition wall but not in the haunch. There is no crack in the haunch from the second load stage of 4.075 load to load stage seven with a load of 9.503.

Pages 5101-2:

"Q: You will see at load stage eight with a load of 10.023, which is more than three times the load that caused the crack in the partition wall, the first crack appears in the haunch?

A: Yes.

Q: And you will see very shortly after that with only a slight increased load there was brittle failure in the haunch and collapse occurred?

A: The load goes up very little indeed.

Q: And therefore, doesn't this show, Mr. Minor, that failure follows and the haunch breaks apart not gradually as the load is applied but when a full load, sometimes more than three times the load that broke the partition occurs, leading almost immediately to failure?.

A: No, it does not show that."

Mr. Minor states that after brittle failure there is a residual strength to a value of about 3 "at which point it continues to take enormous deflections with residual strength and it is that capacity for the structure to take these enormous deformations that kept it up." It could have been 15 years between failure and collapse; he could not give any particular period

Pages 5118-9:

"Q: So what are you saying, Mr. Minor, that the test here that shows that failure immediately follows the load being reached at 9.361, these testings have no bearing on what happened in the structure when fatal load is reached?

MR. MINOR ***A:*** No, they have no bearing on time; it is time we are talking about. The cracking occurred at 9.361, the five inch deflection would still carry 3.3 at that time.

Time is another dimension which is not included in these tests. The other thing not included in these tests is the actual geometry of the silo bank.

MR. MAHFOOD: ***Q:*** You agree however, that so far as the test is concerned, failure was instantaneous on this load being achieved?

A: No. I disagree. It is fifteen to twenty seconds and that is a long time with respect to speed of sound."

In dealing with cracks Mr. Minor stated [p. 5120]:

"MR. MINOR: ***A:*** There are two cracks, one in the haunch partition which probably occurred the first time it was filled and the crack at 9.361 which occurred some time later when the silo was being unloaded and probably occurred at a particular point first and it may have occurred somewhere else on another occasion because of a different type of grain, different humidity, different angle of friction, different density. So that point where the crack occurred might have happened at different points in the structure, different times over different years."

The lack of quality of the evidence in an important area of the case is exposed by its speculative nature.

The crack in the haunch occurred at loads stage II: Can the photographs be relied upon? [Page 5142]:

"MR. MAHFOOD: ***Q:*** Moving to the question of the photographs, Mr. Minor, I suggest to you that what your own photographs show - photographs 6 and 10, Exhibit 27 - is that the tip of the crack is always at the jacking rod in a vertical line which is at least seven inches into the haunch?

MR. MINOR: ***A:*** I would have to say that it is more generally towards the jacking rod than it is towards the six

> inch section but it is not always the case. The position is that we do not know if this crack went through the jacking rod or near the jacking rod. I mean, is it one inch through the jacking rod, or perhaps two inches - I don't know that and I cannot tell from these photographs."

Mr. Minor had set out to establish the following from the photographs taken at the area of the failure:

1. The position of the crack in the haunch.
2. The dimensions of the crack.
3. Whether the steel reached the jacking rod or not.

From these photographs he could not tell if the crack went through the jacking rod or over the jacking rod. The crack varies in width but in no place it is less than 6 inches. He agreed "ninety-five percent is considerable more than six, probably twelve inches, but it is not regular." [p. 5145]

Mr. Minor agrees that what his photographs show is a width of the crack. In Mr. Mahfood's language "varying between ten inches and fourteen inches depending upon where the crack starts in the haunch", to which Mr. Minor answered: "Yes."

It was suggested to Mr. Minor on a question rephrased by His Lordship that [pp. 5145-7]:

"HIS LORDSHIP: Due to the varying width of the haunch in the area there which he has shown, the situation has resulted wherein the steel is at all times at the jacking rod into the haunch - how many inches?

MR. MAHFOOD: Seven inches.

MR. MINOR: ***A:*** I don't think I can say that because if you look at the photograph you see many cases where the bars are not even visible.

Q: Isn't the simple explanation for that, Mr. Minor, that the crack was through the jacking rod that the steel you see protruding is the steel that projected beyond the jacking rod and was straightened and the steel that you did not see clearly protruding was the bars that came up to the jacking rod at a distance of six or seven inches?

A: No, I have to disagree with you, because there is no definition - no one has measured how far they came out; all we know is the centre of the bar should be 7.4 inches. The bar itself was probably an inch and a quarter, so the face of the bar is less than 3.9 inches from the point at which the haunch starts.

Q: You would not be prepared to agree that it is about seven inches?

A: No, you are asking me to be absolutely precise. The bar has a diameter of five-eighths of an inch, and therefore, if you take five-eighths of an inch of 6.9 you find that the bar inside face would therefore be 6.2 inches from the south, that is, always assuming the accuracy of the construction. Now there is absolutely no reason for one to assume that that crack - the collapse crack as opposed to the crack that goes through the section of the six inch junction - there is no reason to believe that that is 6.2 inches from that, the point at which it widens, because clearly the photograph shows it goes backward and forward and it is not a straight line. So therefore, it may well go to the jacking rod sometimes and in other cases it may not go to the jacking rod."

It is suggested to Mr. Minor [p. 5150]:

> ***"Q*** ... jacking rod has to be reached by the horizontal bars and be tied for construction to take place?
>
> ***A:*** I am afraid not, sir. If you look at Safarian it says clearly that it is the practice of placing bars incorrectly and it should not be done."

What do we glean from this evidence? The defendants are maintaining that the cause of the failure of the silos is faulty design and construction. Their allegation is that 50% of the horizontal bars were not hooked around the jacking rod and the rest fell short of reaching the jacking rod. The evidential burden is on the defendants/respondents to establish this to the standard of proof required. In relation to how the steel was laid, how much of it reached the jacking rod and how much went around it, the evidence of Mr. Minor as reviewed falls short of establishing such an allegation. The impreciseness of Mr. Minor's evidence is further exposed when he says [p. 5151]:

> ***"A:*** Maybe the bars were placed one by one on top of the concrete as was the normal practice in America at that time."

And further [p. 5152]:

> ***"A***: I am suggesting it is one of the reasons why it is possible for the hooks to be so badly out of position as they were."

A Report by Professor Mitchell [Exhibit 40] had been put in to support the case for the defendants/respondents. A specimen P 4 with a 9 inch embedment with the hook going around the rod failed at a peak applied load of 22.872 [p. 5168]. A specimen P. 7, the 9 inch embedment of a hook which did not go around the jacking rod failed at 24.982, a slightly higher load. It seems therefore that the simple conclusion to which Mr. Minor was asked to agree [p. 5161] "that the load that was required to break the bond was the same and did not depend upon whether the hook went around the jacking bar" was obvious. Mr. Minor did not agree. He dismissed it by saying [p. 5162]: "none of those tests are relevant to the factors as they are in photograph 39." He was later to say: "I have some reservations but in general that is correct." [p. 5164] The same occurred in relation to the 5 inch embedment. Professor Mitchell's tests were carried out to investigate the bond characteristics and performance of the hook anchorage details in the silos. It was not a test to determine tensile failure but Professor Mitchell had stated that the "failure mode" was "concrete tension failure". [p. 5173]

Mr. Minor was asked:

> "..... was not the purpose" [of Professor Mitchell's test]
> "to simulate the anchorage as built?"

His reply after some exchanges between counsel [p. 5182]:

> "***A:*** I do not know why Mr. Mitchell was unable to perform a test, which was the same as the silo as it exist by ... because of the geometric complexities."

Asked [p. 5183]:

> "***Q:*** But are you saying, Mr. Minor, that apart from what's in Dr. Mitchell's mind as far as you are concerned Dr. Mitchell failed to use an appropriate model for testing the anchorage?

A: In any event, the test he did in the tension specimen do not show what the bond strength is of the hook?"

The fact is that Professor Mitchell's tests did not establish bond failure.

Professor Mitchell did not come to Jamaica at the time of his test. It was an experimental programme carried out in a laboratory in Montreal. [At p. 5195] Mr. Minor was asked:

> ***" Q:*** .. we are checking the tensile strength, we are checking the cracking stress at the point of the 6 inch partition?
>
> ***MR. MINOR:*** ***A:*** Correct, yes indeed, sir.
>
> ***Q:*** At that point, isn't it a fact, and you yourself have stated there was an abundant reinforcement in the silo as built at that point?
>
> ***A:*** I wouldn't say abundant.
>
> ***Q:*** Sufficient?
>
> ***A:*** Sufficient."

The bars which went around the jacking rod had an embedment of 9 inches. It was suggested that a test of embedment of 5 inches was irrelevant as the embedment when construction was completed was either 9 inches or 7 inches [p. 5201].

Mr. Minor's eventual reply was:

> "I don't know whether they were, whether it was 7 inches, 5 inches, I don't know."

It was further suggested that [p. 5207]:

> ***"Q:*** ... the reason why the crack ran through the jack rod is, that is where the steel was anchored,

> the hooks were anchored at the jacking rod and that is why the crack ran through the jack rod.
>
> ***A:*** Perhaps they were, perhaps they were not, but they were not around the jacking rod."

PROFESSOR DENIS MITCHELL

Professor Denis Mitchell is Professor of Engineering at McGill University with impeccable qualifications. He was requested by Jenike and Johanson Ltd. on behalf of the defendants to investigate the adequacy of hook anchorage details in the Flour Mills silo. He was given two structural drawings and Mr. Minor's photographs. The result of his investigation is Exhibit 40 in the case. He examined some diagrams [Exhibit 90] which is Mr. Minor's work which showed examples of some bins missing the jack rod.

> "... these examples seem to resemble very closely what I saw on the photographs that I received from Mr. Minor."

He regarded the reinforcement detail in the drawings as inappropriate:

> "because concrete is extremely weak in tension and unreliable in tension and so reinforcing bars must transmit the tension from the straight wall portion to both curved portions of the wall and so they must carry that tension through the walls. The Code of Practice tells us that in order to do that one must one must lap the reinforcing bars or use a welded connection to transmit the tensions directly in the reinforcement, transmit them from one to the other." [p. 5601]

He was critical of the design in respect to the absence of lapped bars and splicing as required by the Code and that splices should have been staggered. The design would have been inadequate in the sixties because of the lack of splicing and staggering. The hooks as detailed are not a replacement for splicing and "caused a point of high concentration of tensile stress in the concrete" in the haunch. [p. 5616] This created a plane of weakness and could cause failure in the haunch. He carried out tests at McGill University to study the mode of the failure of the hooked bar anchorage.

Page 5619:

> "The actual lapped splice used in the silo was thirty-six inches in the curved wall portion away from the haunch region. ... Spliced detail of thirty six inches was used in the actual silo.
>
> We tried a shorter splice length, an eighteen inch lapped splice length in the specimens T1 and T2; T2A and T2B did not suffer any tension failure in the concrete. There was no bond failure between the steel and the concrete either. They had excellent performance well above the yield strength of the steel; this was achieved without any major stress."

Specimen T4 and T4A were similar in detail to the average details in the structural drawings. Specimen T4A and T8A had "average concrete compressive strengths which were very close to the average compressive strengths that were measured in the actual structure." They both failed in tension. Average tensile strength of concrete inside the specimens was 147 psi. Specimen T8A simulated the hooked bars indicated in the drawings "one hook does not go around the jack rod and the hooks miss each other and are barely touching." Specimen T8A failed in tension between the hooks at average tensile strength of 73 psi. From what could be seen in the photographs the bars in the area simulated to by T8A were not tied to the jacking rod. The concrete used in the specimen was concrete made in the laboratory. That was very good concrete at very high strength . Batch two had average compressive strength close to the average compressive strength of the silos. [p. 5625] When the specimen with concrete similar to the silo was loaded cracks developed In the haunch. In the specimen [p. 5629]:

> "57,000 psi was reached in steel and that stress was actually higher than the yield stress of the reinforcement used in the silo. In other words, the test specimen reached a higher stress in the steel."

He then pointed out that [p 5629]:

> "... the silo walls undergo reversed cyclic loading and that means that the walls are bent one way and then another way. If we had been able to test the specimens in that way the failure would be much less."

Asked to explain that he said: [p. 5639]

> "The load to cause failure would be lower had we been able to test the specimen in the lab under cyclic loading."

It is to be noted then that the experiment had not been carried out in the laboratory under the conditions to which the silo structures had been exposed. His evidence at [p. 5635] is as follows:

"MR. GEORGE: ***Q***: Now which of these specimens most closely resembles the silos?

A: Well, there were a variety of actual details in the silos. In some cases we have the hooks barely overlapping such as indicated on the structural drawings, and in other cases we have the situation where the hooks are missing one another and I don't know how much they are missing. The tests I carried out were the cases where the hooks were actually touching one another, and one would have a variety of different details between those two cases. Therefore, if you like, the response is that you might have a section of wall might be between these two specimens, B3A and B5A.

Q: Falling somewhere in between those two?

A: Falling somewhere in between perhaps."

The inpreciseness of Professor Mitchell's simulated experiment is exposed in the answers given. Professor Mitchell was critical of the absence of splicing and staggering. Instead barely overlapping hooks were used. His laboratory batch of concrete approximating the concrete used in the silo had an average or mean compressive strength of 2738 psi.

At page 5646:

"Q: In relation to batch 2 what do they tell you?

A: They tell us in relation to batch 2 that there weren't very much variation from one cylinder to another that was tested; very small variation, very good control of the concrete properties."

Batch 2 had a characteristic strength of 2569 psi "... and that means that there is very good control of the concrete quality." No cracks were visible in the concrete surface. He was simulating the strength of the concrete in the drawings when making the samples. He also saw the Wiss Janney/Eistner Report. Wiss Janney had a mean compressive strength of 2920 psi, quality of concrete core. A very cyclic loading would cause some bond deterioration. Safety would be lowered by the poor quality concrete such as cracking and honeycombing. It is to be noted that it had not been established that there was any honeycombing in the haunch.

A force of 44.84 kips would have cracked the concrete but it would not have failed. He had tested steel embedment length of 5 inch, 7 inch and 9 inch.

The evidence at [p. 5675] is as follows:

"MR. MAHFOOD: Q Is it an important part of your conclusions that the silo was constructed with length embedment of five inches?

PROF. MITCHELL: A: Not really, sir, ... there is such a variety of possibilities here and that's what makes the problem so difficult. The test I did, however, only vary the embedment length from five inches to nine inches."

He was further questioned [p. 6579]:

"MR. MAHFOOD: Q: Professor, you are suggesting that the work-men might have tied one hook to the other, is that based upon fact or speculation?

A: I wasn't there when the workmen tied it.

Q: Therefore it's only speculation, isn't it?

A: Yes, it would be."

And then later he was asked [p. 5680]:

"MR. MAHFOOD: G: I want to know if you have any factual basis for your premise that the embedment length was effectively five inches either because it was five inches from the partition or because there was an old crack in the haunch, what's the factual premise for that?

A: It could have been either?"

Figure 2(1a) represents potential cracks that go through the jack rod. Professor Mitchell agrees that it also represents the type of crack you would have expected if the steel was not misplaced. [p. 5683]

Figure 2(b) represents the type of cracking that would likely have occurred if the embedment was well short of the jack rod. Asked whether he assumed that there was an old crack in the haunch, he replied [p. 5687]:

"A: I think you could have two ways as I stated earlier. One is where you do have something like about five inches where the hooks missed each other and the other circumstance is simply a crack that occurs going through the haunch some distance, which in effect reduces the embedment length."

The difficulties and lack of preciseness that arose from interpreting the photographs have been exhibited in the following passages of evidence [pp. 5688-9]:

"MR. MAHFOOD: Q: Now, Professor, you see in Photo 10 the broken edge of the haunch, right down from the top going down to the bottom?

PROF. MITCHELL: A: Yes, I do.

Q; And do you agree or do you not agree. Professor, that the whole length of the crack was well within the haunch?

A: It looks like -- it's very hard to tell from the angle, it looks like this one side of the crack was some distance inside. We have to know what plane the crack is going on but it seems to get closer to the partition wall at the bottom and further from the partition wall.

Q: It gets closer to the partition wall near the bottom, further from the partition wall near the top. But. Professor, one thing that our eyes can tell us without being sophisticated engineers, is that the crack is some distance away from the partition wall at the every point?

A: Oh, this face, yes. I can't tell what plane the crack is on. I can't see. We are looking at one edge of the crack."

And at [p. 5690]:

"**Q:** ... but doesn't the photograph indicate to you that the whole of the crack is away from the partition wall?

PROF. MITCHELL: A: I am sorry, I am just looking at one side of the crack. I was just pointing out that I can't see the other side.

Q: You can't see the other side therefore any suggestion that the other side reaches the partition wall is just pure speculation?

A: Certainly, I just can't see, I just won't comment."

And at [p. 5698]:

"Q: Your position today is that most of the failure crack that led to failure was close to the six inch partition?

A: No, I think the failure crack goes through the haunch."

Mr. Minor's evidence will be recalled that the fatal crack was one which commenced in the 6 inch partition wall and cracked right across the haunch.

The interlocking hooks in the design replaces the splice and is a form of anchorage. He considered the quality of the concrete dreadful. It must always be borne in mind that Professor Sparks was creating concrete in his own laboratory and had not tested concrete taken from this failure area in the haunch. He agrees that the "standard reliable way of testing the strength of concrete in the structure that has failed is core tests of the concrete near the point of failure." [p. 5708-9]

He further agrees that "the splitting tensile test done by Wiss Janney based upon core tests near the failure is a good standard way of testing tensile strength".

In his view [p. 5716]:

> "... we also neglect the tensile strength in
> design for strength because it is so unreliable.
> One never count on the tensile strength like
> that for such a structure."

On the suggestion being made that:

> "When you are investigating the cause of failure
> you examine the materials to see the strength?"

His reply was:

> "Right." [p. 5716]

And at [p. 5721]:

> ***"Q:*** ... have you considered the question of whether or not there was any honeycombing the haunch?
>
> ***A:*** I do not know exactly where those honeycombs were placed, they tend to be random in nature, they could be anywhere.
>
> ***Q:*** If you do not know whether or not there was honeycomb in the haunch where the failure occurred why did you mention honeycombing as one of the factors to be considered?
>
> ***A:*** I am not insisting, it is an indicator of poor quality of concrete."

Pages [5723-4]:

> ***"Q:*** ... you tried, did you not, to simulate the structure?
>
> ***A:*** Yes, as best we could, sir.
>
> ***Q:*** And the best way you could, sir, so far as the hooks were concerned was to simulate the hook and build a hook, and similarly, the best way you did so far as the concrete is concerned, was to select concrete which you felt represented the strength of concrete in the silo; isn't that so?
>
> ***PROF. MITCHELL: A:*** Yes, I was told that the average compressive strength was somewhat less than 3,000 and that the specimen should have approximately that average strength, so I went about building the concrete specimens and had an average strength close to the average strength of this concrete."
>
> ***HIS LORDSHIP:*** Average strength of 3,000?
>
> ***A:*** Yes."

The design called for 3,000 psi concrete. He selected 2,630 and 2,800 psi. He admitted: "I never tested the silo, I tested some experiments in a lab."

The important question was whether there was progressive cracking or did the haunch crack for the first time on 26th September 1988 just prior to failure?

He thought that the crack in the partition wall would have caused some deterioration.

In the photograph grain is attached to the vertical failure service suggesting an old crack. In Wiss Janney Report on cores they remarked on the number of existing cracks [p. 5737}:

> ***"Q:*** Have you considered whether those cores came from the haunch that failed or not?
>
> ***A:*** The cores I believe - I am not sure where the cores came from."

The question still has to be determined whether what is interpreted as grain on the vertical surface was there before the collapse or attached itself there when the collapse took place.

Since Professor Mitchell does not know where the cores in the Wiss Janney Report came from, he cannot say whether they came from the haunch or not. Professor Mitchell said that low cycle loading to which the silo was subjected [p.5740]:

> "... is more severe than earthquake type loading, ... and because such a terrible detail was used in trying to distribute transfer the forces though the haunch you have a very critical situation with many, many cycles of

> loading, much more than you would get in a single earthquake."

It is to be noted however, that the other haunches between silos did not fail. However, Professor Mitchell insisted that the normal operating of the silos is very severe loading and is a more severe loading than would be experienced before an earthquake.

Professor Mitchell agrees with a quotation from an Article from one Hanson that: [p. 5747]

> "Low cycle, high amplitude fatigue loading of less than 1000 cycles may occur as a result of earthquakes or other events that <u>cause a loading of the structure beyond its normal service level</u>." [Emphasis mine]

Implicit in this in my view is that earthquakes do cause a loading beyond the normal service level.

At [p. 5751] he was asked:

> ***"Q:*** Do you agree, Professor, that a force of 44.89 kips is far above the normal operating load to which the silo was subjected in the course of its ordinary operations?
>
> ***A:*** The loads that I have been shown for the different loading cases in the silo were much lower than that value; I believe it was 44.84."

<u>THE LAW</u>

The burden of proof is on the plaintiff to establish that the proximate cause of the loss or damage was a peril insured against, to wit the hurricane on the balance of probabilities.

That burden is on the defendant, having alleged faulty design and construction in respect of which there is an exception in the policy, to prove not only that the design and construction was faulty but that the loss or damage was caused by the faulty design and construction on that same standard of proof.

However the defendants/respondents may raise issues and adduce evidence which although not established in their allegations as to causation may be such when all the evidence is assessed as to cause the trial judge to find himself unable to accept that the plaintiff/appellant has established its case to the standard of proof required.

In my view however in this particular case the positions of the parties are clear cut on causation - on the one hand the hurricane, and on the other hand faulty design and construction. The defendants/respondents must go beyond indicating faults in the design and construction. They must establish that these faults are the proximate cause of the collapse.

In ***Leyland Shipping Company Limited v. Norwich Union Fire*** **Insurance Society** [1918] Appeal Cases 350, Lord Shaw of Dunfermline at p. 371 stated:

> "... the proximate cause will be found to be, to use the words employed by Channell J. in Etherington's Case:
>
> > "The real effective cause of what happened.' ..."

And at p. 369:

> "To treat proximate cause as if it was the cause which is proximate in time is, as I have said, out of the question. The cause which is truly proximate is that which is proximate in efficiency."

In ***Queensland Government Railways etc v. Manufacturers Mutual Insurance Company Limited*** [1969] 1 Lloyd's Rep. 214: the piers upon which a bridge across a river was being constructed were designed according to the state of engineering knowledge at the time of construction. Later investigations into the cause of failure of piers showed that during floods piers were subjected to greater transverse forces than had been previously realised. When the piers were brought down by flood waters the insurers on a claim made by the owners relied upon a clause in the policy which exempted "loss or damage arising from faulty design and liabilities resulting therefrom." The dispute was referred to arbitration. The arbitrator found on the facts that:

> "The prismatic piers as designed, and as they were being constructed were inadequate to withstand the transverse forces to which they could be subjected in the Pioneer River."

And that:

> "... the design of the piers in the sense of their prismatic state resulted in loss."

He however gave a meaning to "faulty design" which required "some element of personal failure or non-compliance with the standards which would be expected of designing engineers", and determined that the exclusion clause in favour of the insurers was not applicable. It is this conclusion which was challenged, and in respect of which the Australian High Court stated at p. 217 of the Report:

> "To design something that will not work simply because at the time of its designing insufficient is known about the problems involved and their solution to achieve a successful outcome is a common enough instance of faulty design. ... We have not found sufficient ground for reading the exclusion clause in this policy as not covering loss for faulty design when, as here, <u>the piers fell because their design was defective</u> although according to the finding not negligently so." [My emphasis]

It is important to realise that the crucial finding as to proximate cause was "the piers fell because their design was defective." It was not sufficient to find defects in the design, it was necessary to find that those defects caused the piers to fall. The defendants/respondents have placed much reliance on this case. In my view whatever defects in design and construction that might have been indicated either by virtue of the deficient state of knowledge when the silos were designed with respect to the greater pressure exerted on the silos by grain being discharged as against grain at rest in the silos or the effect of grain when the silos are being filled or otherwise it has in my view not been established that these deficiencies were the proximate cause of their collapse.

In ***Yorkshire Dale Steamship Company Limited v. Minister of War*** and Transport [1942] Appeal Cases 691, Viscount Simon L.C. at p. 698 had stated:

> " ... the proximate cause is not necessary the one which operates last . ... It seems to me that there is no abstract proposition, the application of which will provide the answer in every case, except this: one has to ask oneself what was the effective and predominant cause of the accident that happened whatever the nature of that accident may be."

And Lord Macmillan at p. 702:

> "No formula can be devised which will provide a universal touchstone for the infinite variety of circumstances which may arise. Each case must be judged in the light of its own facts and by resorting, not to the refinements of the philosophical doctrine of causation, but to the common place tests which the ordinary businessman conversant with such matters would adopt. ... I think that the ordinary man, if asked what caused the casualty, would reply that it was caused by the vessel, in obedience to the orders from the commodore of the convoy, deviating from a safe course in order to avoid a suspected enemy submarine."

This was a case in which the question to be determined was whether the stranding of the vessel was a warlike operation. The vessel was travelling in convoy conveying war stores, when it stranded and the stranding was due to a variety of causes including a deviation off course under naval orders to avoid apprehended submarine attack, coupled with an unexpected set of the tide. It was held that the proximate cause of the stranding was a warlike operation.

As Lord Wright at p. 706 stated:

> "Causation is to be understood as the man in the street, and not as either the scientist or the meta-physician, would understand it."

In ***Wayne Tank Company v. Employers Liability Limited*** [1974] Q.B. 57, Lord Denning M.R. at p. 66 puts it this way:

> "Since the ***Leyland*** case it has been settled in insurance law that the 'cause' of a loss is that which is the effective or dominant cause of the occurrence, or, as it is sometimes put, that which is in substance the cause, even though it is more remote in point of time, such cause to be determined by common sense."

If there are "two causes which are equal or nearly equal in their efficiency in bringing about the damage one within the general words making the insurers liable the other within the exception and would exempt them from liability the insurers can rely upon the exception clause." [Lord Denning M.R. at p. 67].

Cairns L.J. endorses the commonsense approach as adumbrated by Viscount Simon L.C. in the ***Yorkshire*** case as the right test. In that case there are two causes of the fire: (a) defect in equipment; (b) operating the equipment without testing it. He stated:

> "I think the man in the street, if asked what caused the damage, would be far more likely to say 'they supplied faulty equipment' than to say 'they ran the system without testing it'."

And further at p. 69:

> "... if there are two causes which are approximately equal in effectiveness, then it is impossible to call one rather than the other the dominant cause. I should prefer to say that unless one cause is clearly more decisive than the other, it should be accepted that there are two causes of the loss and no attempt should be made to give one of them the quality of dominance. On this approach if one cause is within the words of the policy and the other comes within an exception in the policy, it must be taken that the loss cannot be recovered under the policy."

I adopt the test as the proximate cause as adumbrated by Viscount Simon LC, Lord Macmillan and Lord Wright in the ***Yorkshire Dale Steamship Company Limited*** case.

The silos had carried out their functions safely for over twenty years. They collapsed within fourteen days of having been exposed to forces lasting for three days of the most severe hurricane ever experienced in the region and which influenced weather patterns over a period of five days. I amend the language of Cairns LJ in ***Yorkshire Dale Steamship Company Limited*** case to say: I think the man on the street in Jamaica, if asked what caused the damage, would be far more likely to say 'Hurricane Gilbert' than that the silos were badly designed and constructed. On the evidence in my view Hurricane Gilbert was the sole cause of the collapse.

The exemption clause in the Lloyd's Policy with respect to faulty design or construction raised an issue in respect of which the burden of proof is on the insurer. Although the West Indies Alliance Policy does not include the exemption clause had it been established that the cause of the collapse was other than "by or through or in consequence of the hurricane" the plaintiffs/appellants could not have succeeded against the WIA Companies since the cause of the collapse would not have been a peril insured against. If of course there are two proximate causes the hurricane, as well as faulty design or construction whilst the Lloyd's Group insurers would escape liability because of the exemption clause, the WIA Group insurers would not since the policy does not include an exemption clause and "loss or damage occasioned by or in consequence of a hurricane" is a peril insured against. The words "occasioned by or in consequence of" are wide enough to nullify any suggestion that since the silo did not collapse during the hurricane the cause could not be the hurricane.

In ***S. & M. Hotels Ltd. v. Legal and General Assurance Society Ltd.*** [1972] 1 Lloyd's Rep. 157 - the property was insured against destruction or damage "directly caused by storm, tempest or flood" Counsel for the plaintiffs, the assured, submitted:

> "... that while it was necessary for him to prove that there was a 'storm' within the meaning of the policy it is only necessary for him to show that it was a cause, not that it was the sole cause of the damage that occurred."

Thesiger J. at p. 161 stated:

> "This submission by Mr. Lloyd is, and is admitted to be, correct."

If I had found, which I have not, that there were two causes, that alleged by the plaintiffs/appellants and that alleged by the defendants/respondents the plaintiff would still succeed against the WIA insurers but the Lloyd's Group insurers would be saved by the exemption clause.

I feel constrained to agree with and indeed to adopt the language of Thesiger J. at p. 165:

> "So far as the calculations of wind effects and load stresses are concerned I do feel that this case might well have been tried with the assistance of an assessor ..."

I understand that the offer was made by the parties to the learned trial judge but regrettably was refused. Nevertheless, we have to proceed on the evidence that was presented and arrive at our conclusions on an understanding of that evidence.

On the evidence in my view the Hurricane Gilbert was the sole cause of the collapse.

THE JUDGMENT

The approach of a trial judge to the assessment of conflicting expert evidence, given by persons whose qualifications and experience in their particular areas of expertise were not under challenge, must proceed on an initial basis that the expert, though produced by one side or the other, is there to assist the Court in its deliberations for the purpose of arriving at a determination in this case of what caused the silos to fail.

A trial judge may well conclude that a theory or viewpoint expressed by one expert or another is flawed. Indeed, we are very much in the realm of theory in many aspects of this case. The flaw may emanate from several reasons. The expert may have strayed outside the specific areas of his expertise. He may have failed to take factors into account which, had he done so, could have led him either to a different conclusion or affected the certainty with which his opinion was proffered. Furthermore, since even experts can err he may have been in error. None of this supports a conclusion of dishonesty which must rest almost reluctantly on the most compelling indicators.

The learned trial judge rejected Mr. Cader as a witness of truth based upon certain conclusions which, in my view, cannot withstand careful and balanced scrutiny. To take an example, because Mr. Cader's report did not make reference to the absence of honeycomb in the haunch, the learned trial judge rejected Mr. Cader's testimony that there was no honeycomb in the haunch and positively found that there was. This conclusion is a non sequitur.

The omission from the report cannot be evidence that in fact the haunch contained honeycomb. That conclusion must be founded on some direct evidence of the existence of honeycomb in the haunch.

This erroneous approach was extended to the omission of "certain engineering calculations" from the report. The assessment of Mr. Cader [pages 10358 to 10365 of the record] by the learned trial judge I found confusing and conflicting. To cite some of the areas:

> "In terms of behaviour he may well be classified as a model witness." [page 10358]

He had:

> "bouts of stammering and stuttering".

He made:

> "damning and damaging admissions." [p. 10361]
>
> "He clearly did not intend that the court should have regarded that answer as an honest one." [p. 10362]
>
> "Mr. Cader indulged in dodging, mental gymnastics and plain avoidance of questions." [p. 10364]
>
> "Quite apart from being reluctant to admit anything suspected to be detrimental to the plaintiff's case Mr. Cader did not hesitate at times to blatantly change his evidence without blinking an eye." [p. 10364]
>
> "Mr. Cader admitted errors and shortcomings on his calculations on computer runs. His evidence is replete with such admissions in crucial areas of the case. When I consider these admissions along with his demeanour I am forced to ponder what other undisclosed or undetected errors and shortcomings there may have been." [p. 10365]

I find it difficult to reconcile this assessment of Mr. Cader with rational judgment. The path to the discovery of truth was much obscured by the emotive language of counsel in their addresses and the sparks generated in the course of a long and tedious trial. More importantly and relevant to the determination of judicial balance, however, was an obscurantism which surfaces in the apparently rash assessment of Mr. Cader and other witnesses for the plaintiffs/appellants in the judgment.

Whilst the trial judge has an advantage in observing the demeanour of those witnesses who gave evidence before him, it is very less so in the case of the expert witness. The arrogant, assertive and yet truthful expert is not a stranger to judicial experience.

Neither Professor Sparks nor Dr. Oweis escaped the scathing assessment of the trial judge [pages 10365 to 10369], and they were summarily rejected and sent packing in disgrace. His reference to Dr. Oweis as "supposedly the holder of a Ph.D." discloses an element of gratuitous insult not justified by any fact. Suffice it to say, that the glowing commendations of the witnesses for the defendants/respondents were in stark contrast to the reception received at the hands of the learned trial judge by the witnesses for the plaintiffs. In such circumstances, it is incumbent for the appellate tribunal to review the facts, apply the relevant law and come to its own conclusion.

An appellate court is always reluctant to disturb the findings of fact of a trial judge, since the trial judge has the advantage of having seen and heard the witnesses, an advantage denied to the appellate court, and I bear that in mind. However, there are circumstances in which an appellate court will do so and this case cries out for this approach.

In ***Joyce v. Yeomans*** [1981] 2 All E.R. 21, Waller, L.J. at p. 24 stated:

> "The demeanour of a medical expert giving evidence is probably not so important as that of other witnesses of fact when the value of his evidence is being assessed, but in my opinion the observations of Lord Thankerton in the well-known case of Watt (or Thomas) v. Thomas [1947] 1 All E.R. 582 at 587, where he was considering the position of an appellate court when dealing with the finding of fact by the judge, should be borne in mind. He set out two principles which I will quote:
>
>> 'I. Where a question of fact has been tried by a judge without a jury, and there is no question of misdirection of himself by the judge, an appellate court which is disposed to come to a different conclusion on the printed evidence should not do so unless it is satisfied that any advantage enjoyed by the trial judge of having seen and heard the witnesses, could not be sufficient to explain or justify the trial judge's conclusion ...
>>
>> III. The appellate court, either because the reasons given by the trial judge are not satisfactory, or because it unmistakably so appears from the evidence, may be satisfied that he has not taken proper advantage of his having seen and heard the witnesses, and the matter will then become at large for the appellate court'."

This fortifies me in my view that this court should review the evidence and come to its own conclusion in accordance with the principles stated above.

Apart from the viva voce evidence there have been numerous reports and articles in engineering journals tendered by consent as exhibits in this case and authorised by persons who did not give evidence and so were not seen or heard or subject to assessment on cross-examination. The learned trial judge specifically relied heavily upon Exhibit 87, a Paper written by O. F. Theimer, a consulting engineer of Munich, Germany, presented at a Conference of the American Society of Mechanical Engineers in 1968, and Exhibit 9c, an article by Sargis Safarian, a civil engineer in the United States of America, published in the American Concrete Institute Journal in August 1969. He founded the guidance he received from these articles on the fact that they were "written by persons far removed from the scene" without reference to the disadvantage which that very fact creates since the opinions therein stated are general and not specific to the matter being investigated.

If the conclusion by the learned trial judge of the cause of failure of the JFM silos is based upon these articles, the fundamental error is that, extending this to its illogical conclusion, all silos designed and constructed in the late 1960s must fail if and whenever they do, not because of their exposure to forces greater than those generated by their normal day-to-day operations but because they were badly designed as a result of the state of engineering knowledge at the time. This is a fallacy. Every case must be determined on the established facts as related to the specific structure which failed.

Otherwise, all insurance policies on these buildings constructed in the 1960s conceal an element of fraud against the policyholder, and that I do not accept.

It is also important to identify the particular expertise of each witness so as to pinpoint the specific area in which the witness is qualified as an expert. In the area of wind and soils no difficulty arises. Mr. Calvin Gray and Dr. Sparks are the wind experts. Dr. Oweis is the expert on soils. Professor Mitchell is the expert on the question of strength of structures limited though he was by not being able to examine materials from the particular structure but instead had to carry out experiments in a laboratory. By and large these witnesses kept within the areas of their expertise. Mr. Cader, Mr. Minor and Mr. John Ruland are structural engineers. In so far as all or any of them strayed outside their areas of specific expertise their evidence must be treated with caution. As engineers they have a general knowledge which invests them with an ability to speak in general terms beyond their specialist expertise. This cannot be ignored. Their experience as established in evidence, in specific areas can give additional weight to an opinion given. In assessing their evidence in terms of weight on particular issues a discriminating balance must be applied in order to determine the validity of an opinion given in a particular field beyond the boundaries of their specialisation and experience. This caveat is particularly germane with reference to the evidence of Mr. Cader for the plaintiffs/appellants and Mr. Minor for the defendants/appellants, whose evidence seemed to embrace a horizonless panorama. Furthermore, both Mr. Cader and Mr. Minor had specific mandates - the first to establish that the silos collapsed because of the effect of Hurricane Gilbert, the latter because of faulty design and construction. They put together the material for these contending positions. To that extent they cannot be said to possess a clinical disinterest.

In his judgment the learned trial judge said:

> "The failure of the plaintiff to satisfy me that the silos collapsed as a result of the factors that it has alleged, is in my judgment sufficient for judgment to be entered against the plaintiff and in favour of the defendants. However, in view of the full presentations by the defence it is appropriate and important that I should state that I accept the expert opinion of Mr. Minor as to the cause of the collapse."

In my judgment, the following facts had been established at the end of the plaintiffs/appellants' case:

> 1. The existence of Hurricane Gilbert of the magnitude and intensity and its effect given by Mr. Calvin Gray, the meteorologist.
>
> 2. The effect of the wind on the silos in the location on the eastern end of the bank of silos and the creation of torsion and pressures as determined by Professor Peter Sparks, the wind expert, such loads being aggravated by the existence of the head house on the columns which transmitted these loads down to the foundation.
>
> 3. The non-linear nature of the soil beneath the silo bank, as evidenced by Dr. Oweis, its flexibility as well as the settlements created as a result of the application of the windload including the differential tilt.

> 4. The existence of a measured tilt.
>
> 5. The stresses locked into the structure as a result of Hurricane Gilbert.
>
> 6. The fact that the silos fell on the first occasion that loading was taking place after the hurricane.
>
> 7. The strength of the concrete as a result of the testing of cores taken from the site of the collapse.
>
> 8. That despite some admitted design deficiencies the structures had safely performed the operating functions for over twenty years.

Therefore, at this stage of the assessment of the evidence on the balance of probabilities, it was not established that it was these design deficiencies which caused the collapse. The learned trial judge's statement, therefore, that he could have entered judgment at the end of the plaintiffs' case for the defendants/respondents discloses a failure to make a proper determination of the weight of the evidence of the several witnesses tendered in support of the case for the plaintiffs/appellants.

The question, therefore, at the end of the trial would be as to whether any evidence was produced by the defendants/respondents to destroy or diminish the evidence which had been advanced by the plaintiffs/appellants in support of their case, so as to tilt the balance in favour of the defendants/respondents.

The learned trial judge was obviously impressed by Mr. Minor who, in my judgment, could not assist in terms of the effect of the wind and the pressures on the soil since these areas were not within his expertise. In so far as he ventured opinions in these areas, the evidence of Mr. Calvin Gray, Professor Peter Sparks and Dr. Issa Oweis must be preferred. With respect to whether a design was faulty and the construction had defects, which is the area of Mr. Minor's expertise, it was necessary to examine this evidence to discover whether the defendants/respondents have gone further than pointing out some deficiencies to the extent of establishing that on the balance of probabilities these deficiencies caused the collapse.

Mr. Minor was at a disadvantage in that, in order to assess the structure as built, he was only able to view the site of collapse through binoculars and the taking of photographs which had to be interpreted. These photographs were obviously taken in difficult circumstances. Furthermore his thesis in terms of the mode of collapse was that a crack which commenced in the 6" partition wall between silos 10 and 18 progressively migrated into the haunch. This has not been established on the evidence. The point of difference emerging time and time again as between Mr. Cader and Mr. Minor was whether when one is investigating the cause of a collapse of this nature one should go by the design, as Mr. Minor mostly purported to do, or by the structure as built which was the premise upon which Mr. Cader approached his task. In my view, in approaching this task the design is not all that helpful unless it can be established that the structure was built as designed. And then, after this is established, one must proceed to find out whether the structure as built could safely bear the normal operating forces to which it would be subjected in its daily operations. If it could, then the collapse would have been caused by forces additional to the forces to which it is exposed in the normal operation.

Professor Mitchell, whose expertise is not in doubt, suffered the disadvantage in that he had to create concrete in his laboratory as he did not have the opportunity of testing concrete taken from the failure site. He also had to rely for his opinion on what was disclosed by the photographs which were taken by Mr. Minor at the site in the difficult circumstances disclosed by the evidence.

In my judgment, therefore, neither the evidence of Mr. Minor nor Professor Mitchell the only two witnesses called by the defendants/respondents could be sufficient to displace the evidence of the witnesses for the plaintiffs/appellants and the undisputed fact of the hurricane in the determination of what caused the collapse of the silos.

For these reasons, I hold that on the balance of probabilities the plaintiffs/appellants established what was alleged that the forces of Hurricane Gilbert subjected silos 10 and 18 to stresses that weakened them and such weakness persisted and was "locked-in" to the structure and continued to influence the integrity thereof without being apparent and was then unrecognised and was the proximate and effective cause of a sudden violent rupturing of the structure which occurred on the 26th day of September, 1988, when the silos were being filled.

In my judgment, therefore, the plaintiffs succeed and the appeal is allowed the judgment of the Supreme Court set aside and judgment entered for the plaintiffs/appellants with costs to be taxed or agreed, both in respect of the trial in the Supreme Court and the proceedings in the Court of Appeal.

The matter is remitted to the Supreme Court for the damages to be assessed.

(I) Introduction

DOWNER J A (Dissenting)

The principal issue in this appeal is whether the respondent insurers are liable to indemnify Jamaica Flour Mills (JFM) the claimants for the loss suffered by that company when the structure of silos 10 and 18 were severely ruptured on 26th September 1988. As the claim was based on insurance policies it is pertinent to point out that a fortnight before, on the 12th September, Hurricane Gilbert struck Jamaica. The JFM have alleged that the damages to the silos flowed from the unprecedented severity of the force of the winds which accompanied the hurricane. On the other hand the respondent insurers contended that the damage to the silos was caused by faulty design, faulty construction and lack of proper maintenance. They further contended they were not liable on the policies as they have alleged and proved that Gilbert had nothing to do with the collapse of the silos.

An appropriate starting point ought therefore to be, to examine the terms of the policies then in force so as to determine the validity of the claim. Panton J in the Supreme Court found for the respondent insurers after a trial which lasted for some 76 days. JFM was aggrieved by that decision and as a consequence have appealed to this Court.

The Policies

The further amended statement of claim referred to the first collective policy thus:

> "5. By a collective policy of insurance number C-1067 incorporating and including Special Perils Extension Policy No. C-1067 which was undated but insured concurrently with the aforesaid policy and effective from 1st July 1988 for the period 1st July 1988 to 1st July 1989 and made between the Plaintiff and the 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th and 13th Defendants in consideration of premiums paid and to be paid upon the terms mentioned therein the 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, and 13th Defendants insured the Plaintiff against loss or damage (to property as set out hereafter under "Particulars of Insurance") occasioned, inter alia, by or through or in consequence of
>
> (i) hurricane, cyclone, tornado or windstorm including rain accompanying these perils and flood (including overflow of the sea) caused by these perils to the extent or protection of seventy percent (70%) of the total sum insured as set out in paragraph 6 hereof."

To appreciate how this issue was met by the insurers it is appropriate to refer to their amended defence. There the respondent insurers have relied on paragraph 3 as amended to demonstrate that the special conditions in the collective policy exonerate them from compensating JFM for the loss claimed. The gist of their case as regards the policy was pleaded thus:

> "3. The Defendants say that the proximate or effective cause of the rupturing

> of the structure was faulty design and detailing and deficiency in construction."

Following this general clause are particulars which must be examined later when faulty design and deficiency in construction is considered as specific pleas. Then an amendment which sets out an alternative case pertaining to provision for proper maintenance based on conditions in the policy. It states:

> "3(A) Alternatively, if the Hurricane caused defects in the structure of the silos, which is denied, the Defendants will say that the Plaintiff is not entitled to indemnity in respect of the alleged loss by reason of its failure to take reasonable precautions for the maintenance and safety of the silos or to carry out any or any reasonable or adequate inspection of the said silos after the said Hurricane in breach of Condition No. 4 of the Special Perils extension to Policy No C1067 and Condition No. 5 of Policy No. 551 FAFR 147."

Then there is a remarkable passage in the particulars of JFM's statement of claim which looks very much as an admission on this pleading. It will be examined later but it is imperative to cite it now as it reveals how this case could have been conducted if this point had been taken. The article is captioned Design Pressure of Granular Materials in Silos It reads:

> " Some may argue that many silos designed by Janssen's pioneering method do not show distress. Such successful performance, however, should not be comforting since it is achieved at the expense of the safety factor. The safety of these structures under actual loading conditions may have reached an alarmingly low margin, one which is dangerous and contrary to any applicable code. One should

> realize that the lack of silo codes and the use of out-dated technical literature do not relieve design engineers of their responsibility to provide adequate safety margins in their structural designs."

The author is from Sargis Safarian. This extract coincides with the ratio of **Queensland Government Railways & Electrical Power Transmission Railways Pty. Ltd. v. Manufacturers Mutual Insurance Ltd.** [1969] 1 LL Rep. 214 which will also be examined at greater length. Then 3(B) reads:

> "3(B) Further, whether before or after the said Hurricane, the Plaintiff failed to carry out any or any reasonable or adequate inspection of the said silos in breach of the aforesaid conditions."

Be it noted that the amended defence in paragraphs 3(A) and 3(B) recognizes that there are two collective policies of insurance.

Turning to the conditions as stipulated in the policies, special condition 4 for the collective policies of the lead insurer West Indies Alliance Assurance Company Limited C1067 reads:

> "4. The Insured shall use all reasonable diligence and care to keep the premises insured or containing the property insured in a proper state of repair and if any defect there be discovered shall cause such defect to be made good as soon as possible and shall in the meantime cause such additional precautions to be taken for the prevention of loss or damage as the circumstances may require."

Then, in respect of policies by the Lloyd's underwriters the compensation clause provides that:

"...

2. The Underwriters shall not be liable for loss or damage occasioned by or attributable to:

(a) faulty design or construction of, or the removal or weakening of supports to, any property described in the Policy.

(b) workmen engaged in making any structural alterations, additions or repairs to any property described in the Policy.

(c) excavations on or under land other than excavations in the course of mining operations.

3. For the purposes hereof any loss or damage as aforesaid shall be deemed to be loss or damage by fire.

4. In every case of loss or damage the Assured must prove that no portion of the loss or damage claimed for was caused otherwise than by the perils specified above.

5. It is a condition of this Policy that the Assured exercises all ordinary and reasonable precautions for the maintenance and safety of the property insured."

In this instance the schedule to the policy refers to the risk thus:

"RISK: ...or Hurricane and/or Storm
Windstorm and/or Tempest and/or
Tornado and/..."

The Law applicable to the insurance policies C 1067 (West Indies Alliance) & 551 FAR 147 (Lloyd's)

As this is an action on insurance policies, it is essential from the outset to examine the relevant authorities as to the construction of insurance policies so that the proximate cause of the damage to the silos may be determined. The onus of proof is on JFM to prove that the damage was caused by hurricane Gilbert and Panton J found that they had failed in that undertaking. At the close of his judgment he stated:

> "In view of the reasons that I have heretofore set out, I have no hesitation in entering judgment for the defendants. Indeed, as I see it, there is no alternative as the plaintiff has not proven that which it has alleged. Its witnesses have been discredited; their investigations have innumerable errors; and much of the investigations have been stage-managed to produce desirable results. The probabilities are overwhelmingly in favour of the position put forward by the defence."

This passage must be understood in the light of an earlier passage where the learned judge stated that the defence put forward faulty design and construction of the silos coupled with non-inspection and non-maintenance as the causes of collapse of silos 10 and 18.

If the findings made by the learned judge are correct then the principle stated by Lord Brandon in **Rhesa Shipping Co S A v Edmunds & anor.** [1985] 2 All ER 712 supports his stance. The principle was stated as follows at p. 714:

> " The second matter is that it is always open to a court, even after the kind of prolonged inquiry with a mass of expert

> evidence which took place in this case, to conclude, at the end of the day, that the proximate cause of the ship's loss, even on a balance of probabilities, remains in doubt, with the consequence that the ship owners have failed to discharge the burden of proof which lay on them."

In this case it must be emphasized that Panton J did not just rest his decision on the failure of JFM to prove its case. He also found that under the collective policy, faulty design and construction was not covered and paragraph 2(a) of the Lloyd's policies expressly excluded liability for faulty design or construction. Additionally, he could have found for the insurers on the basis adumbrated in the amended defence at paragraphs 3(A) and 3(B) relating to JFM's failure to maintain as referred to above. The learned judge's ruling in this regard is important and it is necessary to cite it. It reads:

> "... However, in view of the full presentation by the defence, it is appropriate and important that I should state that I accept the expert opinion of Mr. Minor as to the cause of the collapse. In accepting the position advanced by the defence, I should stress that this was not merely a matter of accepting Mr. Minor as opposed to Mr. Cader. Whereas it is a fact that I have found Mr. Minor's knowledge of the subject matter under investigation to be sound, and his reasoning compelling, it must be pointed out that I was also guided by some of those articles that were exhibited --- they having been written by persons far removed from the case."

It will be seen that Mr. Minor, the principal witness for the insurers, convinced the court below that faulty design and construction was the cause of the rupture in silos 10 and 18. The learned judge also relied on the evidence of Professor Mitchell and relevant articles in engineering journals to find that there was faulty design and deficiency in construction of the silos. He could also have reasoned that if there was any admission by JFM, and there was that the design or construction was faulty then the insurers would have succeeded. This intermediate stage will be very important when the evidence of Mr. Cader for JFM is examined. Had this aspect of the case been ventilated, the hearings could have been shortened below and even more so in this court. It ought to have been the basis of a respondents' notice.

If the acceptance of Mr. Minor's evidence is correct, then the law stated in **Wayne Tank Pump Co v Employer's Liability Assurance Corporation Ltd** [1974] 1 Q.B. 57 may be applicable to the construction of the policies if there are two proximate causes. Here is how Lord Denning MR put the position where there was evidence from which it could be inferred that there were two causes for an accident namely: the defect in the equipment and operation without testing:

> " The result is that, although this accident comes within the general words at the opening of the policy, nevertheless seeing that there is a particular exception, the exception takes priority over the general words. General words always have to give way to particular provisions."

In relation to this case even if the JFM proves that the hurricane was one of the causes of the rupture of the silos and the insurers also prove that the faulty design or construction or the alternative plea that failure to exercise all ordinary and reasonable precautions for the maintenance and safety of the property were the causes of the rupture, then the insurers in Policy FAFR 107 might not have been liable in view of the following provision which reads:

> "(4) In every case of loss or damage the Assured must prove that no portion of the loss or damage claimed for was caused otherwise than by the perils specified above."

For policy C. 1067 clause 4 - the reasonable diligence clause cited earlier is the maintenance clause. The evidence from JFM in this case was that the rupture of the silos was caused by the hurricane and the evidence from the insurers was that faulty design and deficiency in construction was the cause. There was also evidence and particulars relating to the alternative plea that there was failure to maintain the silos for the functions they were performing. Panton J did not address this latter issue expressly but it was averred and it will be necessary to determine if it was also proved. It must be emphasized that the terms of the insurance contract imposes the burden on the assured to prove that there was proper maintenance. This area was only half-explored in the court below. It would have been a shorter case on appeal if decision had been taken on this point in that court. In this court, it could have been the basis of a respondents' notice especially since Mr. ChinSee adverted to it in his opening address in the court below.

Further support for the approach in construing the policies on the basis that if there was more than one proximate cause, the insurers may not be liable, comes from Cairns LJ **Wayne Tank** supra where at p. 69 he said:

> "... On this approach if one cause is within the words of the policy and the other comes within an exception in the policy, it must be taken that the loss cannot be recovered under the policy. The effect of an exception is to save the insurer from liability for a loss which but for the exception would be covered. The effect of the cover is not to impose on the insurer liability for something which is within the exception."

Two short passages from the judgment of Roskill LJ in the same case give added support to this contention. At p. 71 the learned judge said:

> "I unhesitatingly accept Mr. Le Quesne's submission that, it being conceded that, apart from exception, the loss falls within the policy, it is for the defendants to bring themselves clearly within the exception. If they cannot do so, the defence fails and the claim must succeed."

Then at p. 75 the learned judge added:

> "... I think the law in this respect is the same both for marine and non-marine, namely, that if the loss is caused by two causes effectively operating at the same time and one is wholly expressly excluded from the policy, the policy does not pay."

Also pertinent to this approach is **J J Lloyd Instruments Ltd** [1987] 1LL Rep. 32 where Lawton LJ states:

> "If the defects in design and construction had been the sole cause of the loss, then the plaintiffs would not be entitled to claim either

> at common law (see *Ballantyne v Mackinnon,* [1896] 2 Q.B. 455) or because of an express exclusion in the policy."

The guiding principle as the learned Lord Justice put it at p. 37 is "the cause of a loss has to be determined on the evidence". In this case, the insurers insist that it was faulty design and construction and failure of JFM to exercise ordinary and reasonable precautions for maintenance for safety which caused the rupture.

There was no specific clause pertaining to design and construction in the West Indies Alliance Policy so the common law as stated above governs the issue. However, clause 4 of that policy C - 1067 and clause 5 of the Lloyd's policies relating to maintenance must be specifically referred to and construed in view of the paragraph 3A and 3B of the averments in the amended defence. For convenience, it is appropriate to set out these clauses in the policies again. As for condition 5 of FAFR 147, it reads:

> " It is a condition of this Policy that the Assured exercises all ordinary and reasonable precautions for the maintenance and safety of the property insured."

Did JFM lead evidence as to maintenance and did they also take all reasonable precaution for safety of the property before the hurricane and after? Certainly the policy envisages in clause 2(b) of the Lloyd's policy that there might be necessary structural alterations and additions to the property described in the policy. In such instances the insurers would not be liable for injury to the work-men. The contention by the insurers was that because there was deterioration over the period of 20 years owing to faulty design and deficiency in construction the silos were damaged. Then the failure to exercise reasonable precautions for maintenance and safety was the proximate cause of the rupture. If so, the insurers would not be liable.

As for condition 4 of Policy C. 1067 it provides that:

> "4. The insured shall use all reasonable diligence and care to keep the premises insured or containing the property insured in a proper state of repair and if any defect therein be discovered shall cause such defect to be made good as soon as possible and shall in the meantime cause such additional precautions to be taken for the prevention of loss or damage as the circumstances may require."

Was it necessary for JFM to use reasonable diligence to detect the necessity to cope with dynamic forces set up when the silos were being unloaded? That was one of the critical issues in this case. Also the insurers contended that there were old cracks within the silos which were warning signals as well as the rusting of reinforced steel. Cracks must have occurred before the steel was exposed and rusted.

The Pleadings

The salient averment of the plaintiff in paragraph 10 of the further amended statement of claim is as follows:

> "10. On the 12th day of September 1988, Jamaica, and accordingly the Plaintiff's premises at 209 Windward Road, Kingston 2 was subjected to the forces of Hurricane Gilbert, the most or one of the most devastating and violent hurricane(s)

> experienced and recorded in Jamaica. In consequence silos 10 and 18 together with other silos being part of the property insured were subjected to stresses which weakened them and such weakness persisted and was "locked in" to the structure and continued to influence the integrity thereof without being apparent and was then unrecognized and was the proximate and effective cause of a sudden and violent rupturing of the structure which occurred on the 26th day of September 1988 when the silos were being filled as hereinafter pleaded in paragraph 12. Additionally, the Plaintiff details, calculations and reasons of the mechanics of failure and/or cause of collapse as set out in reports numbers Phase 1 to Phase 6 inclusive by Zetlin-Argo Structural Investigations, Inc. copies of which reports have been delivered to the Defendants."

It is important to note that the pleader stated that the locked in stress was not apparent nor was it then recognised. Further this pleading suggests that this case was conducted on the basis that the Phases 1-6 of Zetlin-Argo's report was to be substituted for pleadings of particulars. To my mind this was unsatisfactory. Phases 1-6 of Zetlin Argo reports constitute expert evidence. It was essential for the proper conduct of the appellant's case to set out the particulars which averred that faulty design and deficiency in construction was not a cause for the collapse of the silos.

Also significant in this regard is paragraph 12 which reads:

> "12. On the 26th day of September 1988 during the filling of grain in Silo 10, whilst the said policies were in force, buildings, machinery, plant, equipment, stock in trade and other contents were damaged or destroyed by or through or in consequence

> of the insured perils, to wit, by or as a result of the damage caused or occasioned by hurricane Gilbert on the 12th day of September 1988 as hereinbefore pleaded and in the alternative in the case of the Principals of the 14th named Defendants and the 15th to the 39th named Defendants by way of subsidence and collapse whereby the Plaintiff has suffered loss and damage to the property insured and loss of gross profit, wages and auditors fees in respect of the interruption and/or interference of its business."

The feature to note in this averment is the plea of subsidence and collapse as the Lloyd's Policies FAFR 147 contains a clause which reads:

> "It is agreed that this Policy is extended to include loss or damage to the Property insured directly caused by Subsidence and Collapse."

The respondent insurers have stated in this court that this plea was abandoned both below and in this court as no evidence was led on this issue and it is a matter which must be examined. This further amended statement of claim was dated 8th December 1989. How was the amended defence of the insurers framed? After formal admission that the premises were subjected to the force of hurricane Gilbert and that the structure of the silos was ruptured on 26th of September immediately following the filling of silo 18 and during the filling of silo 10, they also admitted receipt of the report by Zetlin Argo -. Then issue was joined in the following paragraph:

> " 2. (d) deny that any stresses created by the forces of Hurricane Gilbert weakened the said premises or were locked in to the structure or influenced the integrity thereof

> or that the forces of Hurricane Gilbert created any stresses which were the proximate or effective cause of the rupturing of the structure."

Then the insurers go on to aver in accordance with the condition of the Lloyds policies that:

> "3. The Defendants say that the proximate or effective cause of the rupturing of the structure was faulty design and detailing and deficiency in construction."

The particulars to paragraph 3 are instructive as they are the pleaded response to Zetlin Argo's reports. They detail the following faulty design and deficiency in construction which the insurers insist was the cause of the rupture and it is helpful to set them out:

> "P A R T I C U L A R S
>
> (i) The reinforcement as detailed on the design drawings provided insufficient overlap between bars to allow the tensile force in one set of bars to be safely transferred to the continuing bars under normal operating conditions.
>
> (ii) The reinforcement at the junction of the outer walls is discontinued near the point of highest stress with all bars terminating in the same location.
>
> (iii) Detailing the splicing and anchoring of bars at the same point at the different splice points around the perimeter of the silos without providing for proper overlap to ensure the safe transference of stress.
>
> (iv) Misplacing the designed reinforcement during construction in that the bars in the joint between the outer walls of

> silos 10 and 18 were not all hooked around the jacking bar as called for on the drawings."

Then continuing the catalogue of faulty design and deficiency in construction the particulars state:

> "(v) Failure of the design drawings to stagger the position of the laps in the reinforcement as required by good practice and requirements of Codes of Practice or, alternatively, to take special precautions to ensure that stresses can be safely transferred between the re-enforcing bars.
>
> (vi) Failing to back fill around the elevator pit and tunnel with mass concrete or specifically compacted soil.
>
> (vii) The cross-sectional area of reinforcing steel as detailed on the design drawings is less than that which have been specified by a prudent designer using information available in 1966 on the pressures developed by grains in silos."

It should be noted that the particulars adverted to by Zetlin Argo's report specified in paragraph 10 of the statement of claim supports these particulars detailed in the defence. The support is to be found in articles by renowned experts in design construction and maintenance of silos. Then follows the amendments in paragraphs 3(A) and 3(B) which were detailed earlier. They are alternative averments and they purport to bring the insurers within the terms stated in Condition 4 of the West Indies Alliance Policies and Condition 5 of the Lloyd's Policies. To reiterate, they aver that JFM failed to use reasonable diligence in detecting defects in design and construction and failed to exercise all ordinary and reasonable precautions for the maintenance and safety of the silos. Again, articles exhibited by Zetlin Argo detailed the type of maintenance necessary for the safety of silos.

There ought to have been a specific reply to this plea. This is so particularly since Zetlin Argo's report which is both particulars and evidence contains articles by Safarian, Deutsch, Jenyke and Johanson which tends to support the insurers' case on this point. Having regard to the manner in which JFM presented Zetlin Argo's report as particulars and as an agreed bundle, these articles provide important evidence in favour of the insurers' case with respect to design, construction and maintenance.

Just as the insurers denied that hurricane Gilbert caused the rupture of the silos and so pleaded, so JFM while admitting that the silos as constructed did not conform to the codes, insists that the actual structure was capable of withstanding the normal operation of loading and unloading, and that it was Gilbert which caused the damage to the silos which were in operation for 20 years. JFM pleaded generally and supplied Zetlin Argo reports as a substitute for pleading particulars.

It is now necessary to examine the facts of the case under the headings of the effect of the winds accompanying the hurricane, the analysis of the soil, computer analysis and the insurers' case under the rubric of faulty design and construction and maintenance.

(II) What was the nature of the wind pressure unleashed by hurricane Gilbert?

The introductory evidence on the nature of Gilbert and the probable effect it had in causing the rupture of silos 10 and 18 was adduced by Calvin Gray, the Director of the Meteorological Division of the Ministry of Public Utilities. He explained that the wind speed associated with a hurricane is counter-clockwise and that it was low pressure system. The eye of the hurricane is characterized by a calm as it is the area of lowest pressure. The maximum speeds at the rear of the hurricane recorded at Norman Manley airport was 114 knots or 131 miles per hour. Regrettably, the anemometer which measures wind speed direction failed because of loss of electric power. In any event, it was blown away by Gilbert. There were gaps in the charts which represented the direction of the wind.

The maximum speed read before the anemometer malfunctioned was 120 knots or 138 miles per hour at the Sangster International Airport at the other end of Jamaica.

As regards the counter-clockwise flow of the wind, as it approached a certain point, the wind will be out of the north and after the eye has passed the wind will come from the south. The critical aspect of this evidence as it relates to direction of the wind and pressures is of sufficient importance, that part of it must be cited. Gray explained that there was a set of mountains and hills immediately in the vicinity of JFM and that they run in a east to west direction. So he said:

> "... hence the flow associated with the hurricane would result in a combination of both blocking and channeling effect as the hurricane moves from east to west across that area."

Then he continues thus:

> "... if the wind is approaching this object which is immediately in its path, (indicating) this is referred to as a block because the wind is forced to move over this object in three possible ways, either go over or go around. We note that the hurricane is a system in constant motion, so as the system approaches, if the winds are coming in this direction when it is moving parallel to this at this point that would represent channeling because it would be pushing it along whereas when it hits it in this direction it would be a block and one of the effects of channeling is to speed up the flow of the wind. This does not mean that blocking cannot result in increased wind speed because if the object or the barrier that is responsible for blocking creates eddies or vortices, we could in fact end up with smaller systems in which the intensity of the wind is much greater."

Then in pointing to pressures that are likely in the area of JFM he continued:

> "... For example, if we look at the migratory frontal systems, the wind speeds associated with these systems are the order of forty-five or fifty knots. However, because of obstruction and blocking, you can have these barriers spawning whirl winds or tornadoes and we are very well aware in such circumstances that the speed associated with whirl winds or tornadoes can indeed and in fact end up at over one hundred miles per hour although the basic wind speeds associated with that system were only of the order of, say, fifty knots."

In Gray's opinion, the wind speeds could be doubled. He then stated why there would be a turbulent flow thus:

> "It is more what is referred to as turbulent flow; it is friction in the case of a blocking and in the case of channeling it would be more because of reduced space. If you had a wind passing through just here and you were to restrict the space to be much less, then if you are inside here you would feel it much stronger because that would be reduced space and the same mass of air has to pass through a smaller area."

Another aspect of the nature of the wind accompanying the hurricane is its ability to recognize an object at about fifteen times the height of the object away from its trajectory. When the object is recognised, it affects the pattern of the wind. Here is his specific answer:

> "It can go over that object or go around either side and will in general revert to its normal trajectory at a distance five times the height of the object."

Then the following exchange took place:

> "HIS LORDSHIP: Can or it does?
>
> A: Usually and I say in general because what if another object appears before it has reached.
>
> HIS LORDSHIP: So it reverts to its what?
>
> Mr. GRAY: Its normal trajectory.
>
> HIS LORDSHIP: At a distance of about?

A: Five times the height of the object downwind.

HIS LORDSHIP: Did you say downwind?

A: That is correct."

As regards specifics Gray's evidence was as follows:

"HIS LORDSHIP: Expose to blocking?

A: And channeling. At this point I won't even attempt to indicate which could have been, or contribute it to whether it was blocking or channeling but we are looking at the hurricane and all of the winds coming from the north at one time before the eye passed and then from the south after it passed, then certainly the entire structure and indeed the silos and especially those on the eastern end because of the location, if my memory serves me right, would lead to channeling at one time and at the other instance would lead to the wind speed and wind direction."

All this must be assessed in the light of the opinion that in terms of wind speed, Gilbert was the worst not just for Jamaica but the region. As regards the three basic components of the hurricane, wind, pressure and rainfall, Gray's opinion was that:

> "The effect of pressure, this is the most damaging component of any hurricane"

There was a qualification to put it in his own words:

> "Your Honour, and again being a member of the Essential Service, Emergency Services, this may or may not be important but we were spared this most damaging aspect of it in terms of storm surge activities, we were spared that aspect of it but that is directly related to the pressure."

Gray gave evidence that the eye of the hurricane passed over JFM then the following measurements given by him are important:

> "Your normal atmospheric pressure is ten thirteen point two five millibars, the lowest central pressure associated with Hurricane Gilbert was nine hundred and sixty millibars."

This is how he explained it:

> "As I mentioned, you have pressure forces acting from high to low, hence the pressure differential must result in increased pressure forces on any structure located in its path. Your Honour, if I may just say, I hope I have been clear enough, but for example, if you are travelling in an aircraft, the pressure inside an aircraft is much higher than the pressure that is outside, this is why if you have damage to an aircraft window or such, the tendency is for suction."

This aspect of the evidence appears to have surprised the insurers. They did not insist as they had a right to, that material facts in Zetlin Argo's reports be particularized in the language of pleaders. In one of the many submissions made during the course of the evidence in this long and complex case the following passages relevant to JFM case must be cited:

> "May I refer Your Lordship to Page G-25 of our report, Volume 6 with which my friends, I know, are particularly familiar.
>
> > 'Furthermore, according to the available information, Gilbert reduced the air pressure in the atmosphere to about 964 millibars (normal atmospheric pressure) that existed inside bins 10 and 18. The resulting differential pressure was pushing walls of bins 10 and 18 outwards and had the same effect as grain pressure. (It is our opinion, however, that this differential pressure of 36 millibars was dissipated rapidly and the effect on the strength of the bins was small. Nevertheless, it may have had some damaging effect. This differential pressure was also not included in this investigation.'"

Then the further passage was cited from Zetlin Argo's report:

> "First passage of air through the narrow passageway spaces between the bins and the adjoining buildings created vortices and subsequent pockets of vacuum within the passageways which meant that the air pressure outside the bins became lower than the pressure inside the bins. The higher pressure inside bins 10 and 18, therefore, produced localized forces within the air space inside the bins which tended to push the walls of the bins outward (these forces had the same effect on the strength of the bins as the pressure generated by the grain)."

Panton J ruled that Gray's evidence on this aspect was admissible but he did not in his judgment advert to it specifically and apparently gave it little weight. It would seem however, that it ought to have some bearing on the theory of locked in stresses which is at the heart of JFM's case.

(III) The engineering evidence on the effect of the wind on the bank of silos.

In assessing the evidence of Professor Sparks the expert brought on behalf of JFM in the area of wind engineering, the unusual method of pleading the particulars in paragraph 10 of the Further Amended Statement of Claim must be adverted to again. It will be recalled that Zetlin Argo's report was used by JFM both as evidence in an agreed bundle and as a substitute for pleading the material particulars of the appellant's case in the court below. JFM intended to rely on Dr Emil Simiu another specialist in this field. He was consulted by Dr. Zetlin and his opinion is incorporated in an agreed bundle. Unfortunately, Dr. Zetlin died before the trial and Dr. Simiu who was employed to the Federal Government of the U.S.A. was debarred by his employers from giving evidence in a foreign jurisdiction. It was in those circumstances that Professor Sparks was retained it seems on the advice of Dr. Simiu.

In a case where expert evidence must be the decisive factor in determining the outcome of these proceedings, it is important to delineate the precise nature of the expert's special field. Here is how Professor Sparks defines his specialization. After stating that his basic qualification is in civil engineering and with emphasis on structural engineering, he said:

> "...Since the middle of the 1980's I have been studying in particular the behaviour of buildings in hurricanes and tornadoes.
>
> Q: Now, before we get on to your work in the area of hurricanes I would just like to ask you to explain to us the area of engineering known as wind engineering.

> A: It's a branch of engineering, specialized branch of engineering which deals with the effect of wind primarily upon structures, buildings, bridges, towers and included the determination of wind speeds, the effect of terrain on those speeds, what the wind does to the buildings or other structure and how that structure might respond to those wind loads.
>
> Q: Now, within that chain of wind engineering, are there specific areas like aerodynamics, the effect of hurricane, are there different specialized areas within the broad field of wind engineering?"

Additionally Professor Sparks said:

> "A: There is one area of specialization which is the use of wind tunnels in determining the pressures and loads on buildings, on structures. That is traditionally being an area in which aeronautical engineers have come into the profession and specialized in. From the other end there is an approach from the structure and how the structure behaves and observations about the performance of the structures, and that is traditionally being approached from people in the structural engineering profession and I would suppose that the wind engineering sub-discipline now is a mixture of those two approaches.
>
> Q: What about aerodynamics, where does that fit in?
>
> A: That comes into an understanding of the way the structure responds to the wind, how the air flows around the building and therefore what pressures are generated on the building."

Professor Sparks decided that there was an area of turbulence in the vicinity of the site of the Flour Mills. He came to this conclusion after a test flight in a helicopter.

That there are serious limitations pertaining to accuracy in this field was admitted very early in his evidence. He put it thus in explaining his purpose and particularly his attempt to establish wind conditions and to simulate wind speed measurements:

> "Wind speed measurement that had been made strictly, I should say, near the ground, and those that had been made by reconnaissance aircraft, working for the National Oceanographic and Atmospheric Association, NOAA. The reason for doing this was that in many cases we have a very poor understanding of the wind conditions that exist in a hurricane and we anticipated in fact that there could be considerable dispute as to the cause of failure of buildings."

Another feature of uncertainty was accounted for thus:

> "A: Yes. if you look at Long Mountain it looks like an upside down boat and so the flow coming over Kingston has to be diverted around the mountain. This mountain is 1,400 feet high and forms a major obstruction to the flow. I used the information in this exhibit ...
>
> Q: Exhibit 45.
>
> A: ... to obtain an indication of what would be a reasonable increase in speed. Flow over the mountain ridges have been studied in detail but flow around the side of the mountains of this size have not received much attention."

Any criticism of Professor Sparks must take into account this frank admission. Additionally, this will be a factor which must be taken into account in determining whether JFM has proved its case on a balance of probabilities.

Perhaps at this stage it is pertinent to state that Professor Sparks relied on the meteorological reports prepared by Calvin Gray. He had to interpret these reports to determine the effect of the winds on the silo bank. It was stressed that the wind speeds would vary and that there would be a fluctuating load as the wind comes up and goes down. The movement would be small as the building was very stiff. This statement has very important implications for a formula relied on by Professor Sparks for the distribution of the wind load. There is abundant evidence from other structural engineers on both sides that the formula is applicable for flexible foundations. However, Professor Sparks added that the soil characteristics changed as the soil was very sensitive to the way it was loaded. The precise changes in the soil characteristics was however a matter for a soil expert.

Dr. Oweis who testified on behalf of JFM was the expert relied on by JFM for soil analysis. When his evidence is examined a crucial aspect will be the pressures he relied on for computing the differential settlement of the soil under the silo bank which is the basis of JFM's case. If it is established that the method of calculating those pressures was erroneous, then Panton's J order cannot be disturbed.

Professor Sparks stated that he converted the wind speeds to pressures acting on the silos and the headhouse. Because of the importance of Professor Sparks' evidence which differs from the evidence in material particulars from that in Zetlin Argos' report, it is necessary to cite parts of his evidence verbatim. The agreed bundle also contains Dr. Simiu evidence, and this conflicts with the oral testimony of Professor Sparks. This was anticipated by Mr. George for the insurers as at an early stage in Professor Sparks' evidence. The following passage establishes this:

> "I am glad my learned friend said so, because frankly on this side we thought there were other reasons, which there may well be as well. When Your Lordship sees Dr. Simiu Report he may well come to the conclusion I have come to."

Here is how Professor Sparks explained what he did:

> "A: Yes, sir, I did an independent analysis from that which had been done by other people previously involved in the case. I did this because I thought it was better for me to do my own work than follow the work of others and I used published data of the effect of the overall forces on structures in terms of the overturning effect of the loads applied to the silo and the head house.
>
> Q: And what was the next step?
>
> A: The next step was to make an estimate of the soil pressures that would occur as a result of the maximum loads applied to the structure.
>
> Q: Can you compare your approach to the approach taken by Dr. Simiu and Zetlin Argo?

> A: My approach was based more on the system which is used in Britain, assuming or developing an appropriate period to determine the increase of wind speed over -- determining a peak gust wind period, a gust period, appropriate gust period to apply a load to the structure and then to apply that effective peak load using coefficient for -- perhaps I should rephrase that. Determining peak loads using coefficients, concerning the overall behaviour of the silos."

There was a pertinent objection by Mr. George for the insurers on the basis that they had come to meet the case as adumbrated in Zetlin Argo's reports. Panton J ruled in favour of JFM and as there was no cross-appeal on the matter His Lordship's ruling must stand. It was as follows:

> "HIS LORDSHIP: You [Mr Mahfood] are perfectly within your right to be proceeding as you are at the moment."

Had JFM pleaded their particulars, this divergence could not have occurred. Lord Radcliffe's words in **Esso Petroleum Co Ltd v Southport Corporation** [1956] AC 218 at 241 are appropriate:

> "It seems to me that it is the purpose of such particulars that they should help to define the issues and to indicate to the party who asks for them how much of the range of his possible evidence will be relevant and how much irrelevant to those issues. Proper use of them shortens the hearing and reduces costs. But if an appellate court is to treat reliance upon them as pedantry or mere formalism, I do not see what part they have to play in our trial system."

Emphasizing that the evidence sought to be adduced must conform with the particulars Lord Radcliffe said at p. 243:

> "... I find it impossible to read the statement of claim and the particulars without coming to the clear conclusion that, while the respondents were announcing it to be one of their heads of complaint that the master had brought his ship into the channel with defective control of steering, they were not putting it forward as a ground of complaint that the appellants, the ship owners, had allowed their ship to be at sea in such a defective condition. And that is what they now wish to complain of."

When these principles are applied to the evidence which Professor Sparks was about to adduce, it seems that they were outside Zetlin Argo's reports and In particular the agreed bundle which contains Dr. Simiu's opinion. Having regard to the ruling against the insurers, Professor Sparks continued his evidence and the case must be determined on that basis. That the law on this matter was grasped but not applied was evidenced from the following passage:

> "MR. GEORGE: Now, M'Lord, those calculations, those details those particulars give certain soil pressures and certain resulting settlements. Are we now being given something else contrary and outside the Pleadings?
>
> HIS LORDSHIP: But, Mr. George, if you were being given something else which Paragraph 10 couldn't cover, wouldn't it be in your favour, don't you think, at the end of the day?
>
> MR GEORGE: But you see, M'Lord, the day is here. While the end of the day can be protracted and long, if that day can be

> shortened, it behoves, indeed it is my bounded duty to tell your Lordship that time is being wasted on irrelevancies, on matters outside the Pleadings in this case."

In this long and complex case, it might have been appropriate to have pleaded in the regular manner. This was not done, and Panton J showed his thinking on the state of the evidence and the probable outcome at this early stage. He said:

> "We are dealing with the propriety in evidence coming from him. It seems to me on the face of that, the earlier part of the paragraph of the Statement of Claim is wide enough to permit the testimony of this witness. Now, if it turns out that there are two witnesses, let's say two witnesses called by one party and the witnesses give conflicting, contradictory evidence, well certain consequences follow, I will have to assess it and make a decision."

Professor Sparks stated how his approach differed from that of Dr. Simiu:

> "I took the load on the longitudinal direction of the silos and in the transversed direction of the silo, and I investigated the effect of the wind coming in various directions. I included the asymmetry of the loading caused by the head house and its effect on the foundations. Zetlin Argo and Simiu did not include the longitudinal effect, I think that was a conservative approach."

He continued thus:

> "This is a force which was not included, which should have been included and I believe they placed the more importance on the torque on the bank of silos than I would have done."

Professor Sparks' important conclusions as regards soil pressures due to wind alone was as follows:

> "A: Going by numbers, sigma one, I got 2.3 kips per square inch.
>
> Q: They got 1.69, you got 2.3
>
> A: And where sigma 2 said minus 1.69 I got minus 2.76; sigma 3, minus 3.5; sigma 4, 3.81."

As regards relationship between wind speed to pressure, Professor Sparks expressed it thus:

> "Q: Now, can you just tell me what is the relationship of wind speed to pressure, if for example, the wind speed goes up by a factor of two what happens to the pressure?
>
> A: The pressure would go up to the factor of 4; it's a square relationship."

Then specifically on gust factor Professor. Sparks states:

> "A: Gust factor in hurricane, that is the ratio of the peak wind speed to the average wind speed is a little higher than in hurricanes than it is in extra tropical storms, based on the measurement we have been able to make in the last five years or so."

The report by Professor Lawson, the expert retained by the insurers also admits the lack of certainty in certain aspect of wind engineering. Although he did not give oral testimony, parts of his report which was an agreed bundle was put to Professor Sparks. Here is an extract from that encounter during examination in chief:

> "Q: Dealing at the bottom with the 'Velocity Profile', there is a statement: 'The variation of wind speed with height is called the Velocity Profile. The shape of the Velocity Profile in hurricane is not well established, but it should not be greatly different from equilibrium extra tropical storm profile.' Have you got any comment on that statement?
>
> A: The variation of wind speed with height will continue to a much greater height in a extra tropical storm than in a hurricane. Typically, the gradient wind speed which is essentially the wind speed unaffected by the roughness of the ground, will occur at approximately 500 meters, about 1,500 feet."

The examination continued thus:

> "... The effect of this is that in open terrain like an airport the wind speed, mean wind speed, I should add, at 10 meters or 33 feet, is about 60 percent of the gradient wind speed. This would suggest that the gradient wind speed over Kingston for northerly winds would be approximately 55 meters per second, whereas Mr. Lawson suggests that it would be 71.5 meters per seconds. 71.5 meters per seconds is about the gradient wind speed to the right of the eye in Hurricane Hugo, which had a much lower central pressure and a very fast transitional speed which add to the effect of the gradient speed, increases the gradient speed. So 71.5 seems too high to me, seems unreasonably high."

After suggesting that a wind tunnel model of the topography would be required to establish the exact profile and as this was unavailable, the report deals with the wake effect of the Long Mountain. Then Professor Sparks commented thus:

> "My comment is that the silo was not in the wake of Long Mountain. The wind as we discussed this morning is approaching along the side of Long Mountain and I believe that this misunderstanding arose because the wind direction was referred to northerly or from the north, whereas the wind was not coming from the true north. Had it been coming from the true north then the silo would have been in the wake of the mountain, but we have established that it did not come from that direction, and I therefore believe that the wind speed was much higher than 11 meters per second. I would go sailing on a day when the wind was 11 meters per second and I can assure you I wouldn't be in a boat near the Flour Mill during Hurricane Gilbert. It's a relatively low speed."

In assessing Professor Sparks' evidence on the effect of the wind on the silos, it must be emphasized that he did not support the methods used by Dr. Zetlin and Dr. Simiu in the agreed bundles. On the use of drag coefficients which are used in the design of buildings, here is a significant answer by Professor Sparks:

> "A: I don't feel I would be in a position to justify what Dr. Zetlin or Dr. Simiu's chose to use, because that was not my work."

Yet another limitation in Professor Sparks' evidence as to the effect of the wind forces was that he did not carry out a detailed examination as Zetlin Argo did. Here is his evidence:

> "A: I don't think that the shape of the bank of silos is significantly different with regard to a structure, with regard to its shape, than a typical building of that size.
>
> Q: That's not the question I asked you. We are dealing with issues of design here are we?
>
> A: We are dealing with normal coefficient which would be used in practice.
>
> Q: But this is not a case with anything to design where there are certain unknown factors, am I correct?
>
> A: That is correct, and that is in fact why I did not use those coefficients in my calculations and why I sought to find those for direction.

Then Mr. ChinSee for the insurers observed:

> Q: We cannot find the justification on this side either, rest assured. "

To emphasize his disagreement with Zetlin Argo report which relied on Dr. Simiu's investigation Professor Sparks said:

> "A: This is a plate and this drag force is pulling it this way and I believe that -- I have not read in detail the axises that are used in that are referred to the place. I can't see the relevance of it but that's what it is.
>
> Q: Neither can I, but nevertheless, I see it in the report."

When he was being cross-examined by Mr. ChinSee for the insurers, it was recognised that the shape of the silos has an important bearing on the impact of the winds. So it is important to note the basis of Dr. Simiu's calculations. Professor Sparks explained it thus:

> "Q: ... Dr. Simiu has come out with a value of 1.3, and he is basing it upon this work which relates to tall buildings with a rectangular shape in plan. So he is using this as a reference and his value was based upon whatever was done in relation to tall buildings with a rectangular shape in design?
>
> A: That is correct.
>
> Q: And indeed at Sheet G-8, although it doesn't say so, Zetlin Argo's report uses the same coefficiency?
>
> A: Yes, correct."

That Dr. Simiu's report was imprecise in certain areas was admitted by Professor Sparks. Here is how one aspect was elicited:

> "Q: Professor, what is important here is what I have just referred you to, is that although you would have less overturning effect no reductions have been given in this report for that effect, correct; am I not correct that that is so?
>
> A: As far as I can see that is true."

This defect was also found in Zetlin Argo's report which was both evidence and particulars. It appeared thus:

> "Q: Indeed. If I take you to Sheet G-9 of the Zetlin Argo, a comparison of Dr. Simiu with Zetlin Argo shows that Zetlin Argo does not even recognize that those buildings could have an effect on the overall impression?

A: In their report there is no statement."

The issue at that stage of the trial was the shielding effect that the building in the vicinity of the silos had in lessening the intensity of the force of the winds from Gilbert. The foundation of Zetlin Argo's case was that the differential settlement resulted from maximum pressures on the soil in the southeast. This resulted in a differential tilt and resulted in locked in forces which caused the rupturing of the silos 10 and 18.

The starting point of all this is the wind forces unleashed by Gilbert. So the following admission by Prof. Sparks is contrary to Zetlin Argo's case as pleaded. It is as follows:

> Q: Professor Sparks, just looking at the physics of the air going around the building in relation to the particular torque, would you tell us whether it would be clockwise or anti-clockwise?
>
> A: From which direction and for which wind actually?
>
> Q: Wind from the North, that is what we are dealing with, we have not touched the wind from the South
>
> A: The wind from the North, the mean torque you would expect to be in an anti-clockwise direction.
>
> Q: You would agree with us that Zetlin Argo has used this in a clockwise position?
>
> A: Yes, he used it in a clockwise position, that is correct."

That Zetlin Argo's calculations were on the wrong basis, was admitted. That wrong basis resulted in their finding that maximum pressure was in the Southeast. This is how Professor Sparks put it in evidence:

> "MR. CHIN-SEE: Let me see if we can put that into words. Am I correct in saying that these fluctuations on torsional moments would cause rotational fluctuations at both ends as opposed to a hammering of the structure at one end only?
>
> PROF. SPARKS: My understanding is, in fact there would be a mean torque which would produce a rotation like that and that there would be oscillation about that mean.
>
> A: I would simply add that we are talking about a particular equation which has been pointed out to me which deals with the torsional forces on the silos. There is another torsional effect due to the wind on the headhouse which goes in the opposite direction.
>
> MR CHIN-SEE: Let me go one step further here. Professor Sparks, would you agree with me that the whole of the foundation of the entire bank of silos and not just one corner is subject to these fluctuations affecting the entire soil under the bank of silos?
>
> PROF. SPARKS: The forces on the silos. I believe that those forces would probably be felt by the foundation, the whole structure is connected to the foundation and would probably respond to those fluctuations.
>
> Q: So it is the entire soil under the bank of silos?
>
> A: I can't say exactly what it does to the soil but I would, as the Structural Engineer

looking at the top, we are dealing with the overall forces on the bank of silos from this equation which I would say is part of the overall effect.

HIS LORDSHIP: You would say it would affect the entire foundation?

A: I would imagine its a block subjected to it, not the silos alone.

MR. CHIN-SEE: I take you now to the peak torque. Zetlin Argo -- back to fluctuating torsional moments -- has assumed in his report that they are only clockwise? Let me put it this way, has done his calculations as if those moments were clockwise.

HIS LORDSHIP: Any answer to that?

A: Oh yes, I nodded and winked at the reporters at the same time, yes, that is correct.

HIS LORDSHIP: Zetlin Argo's calculations were based on clockwise?

PROF. SPARKS: Fluctuations really.

HIS LORDSHIP: Is that how you say it?

A: Yes. Perhaps I would say, it was a mean torsional moment in a clockwise direction.

MR. CHIN-SEE: And, of course, these fluctuations are both clockwise and anti-clockwise, prudence at least should require him to put in the calculations for anti-clockwise fluctuations. If you are going to give a true picture, you should give also those calculations?

A: Probably should estimate what happened in both conditions, I would agree."

In explaining the difference of Dr. Simiu's approach from the one he used, Professor Sparks said:

> "PROF. SPARKS: He used --- I think the essence of the question here was whether or not a reduction should have been taken because this building, this mill building was occupying one corner of the site and therefore might provide some shelter in that corner and my answer to that is because it is in the corner and near the ground, it makes very little difference to the overall forces on the structure."

While originally Professor Sparks was of the opinion that reduction of the force exerted on the silos would be 10% he corrected thus:

> "A: It was too high, much too high. I would estimate no more than three percent because the wind leaks around the side of the building - or perhaps I should say, would leak around the side of the building and create very little pressure."

Then he said:

> "A: I must admit to that, that the presence of the building in fact would tend to trap the air in the corner. So the additional effect is not to reduce the overall load on the building but in fact to increase it."

There were other limitations in Professor Sparks' evidence which was admitted by him in cross-examination:

> "A: That they would have very little effect on the overturning, for example, of the silos. They are often poorly co-related-related over small areas, the suction in the corners.

> ... I come back to it again, I have not studied this in detail."

He emphasized this by saying:

> "A: ... No, I think you keep coming back to the local pressure coefficient and there is a fundamental difference between local pressure coefficient and overall pressure, and a gentleman with the reputation of Mr. Lawson fully knows the difference between both."

That by failing to take into account the headhouse or any shielding factor or the anti-clockwise direction of mean torsional moment, Dr. Zetlin arrived at 11719 kips feet when it should have been -4375 kips feet. This was admitted by Professor Sparks.

Zetlin Argo's case was modified from the lips of Professor Sparks in the following manner:

> "Q: Following Dr. Zetlin down the line, we have reduced the error from three percent and we have arrived at the greater pressure in the south western side.
>
> A: In that extreme case that is right."

It was further emphasized thus:

> "Q: The force indicated in the south eastern corner is lower than the force in the south western corner.
>
> A: Yes."

So Professor Sparks has revised Zetlin Argo's theory of the maximum force being in the southeast. Perhaps it was astute tactics on the part of counsel for the insurers not to press the pleading point. If they had succeeded in keeping out Professor Sparks' evidence they would have had to call Professor Lawson to give the evidence on this aspect. It must be an advantage for the insurers to have JFM expert weaken the appellant's case.

In explaining the nature of vertical pressures, and demonstrating how the anti-clockwise motion omitted by Dr. Zetlin was a serious error, there was a remarkable passage which was so important for the outcome of the case that it must be rendered in full:

> "Q: Now considering the anti-clockwise position first and then using the formula at Sheet G.38, the distribution factors are set out there. You agree with the number 1.25 at the south-west corner?
>
> A: Yes, I do.
>
> Q: And at the south-east corner, 0.75.
>
> A: Yes.
>
> Q: Can we just turn over to Sheet G.39, please.
>
> Mi'lord, you will notice that G.39 is left out there.
> HIS LORDSHIP: Yes.
>
> Q: The vertical soil pressure at the southwest corner will be 2.73 X 1.20 (sic) 0.75 = 2.05 kips per square foot.
>
> A: Yes"

Then the clockwise position was considered thus:

"Q: Let us consider the clockwise position and one must take, to be correct one has to take both into consideration.

A: Yes.

Q: Let me give you another page immediately so we don't have to break this. (Document handed to witness) Now we have worked out the equivalent distribution factor as:

$$1 + \frac{6 \times 1.9}{135} = 1 + 0.08$$

or, 0.92 at the south-west corner and 1.08 at the south-east corner. Do you agree?

A: Yes."

The admission by Professor Sparks continued thus:

"Q: Do you therefore, agree in this case the worst vertical soil pressure at the southwest will be o.92 X 2.73 = 2.51 kips per square foot, and at the south-east the vertical soil pressure will be 1.08 X2.73 = 2.95 kips per square foot.

A: On this basis, yes.

Q: Do you agree therefore from the calculations the worst soil pressure due to hurricane Gilbert occurs at the southwest corner and has a value of 3.41 kips per square foot and not a value of 1.69 as set out at the bottom of G.39.

A: On the basis of these calculations then that would be the answer you could get.

Q: Can we therefore look at the south-east corner? At the south-east corner the worst vertical pressure due to hurricane

Gilbert is only 2.95 kips per square foot and not 3.77 as set out at the bottom of G.39."

Professor Sparks also said:

"A: Again on the basis of the calculations that would be the number you would get.

Q: What we have done, haven't we, is to follow Dr. Zetlin save that we have put in the correct factor of torsional effect of the south-east, the minus quantity.

A: That is correct on the basis of these calculations. What you have done is to interpret the moment going one way and he interpreted it another way.

Q: Didn't you agree with us ...

A: Indeed.

Q. You agreed with us that those are to be taken into account and that you had to do two sets of calculations, one showing the movement left of the centre and one showing the movement right of the centre line.

A: Correct."

Then his Lordship intervened:

HIS LORDSHIP: Do I understand you to be saying that the documents that were put to you with which you say you agreed with the calculations, now do I understand you to be saying that all Mr. Chin-See has done is to go the way that you felt Dr. Zetlin should have gone in terms of clockwise and anti-clock-wise?

A: Let me answer this way: I think their interpretation of the wind torque is correct.

HIS LORDSHIP: Who is 'their'?

PROF. SPARKS: A: I am sorry, the Defence.

HIS LORDSHIP: But you agreed that there should have been this opposite movement.

A: Yes, but I have to qualify that by saying what they have done is to put these numbers in the logic of Dr. Zetlin."

Then perhaps indicating the state of the appellants' case at that stage of the proceedings Panton J. made a remarkable statement thus:

> "HIS LORDSHIP: I strongly suspect when this case is ended neither side will be making any closing address."

If Panton J was of the same mind at the end of the case as he seemed to be at that stage it was not surprising that he found at the end of the day that "the plaintiff had not proved that which it alleged." It was the insurers' contention that the silos were rigid bodies and that the torque about a vertical axis would be visited by a shear action and not by vertical forces on the soil as could cause differential settlement. They first had Professor Sparks demonstrate this effect by using a shoe box. Here is how the evidence emerged:

> "A: I will explain to you without reading the notes. I looked at what had been done by Zetlin Argo in interpretation of why they were using a distribution factor and you are correct inasmuch as if this is a rigid body ...
>
> HIS LORDSHIP: That is the shoe box there now.
>
> A. Yes, this is a rigid body; if it is a rigid body then you are correct in saying that a

torque about vertical axis like this would in fact be resisted by the soil in a shear action, that is, it would tend to slide over the soil like this (indicating).

HIS LORDSHIP: What will tend to slide?

A: The torque will tend to make the shoe box turn like this (indicating), that is the action of the torque about the centre. The way Zetlin Argo used their distribution factor, as I interpreted it, and it was done purely on my own in asking what they have done to suggest that if there is not a rigid body that the eccentricity that might exist in essence, the moment about this axis (indicating with box) which do create vertical stresses ..."

Then after persistent questioning the following answer was quoted:

HIS LORDSHIP: That is the box.

A. Yes, if the box acts as a rigid body the movement of that vertical axis does not influence the vertical stresses, the moment or the torque about the vertical axis does not influence the vertical stresses in the soil."

The insurers wished to determine from cross-examination whether the silos were rigid. The relevant passage ran thus:

"Q. Would you agree that silos are one of the most rigid forms of construction possible?

A: I have not done any calculations on the silos so I am not in a position to answer that."

After further probing this was the answer:

A: It is rigid in relation to wind. It depends on the foundation whether it is rigid in relation to soil."

This answer suggests that the Gilbert winds did not affect the rigidity of the silos. Having regard to Professor Sparks' expertise his answer regarding the foundation and its relation to the soil would be determined by specialists in foundation engineering. That would be Dr. Oweis; Professor Sparks is a structural engineer specializing on the wind forces on structures so the following answer was somewhat surprising:

> "Q: It is rigid in relation to construction?
>
> A: That I can't say because I have not examined it."

The next aspect pursued by Mr. Chin-See for the insurers was to determine the applicability of the formula Zetlin Argo used to calculate the distribution of forces. It was referred to in this Court as the unknown formula and for ease of reference I will also use that term. The result of the examination was as follows:

> "HIS LORDSHIP: The formula here that is being referred to is which one?
>
> MR. CHIN-SEE: The distribution.
>
> HIS LORDSHIP: And the formula you are referring to is B over BH plus, plus or minus - yes, I have seen it. What is your answer? You were asked was there any reference.
>
> A: And I said as far as I know there was not any reference, that is why I had to resolve in my own mind what he was doing because there was nothing there I could look up."

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Then here is how it came to be dubbed the unknown formula:

> A: I have not come across the equation before; I have come across a lot of formulas in my work but I have never seen it before."

Professor Sparks admitted that he used the unknown formula to determine the distribution of the wind:

> "MR CHIN-SEE: Q: Let me ask you this, the non-existent formula that you have never seen any text used in the Zetlin-Argo's report, did you use that formula?
>
> A: I used it in a way of trying to determine the distribution of the stresses, and I looked at a number of ranges, again I know that I am not allowed to refer to the calculations. ...
>
> Q: I am just asking whether you used the formula in arriving at those soil pressures you gave?
>
> A: I did, indeed.
>
> HIS LORDSHIP: That is the Zetlin-Argo's formula?
>
> A: Yes."

Professor Sparks under re-examination by Mr Mahfood was probably helpful to the insurers thus:

> "A: I used this equation as a means of estimating the effect of the flexibility of the foundation on the redistributing moments that were applied to the foundations. The applicability of this equation depends upon the flexibility of the foundation."

Then further he said:

> "A: Yes. If the shoe box was perfectly rigid then it doesn't matter where you twist it will, as the Defence rightly puts it produce a uniformed effect that way as well, at the same time it is tilted this way too. If you can think of the head house wrenching this way it will turn it like this. (demonstrating)."

Bear in mind that there is evidence that the silos were rigid and that the formula was appropriate for flexible foundation. This answer under further re-examination by Mr. Mahfood seems remarkable:

> "... I was looking for something in between that was consistent with what had been done before, and so I chose this value of redistribution on the part of Zetlin-Argo. It would be necessary to review the stiffness of the foundation in order to determine where the true stresses lie between the two extremes, a rigid and a very flexible foundation. Zetlin-Argo's equation provided values which are close to the rigid end but that is not something that I had in fact had the information to do; I did not have the information about the values of the stiffness of the foundation, it all depends upon that."

(a) How did Panton J treat the evidence of Professor Sparks?

(b) What ought to be the outcome of the grounds of appeal on this aspect?

The learned judge below had this to say of Professor Sparks:

> "... He was clearly a witness on whom I could not rely so far as proof of the plaintiff's case is concerned. Why would a learned professor use a formula that he does not know to arrive at figures that are of vital importance to the plaintiff's case?"

It was not necessary for the learned judge to add that the Professor wished to deceive the court. However, having regard to the extensive extracts adverted to on the whole, I am in agreement with the learned judge. Mr. ChinSee for the insurers submitted that since the unknown formula relied on by Zetlin Argo and Professor Sparks was inapplicable then the plaintiff's case was not proved. They had failed to prove that there was greater pressure in the southeast than the southwest. It was not necessary at this stage to decide whether the whole appeal fails because of Professor Sparks..

However, the appellant realised that "matters relating to wind" was the main subject matter of this litigation. So ground 22 is presumably the principal ground of appeal. It reads thus:

> "22. The Learned Judge erred in relying on the testimony of Mr. Minor in commenting on the testimony of Prof. Sparks, since:-
>
> i. Mr. Minor is not a Wind expert, and not "properly" qualified to express an opinion as a wind expert, where-as Professor Sparks, based on his work done in investigating hurricanes, Diane, Elaine, Hugo and Andrew, is arguably the leading expert in the world in the specialized area of hurricanes and the effect of hurricanes on structures.
>
> ii. The Defence had a fully qualified wind expert, Professor Lawson, who prepared the report on which the Defence relied and who was in Court and listened to the testimony of Professor Sparks. He was not called to testify. The inference is clear. Professor Lawson was not in a position to challenge the expert testimony of Professor Sparks. The Learned Trial Judge's reliance

on Mr. Minor in matters relating to wind, which is the main subject matter of the litigation, is clearly misconceived."

With respect to learned counsel for the appellant it was the probing cross-examination which made Professor Sparks' evidence unreliable. In formulating the questions put to Professor Sparks, counsel no doubt consulted Professor Lawson. If the insurers judged that they had effectively advanced their case after cross-examining Professor Sparks, it cannot be a ground of complaint that they did not call Professor Lawson.

The other grounds of appeal relating to Professor Sparks' evidence are 7, 8, 9 and 40 which read:

> "7. The Learned Judge erred in finding that Professor Sparks, whose distinguished achievements are a matter of record, 'wished to deceive the Court' because 'he used a formula that he did not know to assist him in determining the distribution of stresses, and in arriving at the soil pressures that he gave ... to arrive at figures that are of VITAL importance to the Plaintiff's case.' The facts are that Professor Sparks reasonably and sensibly used the formula used by Zetlin-Argo, and that there is abundant evidence in the record to justify the use of the formula. It is unreasonable, unfair and unwarranted to conclude that Professor Sparks 'wished to deceive the Court' because he used the formula.
>
> 8. The Learned Judge erred in finding that Professor Sparks 'simply returned on the morning of the 16th and gave what he must have known was a worthless opinion.' His finding is an unreasonable, unfair and unwarranted interpretation of a simple incident in which a witness made an obvious

error and through his Counsel, sought and obtained the leave of the Court to correct the error. Furthermore, there is no evidence whatsoever to support the conclusion of the Learned Trial Judge that in making the correction on a technical engineering issue, Professor Sparks expressed 'a worthless opinion."

9. The Learned Judge came to an unreasonable and erroneous conclusion on a matter which, in the words of the Learned Judge, was of 'Vital importance to the Plaintiff's case,' namely, the soil pressures exerted by hurricane Gilbert. The erroneous conclusion of the Learned Judge is that, 'Professor Sparks' calculations produced significantly different figures from those calculated by Zetlin-Argo and set out in fig. G23 of Exhibit 10 ...' There is no evidence whatsoever to support the conclusion of the Learned Trial Judge that Professor Sparks' calculations produced 'significantly different' figures from those produced by Zetlin-Argo. Furthermore, his finding is contrary to the evidence and indicates that he misunderstood the evidence.

...

40. The Learned Judge erred and misdirected himself on the meaning, purpose and effect of the critical testimony given by Professor Sparks."

Having regard to the analysis of the evidence on this aspect of the matter, to my mind these grounds of appeal are not successful.

(IV) Did Gilbert cause the differential settlement in the southeast under the bank of silos as JFM alleged and sought to prove?

It will be recalled that Professor Sparks stated that soil characteristics changed as it was very sensitive to where it was loaded. JFM contended that the differential settlement of the soil in the southeast corner of silo bank caused the differential twist. This was the basis of the theory of locked in forces which cracked the haunch and caused the rupture in silos 10 and 18. The evidence of the wind expert ought to have an important bearing on the outcome of this case. However, the evidence of Professor Sparks, the wind expert, did not help Zetlin Argo's case. In fact, he stood it on its head. What must be grasped at the outset is that the pressures relied on by Dr. Oweis, the soil expert to estimate the settlement of the soil under the bank of silos was calculated by Zetlin Argo, or alternatively by Professor Sparks. The findings so far was that the method relied on to compute the wind pressures of Gilbert was flawed. A fair conclusion would be that Dr. Oweis' evidence might also prove unhelpful to JFM. Professor Sparks used an unknown formula. Dr. Oweis relied on pressures although he did not know how they were derived.

What was Dr. Oweis' special expertise? Extracts from his evidence are pertinent to understand its significance. Here is how it commenced:

> "A: Yes. I acquired a PH.D. in Civil Engineering from the University of Texas in 1968. Before then I finished my undergraduate in the Middle East and since 1968 I have been practicing Civil

> Engineering and Technical
> Engineering in the United States."

He expanded on this in the following way:

> "Q: Have you been an Adjunct Professor of Civil Engineering since 1984 at the New Jersey Institute of Technology?
>
> A: That is correct.
>
> Q: Could you tell us what subjects you teach there?
>
> A: I have been teaching Soil Dynamics courses and Foundation engineering.
>
> Q: Were you the visiting lecturer at Rutgers University in the spring of 1991.
>
> A: Yes. For the past twenty-five years or so my experience covers essentially technical engineering practice as related to the design and construction of civil structures such as buildings, highways, tunnels, dams. A part of my career concentrated also on earthquake engineering and environmental geotechnology with respect to the management of hazardous waste and solid waste."

So the aspect of his expertise pertaining to soil dynamics and foundation engineering ought to have been most helpful in the court below.

One compelling criticism made by Mr. Mahfood of the judgment below was that there were few references to the evidence in a case which lasted 76 days. This led to the fundamental point, he continued, that there was no adjudication in the court below. Further, he complained that Panton J had asked for written addresses and there was compliance. Despite that, Mr. Mahfood contended there was no reference in the judgment to his address which made direct reference to the evidence. It was because of that approach, it was submitted, that the learned judge did not evaluate the evidence. These complaints were encapsulated in grounds 2, 5 and 43 which read as follows:

> "**2.** The Learned Judge erred in failing to properly address and determine many of the critical engineering issues in the light of the evidence and, instead, merely recited and commented on portions of the evidence without evaluating the evidence for and against the issue or coming to a decision on the issue.
>
> ...
>
> 5. The Learned Judge erred in his lengthy Judgment in completely ignoring and disregarding the Plaintiff's written submissions, which were prepared at the request of the Learned Judge, and which set out clearly and precisely the critical engineering issues, the Plaintiff's submissions on those issues and the <u>relevant evidence to be found in the verbatim transcript of seventy-six days of hearing and ninety-eight exhibits.</u> (hereinafter referred to as "Plaintiff's submissions")."

This ground was repeated in a different way in ground 43 thus:

> "43. The Learned Judge erred in referring to portions of the testimony given by the Plaintiff witnesses without citing the testimony but instead, summarizing the testimony inaccurately and criticizing the testimony without any proper evaluation in terms of the critical engineering issues."

It was admitted that this court being one of rehearing, it could do what the learned judge allegedly failed to do. Because there might be some merit in these complaints I have attempted to repair the breach by showing throughout how the evidence emerged. If the learned judge's order is affirmed there ought to be no further complaint that the basis of adjudication was not amply demonstrated. It is an exhausting exercise but probably essential.

The learned judge anticipated that his approach was open to criticism. He said:

> "...Even if there was the intention, it would be impossible and undesirable in this judgment to quote most of the evidence given at the trial. After all, the notes of evidence occupied over six thousand typed pages measuring generally 14 inches in length and 8 1/2 inches in width. It is therefore proposed to make reference basically to those major areas of the evidence that go to the root of the issues for determination."

To my mind, it was neither impossible or undesirable to make necessary references to the evidence. It is a matter of style. However, the learned Judge's approach is permissible especially since he has mastered the difficult art of précis.

Apart from his competence as a civil engineer, Dr. Oweis was a specialist in geotechnical engineering. His report and the terms of reference were to:

> "A: ... evaluate the settlement that I was charged with predicting and evaluating before hurricane Gilbert and after hurricane Gilbert.
>
> Q: Now there is a statement there in the

second paragraph:

> The results of a nonlinear analysis have shown that under the hurricane loading substantial differential would occur."

Dr. Oweis explained the linear approach thus:

> "A: We started our analysis with a linear approach. The linear approach in simple terms assumes proportionality between load and deformation, which means, if you double the load you double the deformation, or you double the load you double the strain, and because of the nature of the loading which is high load especially during the hurricane and also the proximity of the foundation of the silos to the edge of a steep slope which is now and has been about 45 degrees one on one - 45 degrees - and because of all these conditions we concluded that. ...
>
> A: ... we concluded that a nonlinear approach is quite necessary and without it no realistic assessment of the settlement could be considered rational. That is what I mean by a nonlinear approach."

But the steep slope which contributes to the differential settlement was measured by means of an inclinometer by the insurers' expert, Mr. Minor. He got a figure of 290 or 30 degrees, depending from which vantage point, which coincides with the measurement he derived from calculating the slope from the design drawings. This difference between a measured 30% and an estimated 45% is striking.

Be it noted that Dr. Oweis must have relied on the flawed figures of Dr. Zetlin or Professor Sparks for his statement of high loads during the hurricane. The acceptable evidence will show that silos 10 and 18 were empty during the hurricane and the wind released by the hurricane did not produce as much pressure as normal loading and unloading of silos. The following passage from the evidence in chief of Mr. Minor, the structural engineer, for the insurers, shows the typical pressure of the grain in contrast to that of Gilbert. This is the passage:

> Q: Now, did you calculate any horizontal pressures due to grain in '88?
>
> A: Yes, I only looked at typical values of grain and I only did the calculation in static stage in '88 and using that value I found the silo according to my calculation was unsafe and I did not take the matter any further.
>
> HIS LORDSHIP: You found what?
>
> A: Because I found the structure according to my calculation was unsafe.
>
> MR. GEORGE: What horizontal pressure of grain did you use?
>
> MR. MINOR: I used only the one value which came out at the 500 pounds per square foot.
>
> Q: The same as Zetlin Argo?
>
> A: Yes.

Q: Could those pressures in the silos have been greater than you calculated?

A: Oh, of course.

Q: Those were typical values that you have used?

A: Yes, I said it's typical and I said in the calculations that it was typical.

Q: Did you consider the effect of Hurricane Gilbert?

A: Yes.

Q: Did you calculate any pressures on the walls of bins 10 and 18?

A: Well, from Hurricane Gilbert, yes. Yes, I think I did it twice. On one occasion I got 80 pounds per square foot and another occasion I got 120 pounds per square foot.

Q: What conclusion did you come to as a result of this calculation?

A: It was a very small number compared with the 500 which was typical. I was comparing extremes of 120 with a typical of 500.

Q: Five hundred what?

A: Pounds per square foot.

Q: Due to?

MR. MINOR: A: Grain. so an extreme wind load of 120 pounds per square foot is against a typical grain load of 500 pounds per square foot. It seems okay to me that the hurricane was not going to do any damage for that reason, and don't forget that the silos didn't have any grain in them; those two silos didn't have any grain at the time of the hurricane. What I am trying to say is going back to the point I made this morning about design. If I were designing those bins I would add that 120 to the 500. Although 500 is a low value it would be higher anyway.

Q: You have taken it into account?

A: I would have.

Q: You would have taken into account the supposed impact of the hurricane?

A: Yes."

As for the specific work done by the insurers in this area of geotechnical engineering, Dr. Oweis commented thus:

"Q: Now you are aware that a company has put in a report - Engineering Geology Limited - did a number of analyses.

A: Yes, I am aware of it.

Q: And you are aware of Strucom - a company called Strucom, did a number of computer analyses. You are aware of those analyses by Strucom?

A: Yes, I am aware of them."

Continuing the examination in chief, Dr. Oweis informed the court of his knowledge of the work done by Strucom:

"A: Strucom stated that they did linear analyses which means they assumed linear soil properties.

Then he directed his attention to Engineering Geology:

"Q: What about Engineering Geology Limited?

A: Engineering Geology started in 1989 with a linear approach which is, utilizing springs, elastic springs to characterize the soil. However, in the second set of analyses in 1993 they have adopted a non-linear approach."

JFM founded a ground of appeal on the basis that although the insurers had experts on soil analyses, they were not called to refute Dr. Oweis. That ground reads as follows:

"21. If the Learned Trial Judge had properly addressed and determined the engineering issues described in para. 20 above, he could have come to only one reasonable conclusion, namely, that Mr. Minor's approach in computing settlement by using <u>'actual grain loads'</u> distinct from <u>'average grain loads'</u> and in using the <u>'linear'</u> method of analysis, as distinct from the <u>'non-linear</u> method was wrong, for the following reasons:

i. The only fully qualified soil expert to express an opinion on these critical issues related to soil mechanics was Dr. Oweis, who gave clear, logical and reasoned testimony on the issues.

ii. During the course of Dr. Oweis' testimony, the Defendant had, present, in court, a fully qualified soil expert from their consultants, Limited, in addition to Mr. Minor, who is <u>not</u> a soil expert.

iii) The Defence failed to call their soil expert to challenge the clear and precise testimony of Dr. Oweis. The inference is clear. The Defendant's soil expert could not provide testimony to challenge Dr. Oweis.

iv. The Testimony of Mr. Minor, who is not a soil expert, and not 'properly' qualified to express an opinion as a soil expert, could not properly be accepted in preference to the clear, logical and reasoned testimony of Dr. Oweis."

This ground can be given short shrift. In the first place the onus was on JFM to establish on a balance of probabilities that the differential settlement estimated by Dr. Oweis was correct. In the second place, if the insurers challenged Dr. Oweis' evidence and proved it to be faulty, then JFM would have failed to adduce satisfactory evidence. In the third place, the principle challenged by the insurers on this aspect of the case was that Dr. Oweis made no enquiries to ascertain the basis on which either Zetlin Argo or Professor Sparks calculated the pressures which he used to estimate the settlement. Panton J found for the insurers. On this point it is necessary to examine later the basis for that finding. It is sufficient at this stage to say that this ground of appeal fails.

From the outset Dr. Oweis explained the restricted nature of his terms of reference. He was an evaluator of the differential settlement. Those settlements were a result of factors which he listed thus:

"A: As I testified earlier, the purpose was to evaluate the settlements due to both

> sources; source one, which is dead plus grain load of structure, that is the silos, and source two is the load or the pressure imposed by the hurricane on the foundation, and we prepared a report. This report summarises the settlements under different loading conditions."

In giving his opinion on the analysis of the soil, Dr. Oweis rejected the method of linear analysis as inappropriate for the condition of the soil on which the silos rests. He stated it thus:

> "A. Yes. As I testified earlier, lacking any data we started with linear analysis to get a feel for the problem. In this type of analysis you come and assume a loaded area, calculate stresses and knowing the modulus, the compressibility of the soil based on the Standard Penetration Resistance, the empirical correlation's ..."

The appropriate course he contended was to rely on non linear constitutive laws. The reference was in the report which reads:

> "Evaluation of settlements
>
> Settlement analyses were conducted using both linear and non linear constitutive laws."

And then the next paragraph:

> "The elastic linear analysis described above is accomplished by computing the stresses and then the strains and deformations utilizing the deformation modulus and thickness of various layers. Neither the rigidity of the mat nor the nonlinear behaviour of the soil is accounted for. For this reason, it was necessary to select a model that accounts for the nonlinear soil behaviour and the rigidity of the mat."

That reliance was placed on loads or forces compiled by Zetlin Argo and Professor Sparks was elicited from the following answer:

> "So that as far as describing the soil is concerned we input all these parameters into a two dimensional finite element nonlinear model and you apply the load given by the structural expert and you basically calculate deformation or settlement."

So important was that aspect of the case, that Panton J intervened and the following encounter took place:

> "HIS LORDSHIP: You applied the load supplied by the structural expert?
>
> A: By the structural expert.
>
> HIS LORDSHIP: And then what?
>
> A: And then calculate the settlement."

Then follows a long extract which is quoted in full because it shows how Dr. Oweis calculated the settlement using the dead load, the live load and the wind load given to him by Zetlin Argo and Professor Sparks:

> "Q: Now the next paragraph:
>
> Several foundation loading conditions, as provided by Zetlin Argo Structural Investigations, Inc., were investigated. The distribution of these loads for 100% dead load plus live load is shown in fig. 6(a) and the wind effect in fig. 6(b). The uplift stress on the windward side was

neglected since the soil rebound is negligible based on high unload modulus.

Would you explain that to us?

A: Yes, if you look at fig. 6 ...

A: At page 13. This is a typical illustration of how these pressures were calculated and used in the analysis. The upper figure, which is fig. 6(a) shows the mat which has a dimension of 135 ft. by 54 ft., loaded with load intensity or pressure of 6.38 kips per sq ft. That is not shown on the figure but this is the pressure, not the load - 6.38 kips per sq. ft. This represents, according to my Report, the dead load of the structure which is the weight of the concrete plus one hundred percent of grain load. Later I learned that it is not really one hundred percent of grain load, it is only 85 percent, but at the time I prepared this Report I was told that this was the pressure refers or represents one hundred percent of grain load.

Now this is calculated settlement based first on the dead plus live load as shown in this figure, and because of the nonlinear nature of the program you apply this in several increments. Then after that you see on the lower part of the figure the hurricane load is included and as you can see, the hurricane load theoretically would produce compression on the south-east and tension or uplift on the north side.

However, only the compression side is shown on this figure because we made the premise that after the soil has settled under the dead load and live load, if that load is then reduced because of the wind the footprints would remain the same, the rebound is very small. We made that premise so it was not important to consider the unload."

Continuing Dr. Oweis said:

> We made the premise that the unload of the soil because of the nonlinear nature of the soil is very, very small. So we take the compression, in this case 3.77 kips per square foot in the south east corner and added this load to the model pressure and you calculate additional settlement. So you have two settlements: one due to the historic dead plus live load and the various scenarios, one hundred percent of live load, 90 percent, 70 percent, whatever. You do these calculations and then you add the effect of the wind and based on that we prepared an appendix covering all these cases and from that appendix we showed some cases on Table 2.

Dr. Oweis had an important statement to make concerning the rigidity of the mat and the inapplicability of linear analysis in this case. Here is how it was stated:

> "A: As I mentioned before, the question of the rigidity over the mat could not have been accounted for the linear analysis but with FECON you could input the mat as a

> discrete layer of concrete so you could account for the rigidity of the mat. We did the analysis for two foot concrete which is the actual physical thickness of concrete supporting the silos. In order to assess the effect of increased rigidity either due to the tunnel or due to the superstructure we repeated the analysis with four foot concrete. We did the analysis also with eight foot concrete just to account for possible increased rigidity and we did not see any difference in the result between two foot and four foot concrete and therefore, the solution for two foot concrete is applicable.
>
> Now the technical reason why the two foot concrete was similar to the four foot concrete is that the behaviour - the rigidity of the system is really a function of the ratio between the rigidity of the structure to the rigidity of the soil. For example, if you have a very stiff structure on rock and very stiff material the structure will behave in an inflexible (sic) manner, but if you have not too stiff a structure or even a stiff structure on soft soil it would behave as a rigid structure.
>
> Now the reason why our two foot mat or four foot mat behaved as rigid structure and was compatible with rigid behaviour was that the ratio of the mat and the rigidity of the soil was high because of the nonlinear nature of the soil. The model of soil has deteriorated during loading and that is why the effect of nonlinear behaviour is very important and that is why linear behaviour does not model the physical situation of how the soil behaves."

The differential settlement estimated by Dr. Oweis in the southeast corner in which silos 10 and 18 were situated was explained thus:

> "Taking the lower case: dead load plus 100 percent live load - and reading from left to right you see under that dead load, for example, settlement under Point 1 at the south west corner - 4.2, and then due to the hurricane it jumped to 5.3. At point 4 which is the south east corner it was 4.2 before the hurricane and it jumped to 7.02 after the hurricane."

Then he reiterated:

> "You see that before hurricane settlement at Points 2 and 3, the settlements are 2.93 - they are the same.
>
> Q: So the settlement at the north was the same.
>
> A: And the settlement after the hurricane remained the same because, as I testified earlier, we proceeded with the premise that the unloading the soil would not rebound or would rebound very, very little indeed, and that is why the historic settlement would not have changed after the hurricane; that is why the numbers are the same.
>
> Q: What about the second one, Differential Settlement - before September 12 and after September 12, what does that show?
>
> A: The second portion of the Table shows the differential settlement between, or the difference in settlements between the respective points. If you take, for example, Points 1 and 4 before the hurricane, and because the soil profile used was the same in the analysis, you see the differential settlement was zero - 4.2 minus 4.2 after the hurricane for the last case to be consistent. You see that before the hurricane again it was 4.2 and after the hurricane the difference between 7.02 and 5.3, which is

1.72. So that is the difference in settlement which we call differential settlement."

Dr Oweis and the unknown formula

It will be recalled that Professor Sparks relied on the unknown formula used by Zetlin Argo to compute the soil pressure due to wind load. Further it was stated that the formula was appropriate for flexible structures. Dr. Oweis also relied on this formula. As it forms an important part of JFM's case, it is essential to examine Dr. Oweis' approach. He said:

> "A: The formula is really an axiom in calculating soil pressure, so I use it all the time, I have to agree with it.
>
> Q: Have you done a simple calculation on a sheet to prove the correctness of the formula?
>
> A: Yes, I derived the formula basically.
>
> Q: Do you have that sheet with you?
>
> A: I have it in my notes."

A cardinal feature of JFM's case was that the pressures relied on by Zetlin Argo and Prof. Sparks were the same although their approaches were somewhat different. Here is how Mr. Mahfood for JFM put it:

> "M'lord, the purpose of this is to show that the settlement is the same under Dr. Zetlin and Prof. Sparks - the settlements are the same, and that has been my case all along from day one and still is."

The insurers however contended that the method used by Dr. Zetlin and Professor Sparks were flawed and their computation wrong. This was explored by Mr. Vassel for the insurers in cross-examination.

One aspect which must be adverted to is the rigidity of the bank of silos. It was emphasized that the unknown formula was inappropriate because it was applicable to flexible foundations. So it is pertinent to see what Dr. Oweis had to say on this aspect. Here it is:

> A: My comment really is very simple. I have already stated it, the behaviour from a soil structure interaction problem, what controls the behaviour as far as rigidity of the structure to the rigidity of the soil. So even if you have a very, very stiff structure on dense soil, on stiff soil like rock, the structure would still behave in a flexible manner. But if you have a structure on soft soil where the ratio of rigidity is large the structure would behave in a somewhat rigid manner."

Then he concludes:

> "... So rigidity is achieved whether by us or Strucom but for different reasons."

In the forefront of their attack on Dr. Oweis, the insurers allege that he failed to ascertain how the pressures he relied on were computed either by Dr. Zetlin or Professor Sparks. It was from these pressures he estimated the differential settlement. The insurers contended he acted as a mere technician rather than a professional man who knew how the data he used was derived. That contention was based on the following passages:

> "Q: Can you tell us what is load and what is pressure?
>
> A: Yes, if you take an area like this and I put my hand like this (indicating) the force I am exerting with my hand on this block is the force which is the load but if I divide this load by the area of this block the resulting number would be the pressure which is the load per unit area.
>
> Dr. Oweis: Yes, what I was starting to say, I don't believe that there is a standard form but in many cases -- in my practice I take the total load and compute my pressures to estimate settlement. In this case, however, I was given the pressures."

Dr. Oweis was pressed and the following answer emerged:

> "Q: So that in this case, the expression that has come out in this case, the engineering judgment of Mr. Cader intervened between the loads and the settlements that you eventually arrived at. It was Mr. Cader who from the loads derived the pressures and then gave that to you, am I correct?
>
> A: That is correct, he gave me the pressures; the way you state it is correct."

It was against this background that Dr. Oweis was asked:

> "Q: I want to just put it to you straight, Dr. Oweis. Is it not correct that for this formula to apply, at least two conditions must exist, one that plane sections remain plane and two, that the soil is linear elastic.
>
> A: The first condition is probably correct because when you analyse the bending in the beam, the beam in the building you make that assumption, that is an assumption we always do, but the second one is incorrect

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> because this formula is derived based on statics, it has nothing to do with soil properties; even if there is no soil here, concrete or steel or whatever, rubber for that matter, the formula does establish conditions of equilibrium which means the summation of these pressure distributions under the mat must be equal to the vertical loads and secondly, the moment at any point, the active moments causing rotation of the mat must be equal to the existing moments caused by the soil pressures, that is all that this formula does, it is simple statics."

A significant answer to my mind was clarified perhaps unwittingly in the following terms:

> "A: Thank you. If I understand Dr. Sparks' testimony - and correct me if I am wrong - he advised that torsional forces do not produce vertical forces, and if you are given a problem, a foundation mat on elastic or soil has half space and you apply torsion, it would not produce vertical forces. The only way torsion could produce a vertical force is if you have a secondary vertical force, which means if the mat is connected to a wall, for example, or some inclusion, and that wall is supported to a footing to maintain equilibrium then some vertical forces would have to generate, but in general if you have a mat on the top of the soil profile a torsional force does not provide vertical forces because you have pure shear."

So if the torsional forces of Gilbert did not produce vertical pressures how could it create the alleged additional vertical pressure which accounted for the computed differential settlement in the southeast? On this aspect the insurers have succeeded in gaining an admission from one of the principal witness for

JFM that the unknown formula was inappropriate so it follows that the estimates of the settlement must be flawed.

There was another aspect which the insurers submitted was flawed. The total torsional effect they argued was anti-clockwise so calculation of pressure whether by Dr. Zetlin or Professor Sparks which relied on a clockwise effect of torsion must be flawed. That situation emerged from the following exchanges:

> "... tell me whether you agree with him - recognized that on this page prepared by Mr. Cader, the total torsion including that due to the head house as shown here is being represented as clockwise and proceeded to do a whole host of calculations based upon that; whether in fact and as Dr. Sparks recognized, total torsion is anti-clockwise; would you agree with Dr. Sparks?"

Bearing in mind Dr. Oweis was a civil engineer specializing in geo-technical engineering, the following answer makes his opinion suspect, the answer was:

> "A: I have not studied that in detail. All I was interested in is the soil aspect - all that I was interested in were pressures.
>
> I took these pressures and did this analysis, and again this was my main interest, regardless of who is right or who is wrong, but I have a strong opinion."...

The following answers were revealing. It was difficult in the face of them for JFM to persuade Panton J to accept this evidence to satisfy on a balance of probabilities. The answer would not be odd coming from a mere technician but from an expert it displays a lack of curiosity about his subject:

> "Q: You didn't see this point about the direction of the total torsion in the testimony?

> A: I must have read it but it didn't trigger any interest on my part. I was interested in the final pressures."

So it is fair to conclude that at that stage no reliance could be placed on the settlements estimated by Dr. Oweis. The foundation for his estimates was unknown to him and he therefore could give no explanation to the court as to how they were computed. There was no basis on which he could have been cross-examined on the pressures he had used. It is questionable if Dr. Oweis' evidence was of any value.

Dr. Oweis further on (a) the pressures generated by a horizontal wind load (b) the loads on the day of Gilbert

This question was put to Dr. Oweis:

> "Q: And I will put a general proposition to you to see if you agree with me. Is it not the case that a horizontal wind load alters the distribution of vertical pressures under the silo mat but does not alter the total vertical load?
>
> A: The total vertical load would have to be the same for equilibrium for the same reasons I stated before.
>
> Q: So that you agree with me?
>
> A: Yes."

Since it was the additional pressure of Gilbert which JFM alleged caused the differential settlement the following answer seems to support the insurer's case that Gilbert had nothing to do with the collapse of the silos a fortnight after Gilbert:

> "Q: There is no additional vertical force due to the wind?
>
> A: Due to the wind, yes; there is a couple which is moment, there is irritation but not net, one cancels out.
>
> Q: Additional vertical force due to wind?
>
> A: That is correct.
>
> Q: Now, your figure 6B, Dr. Oweis, do you agree that this only shows an increase in the pressure due to wind but no countervailing reduction?
>
> A: No unload; you mean no unload due to the wind?
>
> Q: Yes.
>
> A: If that is what you mean, yes.
>
> Q: Surely -- when I say no countervailing reduction that is what I mean, no unloading.
>
> I am just telling you because you said if that is what I mean.
>
> A: That is correct."

The dangers of not being curious or concerned about the loads he was given were apparent in these answers by Dr. Oweis:

> "Q: It didn't strike you as odd that in relation to one day, namely day of Gilbert, you were having 8 different dead and live load cases - it didn't strike you as odd, if it did not you can tell me.

A: It didn't strike me as strange."

Since JFM's case was that dead load, live load, and the extra wind load on the day of Gilbert caused the differential settlement which caused the differential twist and which resulted in destructive locked in forces, then live load and wind load on the day of Gilbert must be important. It is on this aspect, that this question was put to Dr. Oweis:

> "Q: In fact a question which is outstanding to be answered is whether in selecting the ones to go into the main body of the report you would not seek to select those which would represent-as closely as possible represent the actual loading condition on the day of Gilbert?"

The answer ought to be instructive for the onus was on JFM to prove its case on a balance of probabilities. Here it is:

> "A: Allow me to answer your first question, the basis for Table 2, what Table 2 is all about. As we discussed before Dr. Zetlin sent certain pressure diagrams, 100% plus dead and live load, 90%, 80%, 70%, etc. etc, so I took those loads, each one of them, we said that those loads are effective loads that caused soil settlement prior to Hurricane Gilbert, then we added the wind load and computed the final settlements. Now the actual loading at the time of Hurricane Gilbert was not really a factor in my settlement analysis because the soil had settled already due to the historic - you can laugh if you want but that is okay - the soil had already settled due to the historic load before Gilbert, but you asked the question if any of these loadings corresponds with the actual load at Hurricane Gilbert. I can answer that by saying if Hurricane Gilbert, dead plus live load is 5.3 or 5.4 kips you

> could pick a case here which corresponds with that out of case 8. Case 8 has something which is very close to the actual dead plus live load at the time of Hurricane Gilbert, but that was not my intention of putting that case."

In explaining his position Dr. Oweis said:

> "A: It doesn't matter what dead plus grain load at the time of Gilbert, the wind load matters, but all that I am saying, M'Lord, is that the soil ..."

He continued thus:

> "A: Whatever the actual grain load, whether 10%, minus something, it has no effect on my settlement because the soil has already settled and the historic grain load..."

Further he said:

> "A: The mat is somewhat rigid. The concrete is still there but the soil has been subjected to so much load in the past, it has settled on that load, and that is all what I am saying. It is very very simple, but If you ask a general question: Is there any of these loading conditions at the time of Hurricane Gilbert I could pick one of them which is close."

When it is recalled that silos 10 and 18 were empty on the day of Gilbert and Dr. Oweis agreed that more load, more settlement, the above passages did not help JFM's case.

Dr. Oweis on measurement of the foot print and loading caused by Gilbert.

It was conceded by Dr. Oweis that the footprint for the silo bank had not been measured but that it could have been. Here is how Dr. Oweis said it could be done:

> "A: In theory yes, it could be; if you have markers before construction on the foundation from ground zero and then you come after so many years and measure the new configuration, then you would actually measure exactly how much settlement has occurred."

As for how it is determined. The following passage states:

> "Q: It is a matter of interpretation?
>
> A: ... nobody measured the settlement, I repeat my answer; nobody measured the settlement to my knowledge.
>
> Q: And it depends upon the engineer's assessment - first of all, it depends upon the reliability of the data that is given to the engineer.
>
> A: Yes."

One important aspect of the case for the insurers was put to Dr. Oweis. It elicited an answer which was favourable to the insurers. The encounter ran thus:

> "Q: Perhaps you can agree with me on this, Dr. Oweis: An analysis which proceeds on the basis that the footprint, historic footprint is caused as far as live load is concerned, the historic footprint was caused by a live load - an average live load per silo of 725 tons, would have underestimated the

true footprint if indeed the silos had a capacity quite a bit more than 725 tons and in the past they have been loaded fuller than 725 - or more fully.

A: I agree with you, Counsel, on one which is fundamental: more load causes more settlement. So if the historic footprint I used, which is 6.38, and it was 725 tons whatever you call it, so the 6.38 is less than the actual footprint pressure then my settlement would be less. I agree with you a hundred percent.

Q: More load causes more settlement.

A: Absolutely."

The imprecision of Dr. Oweis' analysis as presented in his report was tested and the following passages illustrate a telling point in favour of the insurers. They run as follows:

"Q: So we are not, in terms of your footprint from your case 10 load, we are not only talking about an underestimation because of the tonnage that that case load represents but we are also talking about the underestimation of your footprint due to the fact that it is not based upon the worst, or upon some other worse loading cases, for example, that one which you so kindly told us about in evidence and which your exhibit - you have proven in fact in Exhibit, just to remind you ...

A: I remember it, Counsel.

Q: Exhibit 54 --- sorry, what is your answer?

A: Well, you cited by analysis, that that analysis was made to investigate one point that is, if during the historic loading silos were loaded eccentrically that means, the southern two silos are full and the north row is empty at least in theory the southern portion would be subjected to the dead plus live load plus one-third of the live load. That is my analysis, yes, I did that.

Q: And your footprint, case 10, does not take into account that kind of case?
A: No, it does not.

Q: If it did take it into account the footprint would be more.

A: More settlement?

Q: Yes.

A: Yes, indeed."

Here is how the differential settlement of 1.72 was computed:

"Q: Dr. Oweis, would you go back to your Table E-1, please, case 10, Exhibit 20.

A: Yes, Mr. Vassell, I am looking at E-1.

Q: Case 10, I want to ask you about case 10. Am I correct, am I not, that the settlements which you calculated at the south-east and south-west corners were based upon pressures of 8.07 at the south-west and 10.15 at the south-east? 8.07, that is, 6.3 + 1.69 at the south-west.

A: Are you referring to case 10?

Q: Yes, please. I can just run it through: 6.03 + 1.69.

A: At the south-west corner it is 8.07.

Q: And at the south-east it is 10.15.

A: 10.15, yes, total dead load.

> Q: Thank you. And the differential settlement of 1.72 was based upon those pressures?
>
> A: Differential settlement of what, please?
>
> Q: It is 1.72. On your sheet you have it at 1.69 but what happened is that when you did your summary for Dr. Zetlin you carried the 5.33 forward as 5.30. Let me just show you where that is, Dr. Oweis.
>
> A: It is possible, yes.
>
> Q: Let me show you where it is. I just want to establish it for His Lordship. If you look at your Summary in Exhibit 18, Appendix F.1 - and I am referring to the Summary that you sent to Dr. Zetlin with the letter of May 1989.
>
> A: I know what you are referring to; just give me one second. F.1 3, is that what you are referring to?
>
> Q: Yes. Do you see that you carried forward, or represented the settlement at the south-west to be 5.3 rather than 5.33.
>
> A: That is correct indeed.
>
> Q: And that is how the differential settlement became 1.72 rather than 1.69 as shown on Table E-1. Correct?"

As for the origin of these figures a series of questions were put to Dr. Oweis which culminated thus:

> "Q: And you would be saying to him the differential settlement would be towards the

south-west, you would expect that to be towards the south-west.

A: I would expect that from the pressures you gave me and I would put the results in the Table."

Earlier Dr. Oweis had made the important generalization which runs thus:

"... What I would say is that in general the more pressure you have, the more settlement. So I would have to say with these new pressures the settlement at Point I would be more than what I have shown here. I would say that for sure."

The importance of these generalizations was that the bins that collapsed were empty on the day of Gilbert. The grain load was less than the grain load in the southwest. There was no movement of the footprint before Gilbert, so that the pressure was greatest in the southwest. On this basis the differential settlement ought to be in that area. So Dr. Oweis like Professor Sparks has turned Zetlin Argo's case upside down. How did the insurers manage to do this? To answer that we need to examine how Dr. Oweis was cross-examined when certain figures were put to him. Here is how it happened:

"Q: No, it is alright. Now Dr. Oweis, if instead of the value of 8.07 at Sigma 1 and 10.15 at Sigma 4 you had put in Sigma 1,9.005 and Sigma 4, 8.425.

A: could you allow me a piece of paper, please? sigma 9.005 and Sigma 4, 8.425. ...

Q: What you had was 8.07.

A: At the west?

Q: And 10.15 at Sigma 4.

A: Yes, I am with you.

Q: If these latter figures - 9.005 at Sigma 1, and 8.425 at Sigma 4, were the figures that Dr. Zetlin sent to you than you would get a lower differential settlement - am I correct?

A: I can only say -- I can't say you would get more settlement at point 1 and lesser settlement at point 4.

Q: So the differential settlement would be to the south-west.

A: A differential settlement -?

Q: Would be to the south-west and less than 1.72 - correct?

A: I can't - I am not evading the question but I can hardly make a judgment because of the close proximity of the two pressures, 8.425 and 9.005. I need to know the distribution of the dead plus live load and hurricane load to try to make a guess, but I would concur. What I would say is that in general the more pressure you have, the more settlement. so I would have to say with these new pressures the settlement at Point 1 would be more than what I have shown here. I would say that for sure.

Q: You could not go as far as to say that the differential settlement would not be 1.72 but some lower figure.

A: I would say yes.

Q: And wouldn't you also go as far as to say that the differential settlement would be to the south-west rather than the south-east?

A: That is not what I am not sure of. If you give me the breakdown of dead plus live

> load and hurricane load I would be able to answer more intelligently but I went as far as I can go based on that data you just gave me, Counsel. I can only say more load causes more settlement."

Where did these figures come from. It was brought out in re-examination thus:

> "Q: Dr. Oweis, it is common ground that those figures of 9.005 and 8.425 which were being put to you in cross-examination come from the grain load on the day of Gilbert as distributed in the bins between east and west as well as the dead load, as well as Prof. Sparks' wind load - that is the source of those numbers, that is common ground. It was suggested to you that if you had used those numbers you would arrive at different calculations. What is your view of the correctness of using those numbers for the purpose of your settlement calculations."

Then the encounter continued thus:

> "HIS LORDSHIP: Does it make a difference now that you know the source?
>
> A: Now that I know this source, as I testified earlier on may occasions, in my opinion the only logical way to calculate settlement is to use the historic average dead plus live load of the facility."

The contradiction between this statement and Dr. Oweis' contention that more load, more settlement did not assist in proving Zetlin Argo's case on a balance of probabilities. One of the factors which Dr. Oweis said would determine settlement was the 45 degree angle of a slope near the bank of the silos, but it emerged from cross-examination that the slope was never measured by him and consequently that assumption by the appellant was of no assistance in determining settlement. Since he assumed the 45 degrees in his estimate of settlement, this was a further flaw in his evidence. As adverted to earlier, it was between 27 degrees and 30 degrees when measured.

On the matter of loading, it was the insurers contention that the loads on the day of Gilbert together with the dead load of the structure and the wind load were the relevant loads which would determine settlement. That contention was put thus:

> "Q: Let me ask you first, isn't it a relevant comparison that between the settlement due to average load, that is dead load plus live load, and then dead load, live load and wind; is that not the relevant comparison for the purposes of the comment?
>
> A: The purpose of my comment, Counsel, is, I looked at the final result, the average load, plus wind load."

Dr. Oweis has not given any satisfactory explanation of why the loads on the day of Gilbert did not matter. The explanation that the settlement had already occurred was not tenable in the light of his repeated statement more load more settlement.

One salutary aspect of Dr. Oweis' evidence was that like Professor Sparks, he gave the limitation of his professional work. Here is how it emerged:

> "Q: But when a soil expert put forward a value for settlement - for soil settlement, using the best judgment in the world, he could be wrong about the figure he gets in terms of the physical reality that exists in the soil?

A: That is true; that is why I gave a range of 25% plus or minus to any settlement prediction, just for the same reason you stated. There is no absolute certainty. I make a judgment. I could be wrong either way by 25%"

There was a further explanation:

"Q: So isn't there a view in your field, Geotechnical Engineering, that indeed the 25% margin of error is conservative bearing in mind all of these?

A: No, not really, Mr. Vassell, because there are compensating factors.

Q: Yes, I know, after you take into account everything.

A: And this is based on my engineering experience, 25/30 years of engineering experience, whether I was wrong or whether I was right, that is really my margin of ignorance, if you want.

HIS LORDSHIP: 25%.

A: 25% plus or minus, which means the settlement I predict could be 25% higher or 25% lower.

HIS LORDSHIP: That is what the pollsters call margin of error.

Q: 25% error in the settlement could make 100% difference in the differential settlement, correct?

A: It depends where you apply the error.

Q: Yes, it depends upon where the error is?

A: Yes."

It is difficult to understand how in the face of the evidence of Dr. Oweis, taken as a whole, JFM could expect to prove their case on a balance of probabilities.

How did Panton J treat the evidence of Dr. Oweis?

Panton J was harsh with Dr. Oweis. Here is his assessment:

> "**Dr. Issa Oweis** is quite familiar with the courtrooms of the United States of America as he spends five percent of his working time giving evidence in that jurisdiction. To say he displayed arrogance is an understatement. That fact does not detract from him as a witness as arrogance may well be a virtue in some. However, in addition, Dr. Oweis was rude in his behaviour and responses to learned attorney-at-law for the defence, Mr. Vassell. I found it necessary to look behind his rudeness seeing that his evidence, on the face of it, ought to have been a simple matter. I concluded that Dr. Oweis came to give evidence in one direction only regardless of the questions: and to crudely rebuff anyone who would wish to prevent him from having his way. I found him clearly insincere and dishonest in several of his responses, and as a result I would be most uncomfortable in relying on his word."

The following passages from **Joyce v Yoemans** [1981] 2 All ER 21 at p. 26 are pertinent. Brandon LJ said:

> " It has been suggested in argument, and there is some support for the suggestion derived from *Stojalowski v Imperial Smelting Corpn (NSC) Ltd* (1978) 121 Sol Jo 118 to which Waller LJ referred, that, where expert witnesses are concerned, the trial judge has no significant advantage over an appellate court in forming a correct judgment between

> conflicting views. I do not think that the authority referred to does, or was intended to go as far as that. In my judgment, even when dealing with expert witnesses, a trial judge has an advantage over an appellate court in assessing the value, the reliability and impressiveness of the evidence given by experts called on either side."

Then Brandon LJ continues thus:

> " There are various aspects of such evidence in respect of which the trial judge can get the 'feeling' of a case in a way in which an appellate court, reading the transcript, cannot. Sometimes expert witnesses display signs of partisanship in a witness box or lack of objectivity. This may or may not be obvious from the transcript, yet it may be quite plain to the trial judge. Sometimes an expert witness may refuse to make what a more wise witness would make, namely, proper concessions to the viewpoint of the other side. Here again this may or may not be apparent to an appellate court but plain to the trial judge. I mention only two aspects of the matter, but there are others."

However, to describe an expert witness as dishonest is to use very strong language and it would have been better if the learned judge had used a less offensive word.

The grounds of appeal on this aspect were as follows:

> "4. Instead of properly addressing and determining the critical engineering issues in the light of the evidence, the Learned Judge rejected the plaintiff's case that hurricane Gilbert was the proximate cause of the collapse of silos 10 and 18, because of his unreasonable, unfair and unwarranted

finding that the Plaintiff's expert witnesses, Mr. Cader, Professor Sparks and Dr. Oweis were "insincere and dishonest", "wished to deceive the court" and "did not speak the truth." These findings are not a reasonable or appropriate basis for resolving the very technical and sophisticated engineering issues presented to the Court by highly qualified and distinguished expert witnesses.

...

10. The Learned Judge erred in his conclusion that "Dr. Oweis was rude in his behaviour and responses to learned attorney-at-law for the defence, Mr. Vassell" and therefore "found it necessary to look behind his rudeness seeing that his evidence, on the face of it, ought to have been a simple matter ... I found him clearly insincere and dishonest in several of his responses..." It was the duty of the Learned Judge to carefully evaluate the testimony of Dr. Oweis and this evaluation should not have been linked to or coloured by his perception that Dr. Oweis had been rude to "Learned Counsel." Furthermore, in coming to the conclusion that Dr. Oweis was "dishonest", the Learned Judge made a quantum leap from "rudeness" to "dishonesty". He has also disregarded the fact that the rules of practice under which experts testify in American Courts are very different from the prevailing local practice. His finding of "dishonesty" is unreasonable, unfair, unwarranted and unsupported by the evidence.

11. The observations of the Learned Judge that Dr. Oweis is "supposedly the holder of a Ph.D." is grossly unwarranted and indicates that the Learned Judge failed to assess his testimony fairly and objectively."

To my mind, no reliance ought to be placed on Dr. Oweis' evidence so those grounds have not been successful. As for the other grounds, they are as follows:

> "12. The Learned Judge erred and misdirected himself in citing 'examples' of 'statements' by Dr. Oweis which the Learned Judge concluded 'has seriously compromised his professional standing.' The examples are a loose summary by the Learned Judge of the logical and reasoned opinion lucidly expressed by Dr. Oweis on very technical matters related to soil mechanics. The conclusion of the Learned Judge necessarily involves a finding by the Learned Judge that the expert opinion is clearly incorrect. Consequently, the conclusion of the Learned Judge that the opinion expressed by Dr. Oweis on these very technical matters 'has seriously compromised his professional standing' is unreasonable and unwarranted and not supported by the testimony of any qualified soil expert. It receives support from Mr. Minor only, who is not a soil expert and not 'properly' qualified to express an 'expert opinion' as a soil expert.

Panton's J comment is useful. Apart from his description of 'dishonest response' I endorse it. I would have described the response as "odd" or "surprising". Here is the relevant passage from the judgment:

> "Dr. Oweis, as indicated in the earlier paragraph, is accustomed to using the total load to compute the pressures and estimate the settlement. 'Load,' in the engineering world, includes wind load. Dr. Oweis was not bold enough to deny that. However, when learned attorney-at-law, Mr. Vassell asked him whether it was possible to have a wind load at the southeast but none at the

> southwest, he answered that he was not a wind expert so he could not answer the question. If ever there was a dishonest response, that seemed to me to have been one. It was obvious to me that Dr. Oweis was conscious of the importance of the southeast and the southwest to the case for the plaintiff, and he was not prepared to give any response which might have been unfavourable to the plaintiff.
>
> It seems to me that, overall, Dr. Oweis has seriously compromised his professional standing by some of his statements to the Court. Quite apart from what has been noted so far, the Court has to mention some other examples. He is on record as saying that whatever the actual grain load, it would have had no effect on the settlement determined by him as the soil had already settled before Gilbert. Yet, he agreed that more load causes more settlement. He also said that it wouldn't have mattered if the silos were empty or had air in them as the soil had settled before Gilbert. The wind force, he would have the Court believe, would be the same on empty silos as on full ones as he said that the soil had already settled."

Then grounds 35 and 44 follow thus:

> "35. The Learned Judge misdirected himself on an important fact by stating that "on 25th September, 1988, silo 18 was loaded for the first time in its history." This statement is erroneous and misconceived. It has never been contended at anytime and is <u>not</u> the case that silo 18 was loaded for the <u>first time in its history</u> on September 25, 1988. This gross error made by the Learned Judge would have led him to believe, erroneously, that a fundamentally important event occurred in relation to the operation of silo 18, which failed on the 26th, which event occurred only one day before failure and had

> nothing whatsoever to do with hurricane Gilbert. Furthermore, the Learned Judge's error is relevant to a critical issue in the case, namely, whether in computing settlement, the average historical load should be used.
>
> ...
>
> 44. The learned Judge erred and misdirected himself in concluding that "Mr. Cader combined his experience with his engineering knowledge to arrive at the conclusion that there was uniform settlement before Hurricane Gilbert." The evidence is clear that in matters relating to "settlement", Mr. Cader did not profess to arrive at his own conclusions but relied on the advice of the highly qualified firm of soil experts consulted by Zetlin-Argo."

It is clear from the analysis of the evidence that these grounds cannot succeed. Grounds 10 and 11 require no further comment. As for ground 20, I have addressed the issues and found Dr. Oweis' evidence unreliable. It is helpful to set out this ground in full:

> "20. The critical engineering issues which the Learned Judge failed to properly address and determine in the light of the evidence includes the following
>
> (1). 'The main difference between Dr. Oweis and the defence was in the approach taken - Dr. Oweis favors <u>the nonlinear</u> whereas the defence favors the <u>linear</u> approach. Dr. Oweis dismisses the linear approach as irrelevant.'
>
> (11). 'Dr. Oweis concluded ... The only logical way to calculate

settlement is to use the historic average dead plus live load of the facility.

(111) 'The overall position of Mr. Minor is that the defence has done a more thorough computer analysis than the Plaintiff, as the former has considered all the different effects the foundation conditions would have. Zetlin-Argo also attempted to use average grain loads whereas the defence use the actual grain loads.' "

I found Dr. Oweis' unreliable and this ground strange as the defence relied both on a linear and nonlinear analysis of the soil. The use of the average load to compute the settlement is at odds with the statement "more load more settlement". If an incorrect input is used in computer runs, the output will also be incorrect.

Regarding ground 35, it is conceded that Panton J made an error but that error is no ground for setting aside his order. Of ground 44, it is sufficient that the onus was on JFM to prove differential settlement as they alleged. They failed to prove that ground on the basis of Dr. Oweis' evidence so it also fails. The other relevant ground is 45 which reads:

"45. The Learned Judge erred and misdirected himself on the evidence by stating that 'The engineering Judgment of Mr. Cader intervened between the loads and the settlements that were eventually arrived at.' "

It is difficult to understand this ground since Dr. Oweis admitted he got the pressures from Zetlin Argo. It was common ground that there were several cracks in silos 10 and 18, some of which the evidence suggests were in existence for at least two years prior to the rupture. This evidence from Mr. Minor demonstrates that there was an absence of differential settlement:

> " ... Most failures due to differential settlement cause cracking and do not necessarily, unless they get to a very large degree, cause collapse. It may cause some cracking, yes; whether or not that cracking could lead with the aid of some other outside factor to cause the collapse, that might occur, but the general sign of differential settlement is diagonal cracking and it is one form of cracking I did not see in the silo. I saw vertical cracking, I saw horizontal cracking but I did not see diagonal cracking."

The upshot of all this is that if JFM failed to prove differential settlement, then there could be no differential twist; and no locked in force. The basis of the JFM's case would therefore not be established."

(V) Have JFM failed to exercise ordinary and reasonable precautions for maintenance of the property insured in accordance with the contracts of insurance?

or alternatively

Have the insurers raised doubts as to whether JFM kept the premises in a proper state of repair by exercising reasonable diligence?

As the insurers' case was that the rupture of the silos occurred because of the faulty design or detailing and deficiency in construction, it was logical for them to plead in the alternative, that the collapse was caused by failure of JFM to take reasonable precautions for the maintenance and safety of the silos or carry out reasonable inspection before or after the hurricane as they were obliged to by the terms of the policies.

In this regard it is pertinent to repeat the relevant clause in the insurance contracts which permitted these averments. That for West Indies Alliance reads:

> "4. The Insured shall use all reasonable diligence and care to keep the premises insured or containing the property insured in a proper state of repair and if any defect there be discovered shall cause such defect to be made good as soon as possible and shall in the meantime cause such additional precautions to be taken for the prevention of loss or damage as the circumstances may require."

The relevant clauses for the Lloyd's Underwriters read:

> "4. In every case of loss or damage the Assured must prove that no portion of the loss or damage claimed for was caused otherwise than by the perils specified above."
>
> 5 It is a condition of this Policy that the Assured exercises all ordinary and reasonable precautions for the maintenance and safety of the property insured."

So by the terms of the policies the onus of proof lies on JFM to prove reasonable maintenance while the insurers ought to succeed if JFM did not prove its case.

Since clause 4 of the West Indies Alliance Policy expressly mentions "precautions to prevent loss damage" and the Lloyd's Underwriters "reasonable precautions for maintenance and safety," the concept of factor of safety ought to be introduced at this stage. It was acknowledged on both sides that the silos were not designed to cope with dynamic forces although those forces were consequent on unloading which was a normal function of the silos. To demonstrate that the factor of safety was inadequate for static pressures and even moreso for dynamic pressures, it is best to cite the following extract from Mr. Minor's evidence under cross-examination:

> "MR. MAHFOOD: Q: You arrived at a safety factor of 1.395 and at Sheet 5 you arrived at a safety factor of 1.017.
>
> A: That's correct.
>
> Q: And you believe, Mr. Minor, that that safety factor of 1.017 was correct?
>
> A: Moderately good.

Q: And it is your position, Mr. Minor, that a factor of safety of 1.017 although collapse was possible at any time, and here I sue your words: 'Although collapse was possible at any time' with that safety factor it survived for over twenty years?

A: Yes.

Q: Now, Mr. Minor, this calculation of this safety factor was based, was it not, on the static load and Janssen's Formula?

A: That's correct.

Q: Mr. Cader was cross-examined at great length, and you gave a considerable amount of testimony to establish that the dynamic load during unloading created a much greater force, indeed more than twice the force of static load?

A: Yes, locally.

Q: Now, Mr. Minor, on the assumption that your analysis is correct, that the safety factor with the static load is 1.017, can you tell us what was the safety factor taking into account the dynamic load endured by the structure for twenty years?

A: It would be less than 1.

Q: How much less than 1?

A: Quite a lot less than 1.

Q: It is your belief, Mr. Minor, that this structure survived for more than twenty years with a safety factor considerably less than 1?"

Then Mr. Minor explains convincingly the concept of the factors of safety:

> "A: Yes, but I think you are misunderstanding what safety factor is. Safety factor is a factor of safety; it is not the strength we are considering. We are considering its safety so therefore in considering safety we must consider the structure to be as weak as possible. In other words, we take into account the weakest link as it may - it is only in a chain that the structure is as strong as its weakest link. The structure, same as the three-dimensional structure, is stronger than the factor of safety, and that might explain why it is strange."

What was the significance of the figures derived as regards factors of safety. Let Mr. Minor speak:

> "A: No, I was saying that under average loading the stresses were of an intensity which according to the Code of Practice might have caused the collapse."

Since maintenance for safety is closely connected with design and construction for normal functions without loss or damage, then the factor of safety will be relevant again at a later stage in this judgment.

This issue does not appear to have been adequately debated below nor in this court, but the issue was pleaded and evidence was marshalled. Panton J made no direct finding on it. In those circumstances, this court is empowered to decide the issue even though the insurers did not file a respondent's notice. See paragraph 18(4) of the Court of Appeal Rules, 1962. It reads:

> "18(4) The powers of the Court under the foregoing provisions of this rule may be exercised notwithstanding that no notice of appeal or respondent's notice has been given in respect of any particular part of the

> decision of the Court below or by any particular party to the proceedings in the Court, or that any ground for allowing the appeal or for affirming or varying the decision of that Court is not specified in such a notice; and the Court may make any order, on such terms as the Court thinks just, to ensure the determination on the merits of the real question in controversy between the parties."

For ease of reference it is convenient to set out again the specific pleas of the insurers. They are:

> "(3A) Alternatively, if the Hurricane caused defects in the structure of the silos, which is denied, the Defendants will say that the Plaintiff is not entitled to indemnity in respect of the alleged loss by reason of its failure to take reasonable precautions for the maintenance and safety of the silos or to carry out any or any reasonable or adequate inspection of the said silos after the said Hurricane in breach of Condition No. 4 of the Special Perils extension to Policy No. C1067 and Condition No. 5 of Policy No. 551 FAFR 147.
>
> 3(B) Further, whether before or after the said Hurricane, the Plaintiff failed to carry out any or any reasonable or adequate inspection of the said silos in breach of the aforesaid condition."

By these averments the insurers gave notice that this would be a live issue in the case. A good starting point would be to examine what Zetlin Argo on behalf of JFM adopted as the appropriate function for the silos. Then to examine what they regarded as necessary for maintenance and safety. Also important was how frequent proper inspection ought to take place. It must be recognised that the design and construction of silos is a special field of structural engineering. It follows that inspection for maintenance also requires these specialist skills.

As to function, here is what **Sargis Safarian** a specialist in this field said in an article captioned <u>Avoiding Industrial Bin and Silo Failures September 18, 1975. Plant Engineering</u>:

> " All too often, however, a silo is regarded as a common building structure and is left alone once installed. Yet it is a very special structure, whose design and construction is usually not covered by local or national building codes for conventional structures.
>
> Actually, bins and silos are items of operating equipment, and may be treated as such for tax purposes. And, like other types of industrial equipment, they can break down unexpectedly without proper care.
>
> One important difference between silos and conventional buildings - including warehouses - is in the manner of loading. Ordinary buildings are seldom loaded to their full, rated capacity. Floor loading may change, but usually does not dramatically change stress on the structural components.
>
> But almost all bins and silos regularly carry their full design loads. Full loading is not just a drawing board possibility; it is a normal, expected operating condition. And, some of this full design is in the form of severe dynamic forces which occur when stored material is drawn off."

This article was exhibited by Zetlin Argo as part of their investigation as to the cause of failure. As regards inspection and maintenance, **Safarian** said at the beginning of his article:

> "A SMALL STRUCTURAL DEFECT in an industrial storage bin or silo may easily lead to a serious failure and, in the long run, cause as much harm as a catastrophic dust explosion. Neither problem is uncommon; yet, they can almost always be prevented by a program of careful inspection and maintenance, and prompt attention to necessary repairs."

After discussing cracks Safarian states:

> " A good method of surveillance is marking and dating the end points of cracks and measuring crack widths at marked locations. A record of such observations over several months will show whether or not the cracking is increasing.
>
> Foundation defects (especially those associated with uneven settling) can be quite serious, particularly because so much of the total loading on the foundation is from live load which is repeatedly removed and reapplied."

Here in part is what he said about cracks:

> " Cracks occurring under lateral pressure from stored material may result from (1) faulty design, such as neglecting dynamic and thermal stresses, (2) missing reinforcing bars, or (3) combinations of these factors.
>
> The engineer investigating serious cracking should obtain complete information on actual (not specified) rebar size, spacing, and location, along with actual wall thickness

> of the silo. and, loading and unloading of the structure should be discontinued until the problem has been thoroughly evaluated."

Here is Safarian again in an earlier article of August 1969 under the rubric

<u>Design Pressure of Granular Materials in Silos</u>

> "THE PAST 30 YEARS have witnessed significant advances in understanding the behavior of granular masses in silos. These advances, based on extensive theoretical and experimental studies, culminated in recognizing an urgent need for modifying the Janssen and Airy classic, or Reimbert modern static deep-bin methods to insure the safety and economy of silo structures under actual loading conditions. In this paper a method of silo design is presented which, within reason, will meet this need. This method recognizes the role of dynamic effects. It is based on recent experimental and theoretical works of numerous world-recognized silo authorities and on the Soviet and German silo codes.
>
> There is increasing concern among engineers over the many storage silo failures occurring all over the world. Investigations show that the majority of the silo distresses occurred because operational pressures of the stored material were much higher than the pressures on which the designs of the silos were based."

Then the following significant paragraph of the same article appears in an agreed bundle:

> " Some may argue that many silos designed by Janssen's pioneering method do not show distress. Such successful performance, however, should not be comforting, since it is achieved at the expense of the safety factor. The safety of

> these structures under actual loading conditions may have reached an alarmingly low margin, one which is dangerous and contrary to any applicable code. One should realize that the lack of silo codes and the use of out-dated technical literature do not relieve design engineers of their responsibility to provide adequate safety margins in their structural designs."

This statement by an engineer coincides with principle laid down in **Queensland Government Railways & Electrical Power Transmission Pty. Ltd v. Manufacturers' Mutual Insurance, Ltd.** [1969] 1 LL. Rep. 214. The principle is of sufficient importance for maintenance and the further issue of faulty design or construction that it must be adumbrated at this point. Here is how the principle was expressed in the majority decision at p. 217:

> "To design something that will not work simply because at the time of its designing insufficient is known about the problems involved and their solution to achieve a successful outcome is a common enough instance of faulty design. The distinction which is relevant is that between 'faulty', i.e. defective design and design free from defect. We have not found sufficient ground for reading the exclusion in this policy as not covering loss from faulty design when, as here, the piers fell because their design was defective although, according to the finding, not negligently so. The exclusion is not against loss from 'negligent designing', and the latter is more comprehensive than the former."

Then Mr. Justice Windeyer in concurring said at p. 218:

> "...We are concerned with the word 'faulty' as descriptive of an inanimate thing. The words 'fault' and 'faulty' then have a different

sense. They, again according to their derivation, connote a falling short; but not now a falling short in conduct or behaviour. They designate an objective quality of a thing. It is not up to a required standard. It is 'faulty', because it has defects, flaws or deficiencies. This use of the word 'faulty' in relation to a thing is old and quite common. Doctor Johnson defined 'faulty' in this sense as meaning:

> defective, bad in any respect,
> not fit for the use intended.

The word can be applied not only to concrete things, but also to plans or designs to be used to produce intended results."

Then here is an extract from a 1968 article Jenyke and Johanson on Bin Loads .

It was exhibited in Zetlin Argo's report.

" The first large bins and silos were built in the 1860's for the storage of grain. since then, thousands of large and small bins have been built for the storage of a wide variety of powders, grains, lumps, and fibers, which will be generally referred to as bulk solids.

The early designers thought that bulk solids behaved like liquids, and designed the structures for equivalent liquid pressure. Experiments on models and full-size silos by Roberts, (2, 3) (Partner, Jenke & Johanson, Inc., Storage and Flow of Solids, Winchester, Mass) showed that wall pressures do not increase linearly with depth but that some of the weight of the stored solid is transferred to the walls by friction. As a result, floor and wall pressures in the lower part of a bin are less than they would be with a liquid while, simultaneously, the walls are in vertical compression, which would be absent with a liquid. Janssen

> derived a formula for these pressures in cylindrical bins. Alry proposed an alternative method of computing pressures. A great deal of experimental work was done during the following years by Prante Jamieson, Bovey, and Lufft, and culminated in the work of Ketchum, who summarized the state of the art and reduced the available data to a useful form."

Then there is yet an important article of 1988 by Halfield and Bartalc entitled <u>Static Forces and Moments of Grain in a Silo.</u> This was another useful article exhibited to Zetlin Argo's report. It reads:

> " Static pressure of grain on a silo is a significant component of the critical load combination, which also may include dynamic forces due to loading or unloading, thermal effects, and seismic or wind forces. Only static pressure is considered here. However, the usual procedure (Recommended Practice 1977) is to estimate dynamic pressure by multiplying static pressure by an amplification factor.
>
> Grain pressure exponentially approaches a limit as depth increases and has different magnitudes in horizontal and vertical directions. These phenomena are sometimes described as arching and are a consequence of friction between kernels of the grain and between the grain and the silo wall. In the United States (Recommended Practice 1977) static grain pressure usually is calculated from Janssen's formula (Janssen 1895)."

It continued thus:

> " Briassoulis and Curtis (1985b) presented equations for forces and moments in the wall of a cylindrical silo subjected to pressure given by a sophisticated version of

> Janssen's formula in which the unit weight of grain and the ratio of horizontal to vertical pressures vary with depth. Vertical drag force of the grain on the wall and the weight of the wall itself were neglected. The results demonstrated that if an edge of the silo is restrained, circumferential tension increases and localized shear force and bending moment develop."

A fair summary of these extracts is that proper repair for maintenance must include improvements to take into account the effect of dynamic pressure if dynamic pressure was excluded from the original design. Further, faults in the design and construction would have been discovered and repaired if reputable specialist engineers had carried out the frequent inspection recommended by Safarian. So, if reputable engineers with knowledge of silo design and construction had been employed for maintenance, they would have taken ordinary and reasonable precaution for the safety of the property as envisaged by the insurance contracts.

What evidence was adduced, if any, to prove that the silos were maintained in accordance with the knowledge available to specialist structural engineers? John Ruland is a civil engineer. At the time of the collapse, he was the Managing Director of JFM. He carried out a tour of inspection after the hurricane. It is best to cite his own words to judge the extent of the inspection:

> "Q: And this tour of inspection that you carried out, how long did it last?
>
> A: I was in the plant for about four hours."

Then the questions and answers were as follows:

"Q: Now, let us come now to the
morning of the 26th of
September, 1988, that's the day
of the collapse of the silos. How
were you first made aware that
something had taken place?

A: I received a radio phone call
from our technical director in my
automobile about 6:30 the morning.

Q: He told you?

A: He told us that he had heard on
the radio that there had been an
accident at Jamaica Flour Mills
Limited and they were requesting that
the senior management team report
to the Flour Mill as quickly as
possible.

Q: You proceeded to the plant?

A: I proceeded immediately to the
plant."

Then comes the following information which was vital to the insurers:

"Q: And in relation to the areas
where silos 10 and 18 are
located, what did you discover in
the course of the day?

A: Well, we discovered that there
had been a failure somewhere at
the joint at 10 and 18. It
appeared that the ceiling
structure that was over the
control room had apparently
collapsed and had trapped three
employees of Flour Mill
underneath the weight of the
grain and the concrete.

Q: Where was the Control Room located?

A: It was underneath silo 18.

Q: Now, at the time of the accident wheat was being off loaded or had been from the day before?

A: From the record that we constructed the wheat was being unloaded from the vessel into silo 10 at the time of the accident. Eighteen, according to the record had been loaded the previous day, the 25th.

Q: From the records at the time of the hurricane, what was the condition of silo 10 and 18?

A: The record indicated that both silos 10 and 18 were empty.

Q: And silo 18 was being loaded for the first time on the 25th, was it?

A: As I recall, yes, the first time."

Then Zetlin Argo enters the scene thus:

"Q: Now, let me come to the commissioning of Zetlin Argo. Following the accident, what did you do?

A: We, through the structural engineer of Pillsbury Company, we initiated a search for qualified consultants in the area of structural earthquake, hurricane, seismic -- we wanted to have a consulting firm that analysis of the facility and investigate the accident. As a

> result, Zetlin Argo, of whom Dr. Zetlin is the principal, was contacted. We visited the site and after preliminary investigation we agreed to accept the contract."

The evidence on maintenance was of utmost importance as it is on the basis of this evidence that a decision can be taken as to whether JFM discharged the onus of proof to maintain for safety in accordance with the terms of the insurance contract:

> "Q: Now, you yourself had told us earlier that as a result of your inspection you found no structural damage to the silos, except you described the sheeting at the roof between those two.
>
> A: I did not observe any structural damage.
>
> Q: Now, does the Flour Mills also maintain an Engineering Department?
>
> A: Yes.
>
> Q: What is it comprised of, what work does it encompass, the engineering Department?
>
> A: It had at the time of the accident some twenty-odd employees in the department. There was a maintenance engineer who had the responsibility for the general repairs maintenance of the facilities and equipment. There was also an Engineering Shop

that was under another manager; there were lathes, welding equipment, rolls, grinding and corrugating for the processing equipment and both of these supervisors, the maintenance engineer and the shop manager, reported to the Operations Director who is a graduate engineer.

Q: And you say this department comprise some 20-odd employees at the time of the hurricane?

A: Yes.

Q: Now, you described the position of the maintenance -- how did you describe him, the maintenance engineer; and this department is concerned with, among other thingsI am dealing with the maintenance side of it.

A: The general maintenance of the facilities, electrical, mechanical, structural portions of it."

Be it noted there is no information given as regards the qualification and the experience of the graduate engineer who was described as the operations Director. There was no attempt to elicit information whether he was aware of the knowledge relating to the design, construction and maintenance of silos as adumbrated by Safarian and other authors adverted to by Zetlin Argo in their report which was cited above.

Then the insurance companies come into play thus:

Q": Thereafter there was correspondence?

A: Yes.

Q: With regard to the claim, and the insurance company denied liability?

A: That's correct.

Q: and alleged ineffective design and ineffective construction? M'Lord I am showing the witness Exhibit 70 to 75."

Two aspects of this correspondence are worth quoting to demonstrate that the insurers raised the issue of poor construction and proper maintenance at an early date. Here is an extract from the loss adjusters, Thomas Howell Kent on 5th October 1988:

> "At this time I have to tell you that we have found no evidence of an explosion to cause the damage, but we have found evidence of construction faults. These faults could have very serious implications, and I strongly suggest that you obtain advice from your own, or Pillsbury's, consultants, and act on that advice. Your insurers or brokers will be in touch with you direct concerning further insurance cover."

Then the lead insurers on 17th January 1989 wrote in part:

> "We have now received the Final Report from R.B. Hawkins & Associates Limited, Consulting Scientists and Engineers. They conclude that the collapse of Silos 10 and 18 at Kingston Flour Mills resulted from structural deficiency. The Report further concludes that there was no explosion, as originally intimated, and that the collapse was not caused by Hurricane or Earthquake,

> but due to poor detailing of the reinforcement in a critical joint aggravated by poor construction. They further state that as similar poor detailing is common throughout the structure, they are recommending that the Silos should not be filled again, unless they are strengthened and the design checked against up-to-date internationally recognised codes of practice."

As the onus was on JFM to ensure proper maintenance, all that the insurers had to do was to raise doubts that JFM carried out the maintenance adumbrated in the articles in the report by Zetlin Argo. Here is the aspect of that cross-examination of Mr. Ruland as to what he did on his first encounter with JFM:

"Q: And the management, of course - and you said you looked at the buildings and the staff - tell me, did you see any design drawings of the structure on that occasion?

A: No, I did not.

Q: Did you on that occasion go inside the silos?

A: In the tunnel?

Q: Inside the silos - where did you go, you said you went into the tunnel?

A: I did not go inside the silos, I do go into the basement portion where the control centre was.

Q: Is that the same place when we visited the locus, that we went to?

A: Yes, similar to that.

Q: You didn't go into the bins?

A: Inside the bins? I did not.

HIS LORDSHIP: You went into the basement section where the controls ...?

A: Where the control section was.

Q: So in fact you had what one might call a superficial look at the building, the structure?

A: I had a superficial look, correct."

So on his first visit his examination of the silos was superficial.

This extract from Mr. George's submission to this court showed that the issue of maintenance did not entirely escape the insurers. It runs thus:

> "... If a structure is subjected to a force large enough to cause yield in the steel, once the force is removed the cracks will not close completely. The cracks will be clearly visible and act as a warning that all is not well with the structure. But if there is proper splicing, collapse does not occur, only cracking out which if proper inspection inside the silos were carried out would be visible to the maintenance team. In other words a warning is given once yield stress is reached by the appearance of cracks which can be seen by a proper maintenance team. "

This was an obvious response to Mr. Mahfood's brief submission on the issue in this court. The submission runs thus:

> "The silos were well maintained and in fact the structure as a whole would have gained

> in strength on completion as a result of the properties of the reinforced concrete which was applied."

Panton J made two significant comments although he did not directly relate them to the contracts, the defence, the onus of proof or the evidence. They run thus:

> "It is to be noted that Mr. Cader, during examination-in-chief-, said that in 1990 remedial work was done to the silos. Additional reinforcement was provided to bring the bins in line with the requirements of the 1988 Code. They took into account the dynamic effect of the grain pressure. The soil was also reinforced by injecting it with a view to protect against future hurricanes as strong as Gilbert or stronger."

The other was that:

> "The defence was of the view that the collapse was due to faulty design and construction of the silos made worse by non-inspection and non-maintenance of the facility in critical areas."

It is important to cite Mr. Cader's words. They run thus:

> "Q: Just one final matter. It is common knowledge, I think, and I can lead you on this, that in 1990 remedial work was done to the site?
>
> A: That is correct.
>
> Q: Can you tell us what the work was done and why it was done?
>
> A: The additional reinforcement of the silo bins were provided to bring the structure to the requirement in 1988

Code. We took into account the dynamic effect of the grain pressure. We also reinforced the soil. It was done by an injection of the cement and I am not sure of the word used for it, but as far as I know, our company contracted for that particular project was a Converse East from the United States. They designed the weight of reinforcement of the soil to protect against future hurricane load.

Q: And what sort of hurricane are you talking about?

A: We are talking about hurricanes as strong as Gilbert or even more severe than that.

Q: That is all I have to ask the witness sir."

This demonstrated what could have been done earlier if there had been proper inspection and maintenance. Also, Mr. Cader's evidence was an implied admission that the original design and construction were faulty and that it was the faulty design and construction which caused the collapse..

It was acknowledged on both sides that there were old cracks in silos 10 and 18, and the photographs taken by the insurers and exhibited showed rusting reinforcement bars. Before these bars were exposed so that rusting could take place, there would have been cracks observable to a competent maintenance team. These were the warning signs that were never heeded. In this court, JFM never faced this issue as Mr. Mahfood's submission demonstrates. In the court below, only Panton J seemed to have recognised the significance for design, construction and maintenance of Mr. Cader's admission.

If there was evidence to conform to the standards of maintenance adumbrated in the extracts from the articles referred to by Zetlin Argo, then it ought to have come from Mr. Ruland. On the above evidence, I am prepared to find that JFM did not discharge the obligation imposed by conditions 4 and 5 of the respective policies to prove proper maintenance for safety: I would be prepared to decide in favour of the insurers on this issue.

Surprisingly, there were grounds of appeal that could be interpreted as related to this issue of maintenance. They were grounds 29, 34, 37 and 39. They read:

> "29. In accepting the testimony of Mr. Minor that hurricane Gilbert was not the proximate cause of failure, the Learned Judge mistakenly and improperly or unreasonably accepted the very unsatisfactory explanation of Mr. Minor that the silos failed 14 days after Gilbert because 'Its time had come.'"

Then ground 34 reads:

> "34. The Learned Judge erred in stating that he 'was also guided by some of those articles that were exhibited ... they having been written by persons far removed from the case. The Learned Judge failed to appreciate that these articles provided historical information only about the failure of other silos under different circumstances and conditions for the reasons stated in the report and cannot be relied on as evidence of the cause of failure of silos 10 and 18

> which occurred in Jamaica on September 26, 1988."

A careful reading of the judgment in the court below shows that Panton J was aware of the relevance of the articles which were part of JFM particulars and evidence. The judgment in part reads:

> "The documentary evidence presented indicates that the first reinforced concrete grain elevator ever built was at the turn of this century. It collapsed twice -- firstly, shortly after it had been put into use and, secondly, three years later (1903). Since then, it has been known that silos do collapse from time to time. Exhibit 87 examines the reasons for such collapse. This exhibit is a paper written by O.F. Theimer, a consulting engineer of Munich, Germany. It was presented in October 1968 at the Materials Handling Conference at the American Society of Mechanical Engineers held at Boston, U.S.A. The paper was further published in the Journal of Engineering for Industry, May 1969."

Then the learned judge continues thus:

> "I cannot agree with learned Queen's Counsel, Mr. Mahfood, that the acid test in this case is the test of history as for over twenty-two years the silos had operated comfortably. The case does not rest on history. If the case rested on history, then no building would ever collapse as history would always be in its favour ... until it collapses. Of course, if the case rested on history, there would not have been any need for the very expensive services of Zetlin-Argo who purported to be investigators of the cause of the collapse."

Then after referring to one of the articles by **Sargis Safarian,** Panton J concludes thus:

> "These two exhibits that I have referred to give considerable support to the opinions expressed by the witnesses for the defence, and thoroughly discredit the approach and position of the plaintiff. I see no reason to quote from other articles that were exhibited."

These references dispose of grounds 29 and 34.

It could be said that Panton J in his conclusion did not expressly analyse the issue of maintenance, nor did the learned judge expressly adjudicate on it. But it was implicit in his findings as the following passage will show. It reads:

> "Mr. Minor made a record of the first sixty layers of bars. He observed that fifty percent of the bars did not go around the jacking rod. That in his view was very poor construction. There is a distance of about nine inches between the layers. He noted further that some of the bars had rusted. The degree of rusting was not in his opinion consistent with a time span of two or three weeks; it was more consistent with a time span of years. In this regard, he made specific reference to photograph no. 36 from Exhibit 27."

Since the degree of rusting of the bars was consistent with prior cracks, which were warning signs, then it was clear that there was a failure to maintain and inspect, consistent with the insurance policies. This disposes of ground 37 which reads:

> "37. In discussing the question of 'rusting' of some of the steel bars, which was relied on by Mr. Minor in support of his conclusion

> that there were old cracks in the haunch (Judgment page 41.), the Learned Judge has ignored and disregarded the evidence that the rusted bars were not in the haunch and therefore not relevant in determining the strength of the haunch."

Then ground 39 reads:

> "39. Having completely ignored and disregarded the plaintiff's submissions, the Learned Judge, focused his attention on a purely general observation made by Plaintiff's Counsel in opening the case related to 'the acid test of history.' At page 65 of his judgment, the Learned Judge states that 'I cannot agree with learned Queen's Counsel, Mr. Mahfood, that the acid test in this case is the test of history as for over twenty-two years the silos had operated comfortably.' In rejecting the general observation made about the acid test of history, the Learned Judge failed to refer to the most critical part of Counsel's observation - 'There is the structure there and the acid test of history is the best test of the safety factor, and therefore, the real enquiry is what caused the collapse <u>and the only reasoned presentation consistent with the facts of history is the presentation in Zetlin-Argo's Phase 6 Report.'</u> "

This ground has no merit in the light of the analysis attempted in the section.

(VI) Did the Insurers prove that the rupture of silos 10 and 18 was attributable to or occasioned by faulty design or construction?

It will be recalled that in paragraph 3 of the amended defence the insurers state:

> "3. The Defendants say that the proximate or effective cause of the rupturing

> of the structure was faulty design and detailing and deficiency in construction."

The basis of this defence in respect of the Lloyd's policies as stated previously was clause 2(a) which reads:

> "...
>
> 2. The Underwriters shall not be liable for loss or damage occasioned by or attributable to:
>
> (a) faulty design or construction of, or the removal or weakening of supports to, any property described in the Policy."

With respect to the policy of which West Indies Alliance was the lead insurer, the exclusion of faulty design and construction for the risks for which there would be an indemnity, also meant that by the common law that policy has the same effect as the express provision stipulated by the Lloyd's underwriters.

As for the onus of proof, the insurers must bear the burden. They relied on two witnesses namely, Mr. Basil Minor, a structural engineer and Professor Mitchell, an academic with an international reputation in the field of civil engineering.

What was significant was that this was the sole aspect of the case on which the insurers thought it fit to call oral evidence. It is clear from the insurers' strategy that they aimed at a double victory. Firstly they would succeed if JFM failed to prove that Gilbert caused the damage. They would also succeed if JFM failed to prove that their standard of maintenance and inspection for safety was not up to the standard proclaimed in the articles they exhibited. Secondly, the insurers must succeed if they proved that faulty design or construction was the cause of the rupture.

Mr. Basil Minor did both parts of the tripos in mechanical sciences. He is a civil as well as a chartered engineer. He also has had considerable experience in the United Kingdom and abroad in the field of buildings and structures. Specifically he has had experience in designing and building silos as well as investigating failure of structures. He is now a consulting engineer with Norman and Dawbarn. Apart from the initial work with R.B. Hawkins and Associates, the major part of the investigation into the cause of failure of silos 10 and 18 was done on behalf of Norman and Dawbarn. Mr. Cader the structural engineer for Zetlin Argo was the foil for Mr. Minor. Panton J rejected Mr. Cader's evidence and he described him thus:

> "Mr. Cader has to be given pride of place so far as the case is concerned."

That was to overstate his role , Professor Sparks and Dr. Oweis, had the responsibility for proving JFM's case, that Gilbert was the cause of the rupture of silos 10 and 18 while Mr. Ruland had the responsibility to prove that JFM provided the proper maintenance and inspection for safety.

Zetlin Argo had concluded from the first phase of their investigation that the design and construction of the silos was adequate for the purpose of loading, storing and unloading the silos. Mr. Cader admitted that the design did not take into account the dynamic forces released by unloading. That admission was fatal to JFM's case as it meant that the factors of safety computed by Zetlin Argo was exaggerated and the silos were in danger of collapse at any time. Since Zetlin Argo was aware of the stress released by unloading the silos, and exhibited articles from specialist journals to support that, they ought to have pointed out the necessity for proper maintenance for safety of the silos. It is likely that, had they not ignored the manifest defects in design and construction, proceedings would not have been launched to put the blame on Gilbert for the rupture of the silos.

To my mind, Mr. Mahfood sought to eliminate design as an essential feature of this case, although the insurance contracts either expressly excluded faulty design and construction as an insurance risk or impliedly excluded it by not adverting in the list of risks covered. It ought to have been obvious at the end of JFM's case that once the concession was made by Mr. Cader, that the design was faulty, the insurers could have succeeded on that aspect of the case without calling a witness. In this regard, the **Queensland** case was critical in showing that the law was on the insurers' side.

Since the silos ought to have been designed to cope with dynamic forces consequent on unloading, it was essential to define this concept to appreciate the significance of unloading. Mr Minor was an excellent guide. Here he is at the beginning of his examination in chief:

> "A: The Appendix suggests - it says that due to the stresses caused by operating the silos, by filling them with grain, the bars in

the junction of the haunch between the outer wall and partition of silos 10 and 18 were over-stressed. The concrete cracked, there was insufficient length of bar across the crack to hold the silos together, and the silo as a result failed."

Then the examination continued thus:

"Q: Yes, Mr. Minor, you told us that that conclusion has not changed, can you explain briefly how the failure occurred in your view?

A: The bins are subject to be filled and emptied with grain; that is after all its purpose. They are repositories of grain, to store grain between the time it arrives by sea until it is wanted in the mill for milling and production of flour. The purpose therefore of the silos is to act as a buffer to hold the storage of grain for a period of time and then to be extracted, therefore, it is normal that grain goes into the silos to be taken out of the silos and this will happen regularly throughout the years - throughout the years.

The grain in filling the silos exert pressures on boundary, on surfaces on which it is in contact.

HIS LORDSHIP: The areas of the silos on which there is contact?

A: Yes. The weight of grain is not solely taken on the floor, it is also taken on the walls of the silos. If you can imagine a paper bag, you fill a paper bag with rice, sugar, or with grain; the paper bag doesn't retain its square shape, it goes outwards because the sugar or flour or whatever it is that you put into the bag pushes sideways as well as pushing down on the bottom, it is that pressure which silo walls have to be designed for. The silo floor is designed for

> pressure to go downwards due to the weight of the grain."

Then comes the important distinction between compressive stress and tensile stress or hoop tension:

> "Now, there is a slight complication with that in that because the grain is pushing outward and because the grain is in contact with the wall there is friction between the grain and the wall, and the grain can't go down because that friction stops the grain from sliding downwards, therefore, a very high proportion of the total weight of the grain is taken by the friction on the wall, down the walls into the foundation. This means, the walls are carrying a very high proportion of the weight of the grain in the silo.
>
> This puts the walls of the silos vertically into compression. So the walls of the silos are being pushed downward both because of the self-weight and the weight of the grain in them. So the vertical stress is compressive in a silo under normal operating conditions. The horizontal stress however because grain is trying to push sideways is tension and which is called hoop tension."

Mr. Minor then turned his attention to the pioneering work of Janssen the Danish engineer who devised a formula to design silos taking into account when they were being loaded which has been described as a static stage. It is important to go directly to the evidence of Mr. Minor to show how silo failures revealed the inadequacies of Janssen's formula. Here it is:

> "A: It is a formula that was derived by a Danish engineer in late nineteenth century, I believe it was 1890, which determines the pressure in the grain -- sorry, within a granular material inside the silo. When bin

is either being filled or when it is in a static state, when it is no longer being filled." ...

The evidence continued thus:

"Q: Now, is Janssen's formula still the operative one?

A: Yes, sir and no, sir. It is still considered that the Janssen's Formula gives a very good representation of the state of the stress in a granular material while a silo is being filled or while the grain is stationary, in other words, during the time when it is being stored. However, it was found due to a number of grain silo failures that higher stresses are in fact obtained when the silos are being emptied and work on that has in fact been carried out throughout the century although the definitive works were mainly done in the Sixties and early Seventies."

Then Mr. Minor comes to the crucial aspect of this case thus:

"A: During the loading/unloading over months, over the years the bins have been subjected to stresses; they are being loaded on one side and loaded on the other side, unloaded on one side, unloaded on the other side. The crack perhaps might have been there from the very beginning - or perhaps the crack occurred in the first filling or second filling, small cracks - slowly open under each successive filling and emptying; when one bin is full it puts bending moment into the partition. In some areas some bending moment would be positive, in some areas some would be negative, that is, if bin 'A' was full, if on the other hand bin 'B' is full, bin 'A' is empty then moments occur in the same wall, but where in one case the moment had produced tension force in one face at that same point it would now produce compressive stresses. So if filling bin 'A' cracks, filling bin 'B' is likely to close the

> crack. When bin 'A' is filled again that same crack is then back in a state of stress. The crack itself cannot take any tension so the tensile stresses have to go around the crack and it produces above and below the crack, tips of crack, a higher stress than average, because you could see - if you can imagine the stresses being even throughout the vertical plane, but the stress cannot go across the crack, so that stress has to flow around the crack which means that the average stress just above the crack, just below the crack is higher then than that which is throughout the wall."

It continued thus:

> "If that crack meets a harder part of the concrete, it would stop, if not it may move a bit more. With the crack moving the whole wall is flexible and in flexing changing its shape, the moments are re-distributed to parts of the wall which are more capable of carrying that load. Therefore, as the crack opens it eases tension across that crack in the act of opening. However, whatever happens the forces that are exerted must be resisted, so there comes a time when although it is cracked and although the forces have been distributed time and again, don't forget the crack is on side 'A' on one load, the crack is on side 'B' on another load, so there is a series of different cracks all growing larger each time it is loaded or unloaded, eventually we come to a point where there is too much crack and one is relying no longer on the stresses being distributed both by the concrete and the steel reinforcement, but all the stress must be taken by the reinforcement."

Then Mr. Minor proceeds to explain how the rupture was properly compared to an unzipping. The narrative developed thus:

> "A: The steel bars. Once that occurs then obviously it is whether or not the silo stays up. That is determined by the strength of the bars; whether the bars themselves are properly bonded into the concrete in order that they can transfer stress from one reinforcing bar to another reinforcing bar. If there are not enough bars the stresses in the bars would be too high and the bars would break. If there are enough bars on the other hand, we have got enough bond, then the bars would slip and each time it's loaded the bars would slip and each time the other bin is loaded those bars from one side of tension would now go into pressure and then would perhaps push back in there, and each time it is pulled out and has to be pushed back in - but although it is being pulled out the force of pulling causes hoop tension which are always higher than the force of pushing, because pulling and pushing, those bars are bending, but overriding that is pulling which is due purely to hoop tension; so each time the cycle goes it pulls a bit more till finally there is no more anchorage left and everything will slip.
>
> MR. GEORGE: Q: The whole thing will un-zip?
>
> A: The whole thing will un-zip from the bottom to the top."

The following passage sets out the context in which the insurers' case was prepared:

> "HIS LORDSHIP: So, Mr. Minor, subject to anything you may say on Zetlin-Argo this Exhibit 28 is a fair representation of your thinking on the matter, is that what you are saying?
>
> MR. MINOR: A: Yes, M'Lord.

> MR. GEORGE Q:: Mr. Minor, let me ask you: Does this report in any way change the conclusions in your first two reports?
>
> A: In no way whatsoever.
>
> Q: And as you say, at that time you didn't know that Zetlin was involved?
>
> A: Indeed."

The appellant JFM realised the importance of Mr. Minor's evidence and they have devoted some 17 grounds of appeal against Panton's J acceptance of his evidence. Because of the favourable finding of the learned judge, as regards this aspect of the evidence, the classic authority on this branch of the law of evidence must be cited. In **Benmax v Austin Motor Co. Ltd.** [1955] 1 All ER Lord Simmonds put it thus at p. 328:

> "... but the sole question is whether the proper inference from those facts is that the patent in suit disclosed an inventive step, I do not hesitate to say that an appellate court should form an independent opinion, though it will naturally attach importance to the judgment of the trial judge."

Lord Morton was of the same mind and said:

> "... but in the present case it would appear that the learned judge did not doubt the credibility of any witness, and formed his view by inference from the evidence as a whole."

Lord Reid made his contribution thus:

> "...But in cases where there is no question of the credibility or reliability of any witness, and in cases where the point in dispute is the proper inference to be drawn from

> proved facts, an appeal court is generally in as good a position to evaluate the evidence as the trial judge, and ought not to shrink from that task, though it ought, of course, to give weight to his opinion. In **Riekmann v. Thierry** [1896] 14 R.P.C. 105; 36 Digest (Repl.) 679, 313 Lord Halsbury, L.C., said 14 R.P.C. at p. 116:
>
> > 'The hearing upon appeal is a re-hearing, and I do not think there is any presumption that the judgment in the court below is right.'
>
> And later in the same speech he said (ibid):
>
> > 'Upon appeal from a judge where both fact and law are open to appeal, it seems to me that the appellate tribunal is bound to pronounce such judgment as in their view ought to have been pronounced in the court from which the appeal proceeds, and that it is not within their competence to say that they would have given a different judgment if they had been the judge of first instance, but that because he has pronounced a different judgment they will adhere to his decision.'"

It fell to Panton J to decide the important issue of causation. That is why Mr. Minor is the principal witness in this case, not Mr. Cader as it seems to have been the consensus in the court below and on appeal as well. If Panton J is correct, owners of property will be aware of their rights, where the issue of design and construction is excluded from an insurance contract. In some instances, the building contractors may well be liable for negligence and a different set of insurers may have to bear liability for the loss.

In deciding the issue of whether faulty design or faulty construction was the cause of collapse, the collective wisdom of the engineering profession expressed in codes of practice is the safe guide. The Codes are minimum standards to ensure that the silos perform their function of loading, storing and unloading with safety. To ignore these codes and rely on the engineering judgment of Mr. Cader would be imprudent. Further if the codes are ignored for whatever reason and remedial work was not undertaken by JFM as was previously decided it would be in breach of the maintenance clauses in the policies of insurance. The upshot of all this is that the insurers must prove that faulty design and faulty construction was the cause of collapse since JFM sought to eliminate it as an issue in this case.

Counsel for the appellant, JFM has drafted some ten grounds challenging the learned trial judge's finding which accepted Mr. Minor's evidence. It is useful to set out those grounds which deal directly with the issue of causation to ascertain if the insurers have refuted JFM's challenge on appeal. The first ground sets the pace:

> "1. The Learned Judge erred in accepting the 'expert opinion' of Mr. Basil Minor as to the cause of collapse of silos 10 and 18, which occurred on September, 1988. The only reasonable conclusion on the evidence is that the proximate cause of collapse was hurricane Gilbert, which occurred on September 12, 1988."

The next trilogy of grounds raise the issue of causation thus:

> "25. The Learned Judge erred in stating that he 'was impressed by the technical

expertise of Mr. Minor in particular ... The Court cannot ignore the fact that Mr. Minor was the only witness who had the privilege of actually working as an engineer in relation to silos prior to this case.' The critical fact which the Learned Judge ignored was Mr. Minor's admission that he had very limited experience in the area of major structural failures as compared with Mr. Cader, who had considerable experience. - See Plaintiff's submissions pp. 11 and 42. Mr. Minor's 'brilliant mind' is not a proper substitute for his limited experience in the area of major structural failure, and his lack of expertise in the very technical area of 'wind' and 'soil engineering'.

26. The Learned Judge failed to appreciate that the only investigation conducted to establish the cause of failure of silos 10 and 18 was that conducted by Zetlin-Argo in phase 6 of their report (Exhibit 18). In these circumstance, it is unreasonable for the Learned Judge to accept Mr. Minor's testimony as to the cause of failure.

27. The Learned Judge failed to appreciate that Mr. Minor, the witness on whom he relied in finding the cause of failure, based his premature and inflexible conclusion on November 1, 1988 that hurricane Gilbert did not contribute to the failure of the silos based on his work reflected in exhibits 26, 27, 28 and 29 which work is manifestly an exercise in speculation and generalization based on 'quick rough calculations' and without investigation save for the investigation Mr. Minor conducted shortly after the collapse of the silos with the aid of binoculars."

As if repetition made the grounds of appeal stronger, there were three further grounds of appeal:

"28. In relying completely on the expertise of Mr. Minor, the Learned Trial Judge has completely ignored and disregarded the extensive evidence of the critical errors defects and deficiencies in his work. Examples are:-

i. Arriving at his conclusion as to the cause of failure on the basis of design criteria rather than investigating the actual strength of the silos at the time that construction was completed in 1967 and the strength of the materials at the time of collapse.

ii. Creating a computer model in which Mr. Minor incorrectly tied the exterior walls to the roof with the result that the foundation mat rotated like a rigid body with no differential settlement and, therefore, no differential tilt and there was no distortion of the silos which was the source of the stress concentration at the joint.

iii. Using linear springs to model non-linear soil.

29. In accepting the testimony of Mr. Minor that hurricane Gilbert was not the proximate cause of failure, the Learned Judge mistakenly and improperly or unreasonably accepted the very unsatisfactory explanation of Mr. Minor that the silos failed 14 days after Gilbert because 'Its time had come.'

30. The Learned Judge ignored the fact that Mr. Minor's opinion as to the strength of the Joint that failed, which was a critical issue, was patently absurd, namely his testimony to the effect that after construction had been completed, the anchorage in the Joint was weak enough to fail on the first day of operation but strong enough to hold for two hundred years."

Then the last four grounds approach causation in a different way. Here they are:

> "37. In discussing the question of 'rusting' of some of the steel bars, which was relied on by Mr. Minor in support of his conclusion that there were old cracks in the haunch (Judgment page 41), the Learned Judge has ignored and disregarded the evidence that the rusted bars were not in the haunch and therefore not relevant in determining the strength of the haunch.
>
> 38. In arriving at his conclusion that the cause of the failure was faulty design and detailing and deficiency in construction, the Learned Judge has wholly ignored and disregarded the strong and cogent evidence in the case that the force that was required to break the haunch was far in excess of that which was generated by the normal operations of the silos and that the probable proximate cause of the failure of bins 10 and 18 on September 26, 1988 was hurricane Gilbert, which hit the bank of the silos on September 12, 1988, inflecting its greatest damage at the bottom of the bins within the junction between bins 10 and 18. The bins failed and collapsed with the additional stresses resulting from the filling of grain in bin 10 on September 26, 1988.
>
> 47. The Learned Judge erred in relying on the testimony of Mr. Minor that 'stresses due to wind load, hurricane intensity was a mere fraction of the stresses due to grain.' He failed to appreciate that this was merely one of the innumerable 'red herrings' introduced into the case by Mr. Minor and was not relevant to any issue in the case.
>
> 48. The Learned Judge erred in accepting the conclusion of Mr. Minor, in Ex.

28, that 'we have checked the effects of the recent hurricanes and earthquakes since the silo block was built. We have also had some samples of the materials of which the silo was built, tested. The result of these further deliberations has been to confirm to us our initial opinion that they had no bearing on the cause of failure and that collapse was due to poor detailing of the reinforcement in a critical joint aggravated by poor construction...' It is clear from any reasonable and balanced assessment of the work done by Mr. Minor was reflected in Exs. 26, 27, 28 and 29, that his investigation was vastly inferior in terms of quantity and quality to the work done by Zetlin -Argo reflected in Phases 1-6 of Zetlin-Argo's Reports. This vast disparity in the quantity and quality of the work was ignored by the Learned Judge in commenting adversely on the cost of the investigation done by Zetlin-Argo."

Then there was a further general ground on this issue. It reads:

"52. The Learned Judge erred in applying vastly different standards in evaluating the expertise, credibility and testimony of the Plaintiff's witnesses, as compared with the standards he applied in evaluating Mr. Minor and his testimony. He came to conclusions severely adverse to the Plaintiff's witnesses, with little or no evidentiary support. On the other hand, he relied on Mr. Minor's objectivity and veracity and concluded that Mr. Minor did not take a partisan stance and 'brought an open mind to the problem of the collapse', despite the overwhelming evidence to the contrary, clearly identified in the Plaintiff's submissions, which the Learned Judge ignored and disregarded. Furthermore, in accepting the 'expert opinion' of Mr. Minor as to the cause of failure, the Learned Judge ignored the fact that Mr. Minor is <u>not</u> a soil expert and has very limited experience in the area of major structural failure. The Learned

Judge also ignored and disregarded the powerful evidence, clearly identified in Plaintiff's submissions, of the serious errors and deficiencies in his work."

The machanism of collapse

In response to counsel, here is how Mr. Minor outlined the mechanism of collapse:

> "The mechanism of collapse was the first thing I had to discover. Clearly, the mechanism of collapse was that the partition wall separated from the haunch and the outer two walls, that is the first thing I looked at. Secondly, I had to discover, in my opinion why that initial failure had taken place. I looked to see what contributory factors could have occurred such as, was there evidence of any differential settlement. I saw no evidence of differential settlement insofar as one could see; I could not see it. I looked to see the quality of the concrete, I looked to see the quality of the reinforcement, I looked to see how the reinforcements were placed, whether the walls had the dimensions that were shown in the drawings. I looked at all these various things in order to get a picture as to why the collapse might have occurred both in that position and perhaps at that time."

Then Mr. Minor described what he discovered thus:

> "I discovered that there seemed to be very little protrusion of reinforcing bars out of the concrete at the point where collapse occurred. I had not at that time seen the drawings, it just struck me as strange that there was so little reinforcing sticking out of the wall at the point of collapse. I then looked at the drawings, I then came back to the site having looked at the drawings and did a survey of the number of bars that

> protruded out of the concrete and the manner in which they protruded out of concrete."

What did the table taken by Mr. Minor and photographs reveal?

On 14th October 1988, Mr. Minor accompanied by an explosive expert, Mr. Pugh visited the silos. Here is how the evidence emerged:

> "Q: According to this table 1: 'Examination using binoculars on 4th October, 1988, of the condition of end hooks to the steel reinforcing bars protruding from the fractured face of the wall separating silo 10 from silo 18. The examination was conducted to determine whether each of the two bars in any layer might or might not have been hooked around the vertical jack bar shown in figures 6 and 8'.
>
> Now, you say you managed to get sixty layers?
>
> A: Yes."

The drawings had the distance between the bars as nine inches. This was recounted thus:

> "HIS LORDSHIP: These layers you are talking about, they are in the area of collapse?
>
> A: Yes. I think that was the end of the wall which separated bin 10 and 18. I was looking at the end of that wall, that cracked surface and the first layer is the lowest layer above bin floor that I could see, and there were effectively two bars in each layer."

The relationship between the drawings and the structure was explained:

> "A: The design drawings, sir, calls for the reinforcing bars to be put into the walls in pairs, one on each side of the wall every nine inches in height up the wall. So what I mean by layer is, a pair of bars at any one height, and the next layer is a pair of bars nine inches above that."

The bars ought to go around the jacking rod but the construction was faulty in that regard:

> "A: ... If you look to the third and fourth layers above that, you will see that the bars are sticking out and they don't have a right angle hook around them. The bars are supposed to have a right angle hook on them. Those bars do not have right angle hooks on them, therefore it's probable that they might have been pulled straight during the collapse. It may have been that the jack rod pulled them straight."

Then the evidence continued thus:

> "Had the bars been around the jacking rod - the bars are supposed to be like that around the jacking rod. For the jacking rod to appear on the other side of those bars, those bars must straighten to some extent to let the jacking rod pass through them. Now the bar which is not straightened at all and remains bent at 90 degrees could not have been around the jacking rod. In order to allow the jacking rod through it must pull out to a certain extent, so any bar that has straightened to a certain extent I have assumed went around the jacking rod. It may not have been done, but I assume that it had. Any bar that is at right angle or is still embedded in the concrete clearly did not go around the jacking rod.
>
> If we go to the next layer, I say only one bar is visible again, and again it had probably

> been bent around the jacking rod because it was straightened to some degree."

The following encounter shows the defects in construction and the consequences:

> "Q: Mr. Minor, what is the relevance or significance of whether the bars were or not around the vertical jacking bar?
>
> A: It would determine whether or not they were properly placed in the crack - whether the construction was in accordance with the design or not in accordance with the design."

Then the following passage must be given in full to appreciate the force and logic of the insurers' case:

> "Q: And what effect would that have if any on the bond strength?
>
> A: Well, work done subsequently and clearly it was certified, I think at that time if we did not have the correct amount of overlap between one bar and another bar, then clearly the bond stresses at bars which were not of great overlap would be higher than it would have been if they had the correct overlap; it is of course, sir, a source of failure. This is as if you have buttons down your shirts and half of the buttons were not through the button holes; if it were to crack at that point and the bar did not go through that crack then the bars could not help in stopping the structure from collapsing.
>
> MR GEORGE: Q: But generally speaking, what could you conclude from the table in the construction of the silo?

> A: I found that 50 percent of the bars were definitely not around the jacking rod.
>
> Q: Is that good or bad construction?
>
> A: That is poor construction, very poor construction."

Mr. Minor explained how the death of three workmen occurred:

> "A: Photographs 9 and 10 are taken from the roof of silo building. On top of each silo is a manhole. We lifted the manhole cover and looked down into the silo; photograph 9 is taken downwards inside silo 18. You can see the bottom, that half of the bottom of the silo is separated; it was when that bottom of that silo fell downwards that it killed the operators who were in the room immediately below."

Zetlin Argo's case was that differential settlement caused by Gilbert resulted in locked in forces which cracked the haunch. The evidence from Mr. Minor effectively refuted that theory:

> "Q: What were you looking for?
>
> A: We were looking for settlement cracks.
>
> Q: Did you find any?
>
> A: No. We found cracks, sir, but we didn't find any settlement. A typical crack is shown on photograph 16.
>
> Q: Vertical?
>
> A: It is a vertical crack and it is larger in the middle than it is at the top or at the bottom.
>
> Q: This is not a settlement crack?

> A: No, I think that can be attributed to the shrinkage of concrete."

A feature of the insurers' case was that the cracks observed by Mr. Minor when he inspected the silos were there for a considerable time, between two to four years. He reiterated that they were a result of faulty design and poor construction. The implication was if there was proper inspection the cracks would have been observed and the faulty construction remedied. One proof of the existence of the cracks for a prolonged period was the rusting of the reinforced bars. Here is how that evidence was brought to the fore:

> "A: Yes, sir, it shows that the cover to the reinforcement walls was less than it ought to have been because the bottom of photograph 24, the bars are rusty. Not only that, you will see that there are cracks along the line of the bars. If you look at the bars that extend around you will see that there were cracks. This indicates that the bar was close to the surface, the bar rusted and in rusting, steel takes up a volume many times its own volume. I think eight times its own volume, and has the tendency to burst the concrete that is over it."

The answer continues thus:

> "So in rusting it is pushing the concrete away causing the cracks you will see at the bottom of photograph 24. Similarly, if you look at photograph 26, you will see again the same sort of happening where the bars rusted and there were cracks tangentially around the surface of the wall, on the line of the bar which indicates that the bars are rusting.

> MR GEORGE : Q: The bars are rusting. Does that do anything to the strength of the structure?
>
> A: Clearly it is cracking the concrete more. I would say it is an indication of poor construction because the bars should not have been this close.
>
> Q: Close to the ...?
>
> A: Close to the surface. The concrete around the bars is supposed to stop them from rusting. If they are very close to the surface the concrete is not able to provide that protection."

Then the evidence in part on photograph 36 runs as follows:

> "... In fact, you will see another bar just above that is rusty at that point. That indicates that there had been a crack in the wall there for sufficiently long a time for the bars to have rusted. Not only that, the crack must have been wide enough to have allowed the entry of water into the concrete. Therefore, as I only came to the site -- this photograph was taken eight days after the collapse -- clearly that crack had been there before the collapse, a significant time before the collapse."

This passage is an effective answer to Zetlin Argo's thesis that there was proper inspection. For these long standing cracks ought to have been detected. Then for an estimate of how long the cracks existed:

> "Maybe a year, maybe two years, maybe five years. The degree of rusting is not consistent with two or three weeks."

Another aspect of the evidence which assists in proving the insurers' version of how the cracks were formed, emerges thus. With regards to photograph 37 the explanation was given:

> "A: There are three points of interest in this photograph. One is that the width of the cracked zone varies. being quite narrow, being wide, but a large number of the hooks clearly are still embedded in the concrete, and thirdly, there is grain on surfaces at that point. Some of the grain is clearly crushed, others, the grain appears to be a bit more grain, I don't think you will see any full sized grain, but it's broken and totally crushed grain on that surface"

In explaining how the grain got there Mr. Minor said:

> "A: Well, if there had been a crack at the time when the grain in there was sufficiently high up for the grain to get into crack, if the crack then closes when the other bin is being filled, then the pressure exerted when the crack closes by filling the other one would have impacted that grain onto those surfaces."

Another area of poor construction was the quality of the concrete:

> "MR. MINOR: A: The previous one has arrows in order to indicate jacking rod. If you look at photograph 49, there are two points on the extreme right that have arrows allotted to them and they are indentations - horizontal indentations in the wall of the silo. This indicates areas where the concrete has not been properly compacted against the shuttering. There was probably honeycomb at this point and this sort of failure which in fact you can see on all the walls at various levels, not just where the arrows are, is caused by concrete which when poured is

too stiff. It therefore does not flow around the bars in the concrete.

HIS LORDSHIP: It is caused by what?

A: The concrete, when it is poured being too stiff, and instead of flowing around the reinforcing bars as it should it is held back by the reinforcing bar, and therefore does not come up against the smooth side of the shutter."

Further Mr. Minor explaining the faults in the concrete continued:

"MR. GEORGE: Q: When you say stiff, you mean?

A: I mean it doesn't flow. Concrete when poured should flow very easily so it would take up the shape in which it is placed in a uniform compacted and regular manner. So this some indication that ...

Q: One second -- sorry, you were saying?

A: ... at this point, one might get cold joints, one might get honeycombing, or other forms of poor construction. Unfortunately, on sites it is common occurrence, in order to alleviate problems of concrete not flowing properly, those on sites add additional water to concrete to get it flowing better. Now, this is a Cardinal sin in concrete construction, adding water after it is being mixed.

Q: And the quality of this concrete indicates that this might have been done?

A: Indeed - sorry, the tests indicated that it may have been done in that the water/cement ratio was very high.

Q: The Sanberg test?

A: The strength of concrete is dependent upon the ratio of cement to the amount of water.

HIS LORDSHIP: And once you have dealt with that ratio and have made your mix that is it?

A: That is correct, Your Lordship. You design mix with a specific ratio of water to cement. To add water afterwards is to change that ratio and to reduce the strength of the concrete."

Then Mr. Minor explained how honeycombs were formed:

"A: Your Lordship, if you remember there were two layers of bars at every nine inches. If the bars are close to the shutter it is normal when pouring concrete in wall to pour concrete down the middle, between the layers of bars. So as the concrete comes down it then goes out towards the shutter. If the concrete is very stiff then, and there is a horizontal bar, if it is close to the shutter then a shadow forms as it were because the concrete does not flow behind, between the bar and shutter, only a small proportion of concrete, thus leaving honeycombing which with the attrition and the abrasion that the grain would have done over the years would have caused that imperfect honecomb concrete to come away leaving that indentation to the wall."

Another aspect of poor design emerges as follows:

"Q: I think you have told us that the lap length is necessary.

A: It is the proper way of doing it in order to safely transfer stress from one bar to the next bar, the continuing bar which takes its place -- the two bars should be placed

> alongside each other for a length which is called the 'lap length.'
>
> HIS LORDSHIP: Did the design call for it?
>
> A: No, M'lord, the Code of Practice calls for it; this is where the design is very bad.
>
> Q: You say the design is very bad?
>
> A: Yes, it is not just the construction was bad, the design was bad."

In eliminating Gilbert as a cause of collapse Mr. Minor did calculations and concluded thus:

> "Q: So what conclusions did these calculations lead you to in relation to the cause of the collapse?
>
> A: Basically it showed that the wind load itself never put any stress in the silo at any point in an area where there was a likelihood of failure occurring, and stresses due to wind load, hurricane intensity, was a mere fraction of the stresses due to grain and that was just typical grain, it wasn't a particularly high granule and therefore the hurricane itself caused no damage to the silo - none whatsoever."

Bearing in mind that the onus was on the insurers to prove on a balance of probabilities that design and construction was the cause of collapse , the response of Mr. Minor is of utmost importance:

> "Q: Nor would you. Would you tell us briefly why you say that you would not have designed the building that way; very, very briefly.

A: If we are not talking about the actual loadings which I consider are to be considered but just consider the distribution of concrete and steel within the silos, it is in my opinion, and I think that it goes to the Code of Practice that the only proper way of transferring stress from one reinforcing bar to another reinforcing bar -- I was saying the proper way of transferring the stress from one reinforcing bar to another reinforcing bar is, those two bars which are to transfer the loads they should be in close proximity to each other along the length which is called an overlap or splice length."

Then he gave a demonstration with his hands thus:

"A: If this is one bar and that is the other bar then the two bars should be like that in concrete, in close proximity - the two bars are in the close proximity to each other which transfer the stress when these two bars try to pull apart. So if the two bars are just doing that then as my hand comes apart the stress is limited to the concrete here. If they are overlapping the stress is all around these bars, there is a large area of concrete over which we could transfer the stresses from this bar to that bar. Is that stress transferred to concrete? No, it has not been transferred. Now, in the design drawing."

Then he continued:

"A: ... The design as shown on the drawings shows no overlap whatsoever.

Q: The design itself?

A: The design itself shows no overlap other than some hooks around a vertical bar."

Continuing the response on faulty design with special reference to the need for staggering, Mr. Minor said:

> "A: What the Code requires is that if one layer of bar is overlapping here the next set of bars should overlap here and the next set should overlap there. (indicating)
>
> Q: What do you call that?
>
> A: That means they are staggered. so if this overlap fails you have above the bars which are not overlapping, under it or at this point. If this overlap fails the bars above and below continue, and similarly with this overlap over here, the bars above and below continue; so you would not have them all failing together."

He further explains the design specification in the code thus:

> "HIS LORDSHIP: Are you saying it should be something like this, in this space here below you have one set here, one set there?
>
> MR. MINOR: That's correct.
>
> HIS LORDSHIP: You would not have one underneath here, you would have the space?
>
> A: That's correct. The Code goes one step further, it says that every three sets must be staggered; so you have another set which is staggered as the previous two."

Turning to Codes of Practice design requirements, Mr. Minor said:

> "A: Yes, this Code of Practice is the American Code, it is not as explicit in condemning it as the later codes were or the British Standard Code was explicit, but this one does say here in Clause 805 (b) in the fourth paragraph, it says -

> 'Where more than one half of the bars are spliced within a length of 40-bar diameter or where splices are made at points of maximum stress special precaution shall be taken, such as increased length of lap and the use of spirals or closely spaced stirrups around and for the length of the splice.'

So they are making here special provisions where more that one-half of the bars are spliced within a length of 40-bar diameter. For five-eighths bar, 40-bar diameter means any bar within 25 inches of the splice has to have special precautions applied."

Then pointing to specific faults in the design of the silos, Mr. Minor continued:

"Q: Any such precaution is in the design?

A: First of all there was no lap length, so they can't get increased lap length, because it isn't there."

Perhaps the most telling aspect of Mr. Minor's evidence in this regard comes when he referred the British Code of 1969 bearing in mind the silos were constructed in 1967. Further, the Jamaican Draft Code by reference adopted the British Code. The encounter ran thus:

"Q: Would you look at paragraph 310 (j)?

A: Yes, the first point on laps in bars says -
'1) General: Laps in bars in any member should be staggered'
where do you see that?

A: Clause 310 (j) (1) on page 35 of the Code.

Q: And it sets out certain other requirements?

A: There are other requirements besides that but that is the first requirement for the lapping of bars.

Q: Were any of these requirements satisfied in the design?

A: That first requirement was not satisfied in the design nor was the second one, nor was the third.

Q: As set out in (j)?

A: As set out in (j)."

There were additional provisions in subsequent codes and the failure to maintain in accordance with the consequences of dynamic loading has been referred to earlier.

A puzzling aspect of this case is the view of Zetlin Argo as regards design and construction as the cause of failure. They eliminated design and construction and insisted on the actual strength of the structure as it was designed and existed on the day of collapse. There must be a fallacy in that argument as the original design did not take into account the stresses released by unloading although unloading took place for some twenty years.

In contrast, the insurers attributed the case of collapse to faulty design and construction. The insurers pointed out that Zetlin Argo's method of investigation was faulty. The insurers state that it was tension failure which caused the collapse and gave verbal and mathematical reasons for this. Zetlin

Argo said it was vertical failure which was the cause of failure. Mr. Minor summarised the position thus:

> "HIS LORDSHIP: No sign whatsoever of vertical shear failure?
>
> A: Not only that but I can find no calculation in any of the Zetlin-Argo's calculations showing that they have investigated the vertical shear failure of this wall but they have investigated at great length the direct tension failure of this wall which the statement says did not occur. I fail to see why they investigated a tension which they say did not? occur."

In further answer to the court, Mr. Minor said:

> "HIS LORDSHIP: And these two forms of failure are distinct -?
>
> A: They have distinct - they are caused by different stresses and they result in a different appearance in the failure zone."

Realising that the onus was on the insurers to prove faulty design and construction especially since JFM sought to prove that it was actual strength which mattered, the following answer was convincing as it summarised the previous testimony:

> "Q: But in this particular case, how do you say the collapse of the structure came about?
>
> A: The structure was inadequately provided with reinforcement insofar as the location of the amount ..
>
> HIS LORDSHIP: Insofar as the -?

A: The location of the reinforcement and probably the amount of reinforcement as well. This under-provision of reinforcement resulted in cracking occurring at discrete points in the walls."

Then follows a detailed explanation as to how the tension stresses set up by loading and unloading the silos occurred:

"MR. MINOR: A: Due to the manner in which grain is taken out of the silos, for example, you might get high stresses occurring in the walls at some height of say 20 feet above the bottom, so because of particularly high stresses that particular wall cracks and because it cracks, the cracks gets to any width, the wall would flex a little bit and the load would drop just marginally, so the inherent strength still left in the wall after it is cracked matches forces that are now on that wall. That crack might be only over a length of four or five inches the first time at one side of the wall. Now when the other silo is perhaps empty at some future date one perhaps get an over pressure - over stress again and crack might then turn the other side of the wall; it might be only two or three inches long, and because the nature of grain tends to be very similar it tends to produce the same colour type, it doesn't mean the grain is always the same, sometimes it is different."

One of the criticisms made in a ground of appeal is that Mr. Minor was permitted to make long speeches in his evidence in chief. However, in a technical case of this nature it is permissible and desirable to allow the witness to give his explanation without counsel intervening, provided the witness is on track. Here Mr. Minor was on track. So he continued thus by referring to the grain inventory:

> "... If you look at the grain inventory you will see that they have two or three different types of grain in the silos at any one time. For this first grain we are talking about, it produced these high stresses at the height of 20 feet or so.
>
> If you had a slightly different grain it might produce these high pressures at a height at the middle of that high pressure, say 25 feet, so now instead of cracking 20 feet a new crack might start at 25 feet or perhaps it might not because the design at 25 feet above might be good, they might put all the reinforcement around the jacking bar. So perhaps at this point it might not crack but with a different wheat, with a different area at different times then perhaps the crack occurs somewhere else and slowly over these years these little cracks - and each time the grain is slightly different that point of high pressure might move up or down at some point about 20 to 30 feet from the bottom and slowly these cracks in effect might start touching each other, and when cracks touch each other the forces now have to go further around, they either have to take the steel now, the steel that goes through."

Mr. Minor then deals with bonding thus:

> "The steel now is through the crack and the steel, each time it's loaded has to now bond with the concrete. I don't know how to describe this but I could perhaps try. If the bar isn't held in the concrete and the bar pulls, and it is being pulled by the load that is there, it sets up very high stresses in the concrete around the bar, and particularly high at where the face of the crack is, but as the bar goes further into the concrete mass

> the stress between the bar and the concrete reduces. Although there may be an average stress, a high peak stress occurs right at the face of the crack. So what happens is that the bar tends to slip very marginally at the face of the crack and then the average bond takes hold and the rest of the bars stay there, but the next time it's loaded that high stress is no longer on the face of this crack, that high stress is now a quarter of an inch into the concrete because that is where the high stress would now have to take place because the bar already slipped in the first place."

The climax of Mr. Minor's narrative occurs thus:

> "So each time that bar is stressed this slip goes further into concrete. It may slip by a very, very small amount but over the years that slippage slowly becomes more and more until the bond is totally broken between the bars and concrete and the thing gives way.
>
> MR. GEORGE: Q: When it snaps it's large?
>
> A: Well, once you get a large - let's say ten or twelve feet of wall going, the stresses cannot longer flow around the damaged portion, the whole thing then goes, and because all the bars, one above the other, they are not staggered, and because there is no overlap it just go straight through like a zip, and the zip analogy is Dr. Zetlin's analogy, it is not mine."

One aspect of failure ruled out was the failure of the foundation. That emerged after examination of an article by I.F. Theimer referred to earlier. The article was written in 1969 and confirms that knowledge of dynamic pressure from unloading was known for many years. It is important to reiterate that the article by Theimer was introduced by Zetlin Argo and the following passage from Mr. Minor's evidence is instructive:

> "That figure 39 I think is of interest to compare the picture of the failure due to inadequate reinforcement and the picture due to failure at the foundation is shown that the failure due to inadequate reinforcement show a striking resemblance to the failures at JFM, whereas the failure due to foundation failure shows no resemblance whatsoever."

The nature of the cracks is an important indication of the type of fault in the design and construction. Mr. Minor illustrates it thus:

> "Q: And you agree with the statement by Theimer that vertical cracks are always a sign of insufficient hoop steel reinforcement?
>
> A: With a slight modification. I would say significant vertical cracks are always a sign of insufficient, but you could have very fine cracks which you wouldn't see with your eyes, but you could detect with a magnifying glass. Those might, or would be due to high stresses in the reinforcement. Perhaps there might be cracks that occurred during construction. I wouldn't totally agree with Mr. Theimer on that but long continuous cracks which are visible with the naked eyes, that indicates over stress in the reinforcement and therefore insufficiency of reinforcement."

A striking feature of the inadequacy of Zetlin Argo's investigation is the failure to abide by their own terms of reference. It reads:

> "'Scope: to evaluate the adequacy of the original 1966-67 design of bins 10 and 18 to 0resist the anticipated external loads,

> including wind and earthquake as prescribed by the 1966 Jamaica Building Code, as well as the internal loads and forces generated by normal and the usual conditions of service and operations of the bins in loading, storing and discharging varieties of grains.' "

These terms of reference are ambiguous. Yet they ought to have protected JFM in enabling it to decide whether it had reasonable prospects in instituting an insurance claim. These terms rightly acknowledged the importance of design criteria, yet Zetlin Argo's report and its spokesman, Mr. Cader insist that actual strength is what matters not design criteria in determining failure.

But designs are created to bear anticipated loads and good designs are based on the general experience and skills of the engineering profession. A structure based on a good design will function safely. If defects are detected in the design because of new knowledge, a prudent owner will remedy the defects. This is what the insurers expected and these principles are embodied in the contract of insurance. Further, there are codes of practice which are minimum standards for functioning with safety which no designer or maintenance team ought to ignore.

Then the terms of reference refer to the 1966 Jamaica Code and the original 1966-67 design. By referring to the British Code which has been updated to take into account the action of dynamic forces released by unloading the silos, the terms of reference recognise that repairs ought to have been instituted to cope with dynamic forces. The terms of reference accept that the usual conditions of service and operations include unloading which sets up dynamic forces - yet Zetlin Argo and Mr. Cader calculated factors of safety which ignored dynamic forces. The factors of safety is the engineers' formula which indicates whether a structure can perform effectively and with safety. It is on that basis that the insurers excluded design or construction fault which cause loss or damage from the list of insurable risks. That is a risk which ought to be carried by the builders' insurance policies. Equally, failure to maintain for safety was not an insurable risk for the silos as structures. That is a risk that ought to be insured against by consulting engineers who ought to have been retained by JFM to carry out periodic inspection for the purpose of maintenance. The risk would only require compensation if the consulting engineers were not cognizant of the developments in the construction and maintenance of silos.

Against the background of these terms of reference, it could be predicted that the investigations would be inadequate. It would appear that Zetlin Argo were reluctant to investigate the consequences of dynamic forces released by unloading.

How did Mr. Minor define dynamic loading? He did it thus under cross-examination:

> "... Now the position is that if you look at the dynamic loading, as Mr. Cader himself pointed out, dynamic loading is occurring in a small area. The only difference between myself and Mr. Cader in this is that I say it occurs in a band which may be a circular band or an elliptical band whereas Mr. Cader suggests it occurs in a patch. However, we both agree it is a limited area. So what has happened is that you have these very high stresses occurring in a very limited area and

> it causes cracking of the structure but the remainder of the structure is there. The remainder of the structure has stiffness."

Mr. Minor previously pointed this out in examination-in-chief thus:

> "...So initially near the bottom the pressure is reduced but at some level, further up, the pressure is doubled, maybe slightly more than doubled the pressure due to filling."

The design defects of the silos were manifold. It is clear that the minimum standards laid down in the Codes of Practice ought to be taken into account by the designers. Further they are the yardstick on which this court must rely to determine design faults. This is a more reliable guide than the engineering judgment of Zeltin Argo or Mr. Cader.

Here is Mr. Minor's opinion on the failure to design for hurricane wind load and unloading of silos for a variety of grains instead of just wheat:

> "A. No, large parts of this was not done. You see, the Jamaican Building code requires for wind speed of 120 miles per hour should be taken into account in the design process. Zetlin Argo do not allow for any design process that the strength should include for a wind load of 120 miles per hour."

Then he continued thus:

> "A. In the calculations that Mr. Cader took us through on the factor of safety, you will recall that took into account the wheat load. He didn't add to that wheat load a load due to wind. Now, in the wall there would be a load. If there hadn't been a high wind at any time, then not only would that be a load

> in that wall due to wheat, there would be also a load due to wind at the same time, and therefore a higher load than due to wind, wind alone, and then his factor of safety would be lower than he calculated if it had been done in accordance with the design requirement of 1966. Further, there are two more things wrong with this scope: '... the forces generated by normal and the unusual conditions of service and operations of the bins in loading, storing and discharging varieties of grains.' Lastly, for a variety of grains they have looked at one and only one, wheat, not a variety of grain."

The inescapable inference must be that there would be damage to the silos if they were in operation since they were not designed either to 1966 Codes or the later Codes which catered for the dynamic effects of unloading. So the following account by Mr. Minor ought not to be surprising:

> "A: Well, the photograph taken one week after the collapse showed that there was apparent damage and that could have been seen.
>
> Q: Apparent damage of what kind?
>
> A: Of old cracks, rusting, obviously one could see the poor compaction of concrete, the honeycomb. Whether there were damaged covered honeycombs I don't know, but certainly rusting and old cracks and visible in the photographs taken weeks after the collapse."

Certainly this lapse of failure to inspect after the hurricane was in breach of the policy which the learned judge noted. Even more telling as it emerged by way of admissions since the Wiss Janney report was adduced by JFM and Mr. Cader, the structural engineer for JFM. This was the evidence:

> "Q: And in the Wiss Janney Report, Figure 14, Exhibit 15, 'Core samples taken from piece of concrete shown in Figure 2 shows a series of old cracks.' 'Figure 2 - Piece of concrete consisting of the curved portion of either bin 10 or 18. circles designate coring locations and sizes of cores.' Mr. Minor, did you hear Mr. Cader admit to cracking in certain sections.?
>
> A: Yes, I did, cracks in all three walls where they in fact met the haunch.
>
> Q: and that was before the hurricane?
>
> A: Yes, that was before the hurricane.
>
> HIS LORDSHIP: There is no issue on this."

Once again Panton J was revealing during the course of the judgment, how his mind was being influenced by admissions. For these admissions went to poor construction as well as failure to maintain for safety. It is clear that Zetlin Argo's report was flawed. It concluded thus:

> "IV. Since bins 10 and 18 have an appreciable Factor of Safety to resist the prescribed loads of 1966 and since they behaved safely under the severest loads of the past 20 or more years, it is our opinion that it could be concluded that the original 1966-67 design had no bearing on, and was not the cause of, the separation in September 1988 of the walls at the joint between bins 10 and 18."

The factors of safety computed by Zetlin Argo ignored vital matters, the most important failure was to compute for dynamic forces due to unloading of the silos. Certainly, unloading was a fact in 1966 and continued until 1988 when the rupture occurred. How could they be said to have an appreciable factor of safety when the numerous cracks which could have been detected on a proper inspection inside the silos were undetected? These cracks would have revealed faulty construction to engineers skilled in the design, construction and maintenance of silos.

The forces when silos 10 and 18 were emptied

Mr. Minor explained the shape the grain takes when the silos are emptied thus:

> "MR. MINOR: A: In emptying the silo from bottom - these bins have a very shallow cone to them and grain of the sort tends to empty in a funnel shape which has steeper sides than the bottom of the silo, so in emptying a funnel occurs in grain; the grain on this funnel is sliding upon other grain and that funnel goes up until the funnel hits - there is this widening all the time until it hits the wall. So it's a conical shape funnel. Now, if the exit point is in the middle of the cylinder, as long as that cone is fed even, it will meet the walls, but imagine a cone inside the cylinder, it will meet the walls around the same level all the way round, but if you were to take the exit point off centre, then if you could imagine a cone inside the cylinder, the cone would hit the cylinder very close to the bottom on the side where the outlet was closest to the bottom wall and would go up and hit the wall - much higher altitude, elevation, on the side of the wall, away from

> the exit point and then the locus of that would, of course, be an ellipse, if you remember from your days of doing geometry. Now in the case in point these silos were just off centre, the exit point for these two silos."

Then the force in a narrow area is accounted for thus:

> "A: Yes, whereas at the point at which that cone meets the wall, we have, of course, what's called the transition point and it's at that transition point that you get these very high pressures. The stagnant grain outside that cone, between cone and walls, the pressure in there is slightly alleviated during unloading. At the transition point the load could be doubled or even and above the transition the load would be what it was before unloading started. So you get a very high peak load, which is over a fairly narrow band and it is band follows the transition line."

Computations based on the correct data or assumptions are the bases of engineering design and construction - engineering is a branch of applied mathematics. Using the figures from the British Code for wheat and relying on **Janssen's** formula Mr. Minor gave the following estimate:

> "MR. GEORGE: Q: And this value which you have obtained which you have told His Lordship is static, is due to static loading? What would happen when you would have dynamic?
>
> MR. MINOR: A: That value of 629 might double to 1258 pounds per square foot.
>
> Q: And I think you have explained. Would this be over the whole of the silo or a band?

> A: It would be a band at a height from the bottom, which is determined by the angle of the funnel and the location of the outlet in the silo."

At this point of the evidence, Panton J intervened and Mr. Minor clarified the position in such a way that it is instructive to recount it in part:

> "A: Static loading, My Lord, means when the grain is at rest.
>
> HIS LORDSHIP: It has already been loaded?
>
> A: Yes, Mi Lord, but while it's being filled the only grain moving is grain arriving on top. The grain in the depth of it is stationary. However, when you open the bottom the grain starts moving and although there are dead zones within the grain, the majority of the grain is in a state of motion and that's when the dynamic loading is occurring.
>
> HIS LORDSHIP: So the pressure doubles?
>
> A: In an isolated band, M'Lord. It's a localized effect, it's not a general effect.
>
> HIS LORDSHIP: But the pressure is greater?
>
> A: It's twice as high in a local band."

On the quality of concrete used in construction of the silos 10 and 18

Wiss Janney examined samples of concrete recovered after the rupture by Zetlin Argo. They carried out core tests and reported. Here is Mr. Minor giving his first impression on the report:

> "MR. MINOR: A: We have a very wide range of compressive stresses given on the eight samples that were actually tested, and they vary over a very wide range and therefore that indicates at the first glance that probably the concrete is of poor quality, insofar as it is a very mixed strength."

A good example to refute Zetlin Argo's thesis that it was the locked in forces which caused the rupture comes from this passage in Mr. Minor's evidence. He said:

> "Wiss Janney is quite clear in saying old cracks, delaminations, there are honeycombing and none of those could possibly be as a result of impact damage causing crack.
>
> Q: In one word, Mr. Minor, how would you describe that concrete?
>
> A: Awful."

This evidence coming from Wiss Janney who were retained by Zetlin Argo is a further admission that there was failure to inspect and maintain silos 10 and 18 which caused the rupture. In any event, the silos were badly designed and constructed.

In furthering his opinion that the concrete was of poor quality, Mr. Minor examined the results of the core tests done by Wiss Janney and the relevant parts of his response were as follows:

> "A: It's wide, a very wide range of compressive strength that can be gained by the Standard Deviation and Coefficient of Variation which is also given by the samples. The Standard Deviation is 1,180 psi either side of the mean of 2,921 when you take all

> eight samples into account and that leaves one with the Coefficient of Variation of 0.4. The Coefficient of Variation is giving you the -- it's the ratio of the Standard Deviation to the mean."

Then in furthering his explanation he said:

> "... whereas the concrete cores have a very high Coefficient of Variation and it's that high Coefficient of Variation which indicates that the quality of the concrete was not good."

Illustrating how poor the concrete was, Mr. Minor continued thus:

> "Q: Is it normal to get such a wide range of compressive strength as you get at Table 3?
>
> A: No, this is awful.
>
> HIS LORDSHIP: This is what?
>
> A: This is outside the range that any Code of Practice allows."

This is very important evidence to establish the insurers' case that the construction was faulty. For the court ought to rely on the collective wisdom of the engineering profession as a safe guide as to what are the minimum standards necessary for safety. When the Codes are ignored by designer and builder and a rupture occurs, there is presumption in favour of the insurer. Of course, the presumption can be rebutted, but instead of rebuttals in this case JFM has provided supporting evidence by admissions.

This wide range of compressive strength must have had consequences for the structure. Here is how Mr. Minor explains it:

"A: It could be due to a number of factors. One is that you know that these samples were taken from different places and therefore these samples may not have been taken from the same batch of concrete. One batch of concrete may have been weaker than another one. It could say that the concrete itself was not properly compacted and that means that some has more air than others or it could say that the concrete has not been properly mixed, in that one had more cement than that other areas or more water than another area. It is telling us that the concrete was very wide range. It's obviously the mix is not consistent, there is no consistency throughout.

Q: The narrower the range the more sort of homogeneous or consistent?

A: Yes."

The Wiss Janney Tests: an examination by Professor Mitchell

It will be seen that the core tests by Wiss Janney on behalf of Zetlin Argo gave a coefficient of variation of 0.07. That done by Professor Mitchell from concrete made in his laboratory resulted in a figure of 0.40. It was put thus by Mr. Minor:

"HIS LORDSHIP: What is o.07?

A: The coefficient variation, M'lord. Now you recall yesterday afternoon that the coefficient variation that we took from the Wiss Janney Report for the concrete was 0.40 - in other words, about six times higher than this batch of concrete here."

The upshot of these tests was that the concrete mix done by Professor Mitchell which the insurers are saying, was properly done, would be four times stronger than the concrete recovered from the silos which were tested by Wiss Janney. This aspect of the evidence is so important for the insurers' case, that it is appropriate to get Mr. Minor's own words. Here they are:

> "A: Well, I was comparing Batch No. 1 of concrete that was produced by Dr. Mitchell in his laboratory and tested with the cores that were taken by Weiss Janney and tested by Weiss Janney, and I was saying one could compare the standard deviations. In one case the standard deviation is 332, that is Dr. Mitchell's, and in the case of Weiss Janney the cores from the actual silo the value was 1140."

There are several other comparisons that could be made between the concrete made by Professor Mitchell and that tested by Wiss Janney. One more will suffice:

> "You could also do other comparisons. You could compare the lowest value obtained from the result of the cores which was 1,540 as opposed to the lowest value of the eight tests done by Mitchell which is 3,959 and again you get a ratio of over two. All we are saying, there is uniformity in the results in Mitchell's Batch 1, which there should be, and unfortunately the values of the strength of the concrete in Mitchell's test batch number one are higher than the values obtained from the eight samples taken from the silos. Because they were higher Mitchell did a second batch in order to reduce the strength of the concrete to try and make his tests more applicable, to make the concrete closer in its strength to the values that were obtained on the site, and so he did Batch 2."

These comparisons have been made by using the statistical concept of the standard deviation. So an explanation by Mr. Minor would be in order:

> "A: It is a statistical measure to determine how something varies and to determine what values, what extreme values one might expect. You have what is called a normal direction or a Gaussian direction. That is named after Gauss, he was a nineteenth century mathematician but he was more known for electrical things - the Gaussian Theorem of Electromagnetics. Now the normal direction is that which is assumed to operate with concrete. What you find is, you take many, many samples that you get a curve which comes up and comes down like that (indicating), and if that is the number of samples on this orbit and along here is the strength, then you get this curve that goes up and down like that. The middle of the curve is the mean and the amount by which the curve widens, if it is a very flat curve it might do that (indicating), it might widen like that. That curve would have a very high standard deviation; whereas if the curve is like this, that would have a very low standard of deviation; if it is narrow like this it would have a very low standard of deviation.
>
> Now what it is tell us, (sic) this mathematical (sic) method, is how wide that is and therefore what scatter of strength in compression you might get in the concrete. That is the use of the standard deviation. It is not used only for concrete, it is used for many, many statistical reasons. Whenever you take a small sample and want to see how a larger sample might behave relative to that sample you use normal or Gaussian direction; there are others but those are the two most common directions."

The way structural engineers work in concrete was given by Mr. Minor thus:

> "... It is just that we normally work in concrete with one in twenty chances."

Comparing the consistency of either reinforcing steel bars with that of concrete, this was the response:

> "A: It means that the quality of the steel is consistent; whereas the quality of concrete is not consistent. And you can do the same test on Mitchell's and you will find Mitchell's concrete is consistent by having coefficient variations of between four percent and seven percent. In fact, they are as good if not better than the actual reinforcement bars as far as consistency is concerned."

It is important at this stage to reiterate that Zetlin Argo in their investigations, found that the factor of safety based on their calculations was adequate for the silos to perform its functions. If their calculations were based on wrong assumptions or if the factual basis on which they relied was incorrect then they would have computed a factor of safety which was erroneous. This is what the insurers were saying and since on this aspect of the case, the onus is on the insurers to prove on a balance of probabilities, it is essential to recount what they said. It is an instance where Mr. Minor is refuting Mr. Cader's methodology:

> "MR. MINOR: A: This is basically a matter of all the calculations that have gone before with respect to factors of safety - and the Court went through those in the cross--examination of Mr. Cader - the position on factors of safety is that Mr. Cader used values for the strength of concrete insofar that he used concrete in tension values of

> the modulus of rupture. He didn't use the actual values of the tensile strength he obtained from the samples nor did he use value of zero tensile strength which the Code requires; nor did he use the statistical lowest value for the strength of concrete in tension; nor did he use the ten percent value that Zetlin Argo mentioned elsewhere as the strength of concrete in tension; but he used value of concrete in strength and tension values of the modulus of rupture, which is a very high value indeed. In fact, that is the highest value you can obtain."

The passage continues thus:

> "Q: It is the highest value you can obtain?
>
> A: Yes.
>
> Q: When is it that one uses this modulus of rupture?
>
> A: It is used solely in determining the deflection of concrete beams or slabs."

The use of the modulus of rupture is to measure deflection not to measure strength. The other use is to measure consistency. So it ought to be ascertained from Mr. Minor the definition of deflection:

> "A: Deflection is the amount - - if my hands were slabs and then loaded, it is to determine how much the centre of the slab drops when you load it.
>
> Q: So it is to calculate that.
>
> A: It is to calculate the drop, not the strength but the amount by which it drops."

In explaining the other use of the modulus of rupture, Mr. Minor said:

> "The other use of the modulus of rupture is, it gives an indication of how consistent the concrete that is mixed is. As I said, you take great care over making this beam because the concrete is very fragile in tension. If the concrete is a poor mix and you do this test on it, then the likelihood is that you will get a weaker concrete; whereas, where there is high tension it will fail. So it is a test to see how consistent the mix is. It is not so much a test of strength but of consistency of material.
>
> Q: It is used in cases such as for building a bridge?
>
> A: It is used in fact mainly not for reinforced concrete structures, it is normally used for concrete that is going to be used for building roads which is not reinforced because the moment you put reinforcement in you automatically include stresses.
>
> Q: Include stresses?
>
> A: Something that raises stress.
>
> Q: I see.
>
> A: And therefore the modulus of rupture is not really consistent with a reinforced concrete structure for strength calculation. It is used however, for road construction; outside of road construction it is hardly used at all."

Let Mr. Minor define the factor of safety and demonstrate how the modulus is an imperfect tool to analyze the safety factor. Here it is:

> "A: Yes, Mi'lord. What I am saying is, in arriving at a factor of safety what you want to do is to check whether the maximum possible load you can put on the structure , otherwise there is no logic in having a factor

> of safety; it might not be a factor of safety, it may be a factor of comparing the highest load with the highest strength or it may be any other factor you choose but the factor of safety must compare the highest load with the weakest strength, otherwise it is not safe."

Mr. Mahfood for JFM was critical of Panton's J conduct of the case and the reasoning in his judgment. In fact he stated that the learned judge did not grasp the critical engineering issues in the case. But the following passage from the judgment does not support these strictures. In fact the learned judge demonstrated that he grasped the insurers' stance on the issue of design, construction, failure to inspect and maintenance. Here is the passage:

> "The defence has challenged every important aspect of the plaintiff's case. It is not an over-simplification to say that the defence regards the plaintiff's case as based on a myth. In addition, the defence is of the view that the plaintiff's case as presented contains innumerable errors thereby making it absolutely unacceptable when one applies the appropriate standard of proof. The defence was not satisfied to merely challenge the plaintiff's case with a view to destroying it. They went beyond that effort and called two witnesses, hoping that their expert opinion as to the cause of the collapse would gain the favour of the Court. The witnesses were Mr. Basil Minor and Professor Dennis Mitchell. There is no doubt that their evidence was very important. The strong view expressed by and on behalf of the defence was that the collapse was due to faulty design and construction of the silos, made worse by non-inspection and non-maintenance of the facility in critical areas."

Mr. Minor's opinion on the tests done by Professor Mitchell as regards the factor of safety.

Professor Mitchell , a civil engineer with an impressive academic record and a wealth of experience in investigating structural failures was retained by Mr. Minor principally to carry out tests as to the actual strength of the hook anchorages as detailed: he tested these hook anchorages in tension and in bending. The ultimate purpose was to calculate the factor of safety in the critical area of the haunch under dynamic forces. Mr. Cader had calculated the factor of safety to be around 4 which was impressive, having regard to the consensus that a factor of safety of 2 would have been excellent. A factor of safety of 1.75 is the agreed minimum. It must be borne in mind however, that Mr. Cader's figure of 4 took into account only static forces.

The test to measure the tension stress had specimens which were properly spliced or overlapped. There were also tests done as designed and also tests as to construction. Here is how Mr. Minor read the results from the tables prepared by Professor Mitchell:

> "... You will see in Table 5.1 on page 14 specimens T2 and T2A, which have the large overlap to transfer the tension. The special test was continued before the test actually failed. At the time the test was continued the applied load was 23.2 and 23.3 kips.
>
> In specimens T4 and T4A, which are as designed, the specimen failed when a load of 22.9 and 21.2 kips respectively were applied. Those values are close and the difference maybe either due to the difference

> in concrete strength or the difference may be purely due to experimental scatter. I wouldn't like to say which was which but they are close.
>
> T8 and T8A are the ones of interest to us insofar as they might be thought to represent the strength of the hooks in tension as built, and here we find that T8 which was the sample with the strong concrete, we get a failure occurring at a load of 13.1 kips, and for T8A, which is the weaker concrete we get the failure occurring at a strength of 10.5 kips."

Then there were bending tests. Again tests were done on the basis of what ought to have been done pursuant to the loads, then test in the design of the silos and then test of the silos as constructed. Here is how Mr. Minor states it:

> "In the second specimen one bar was taken through the splice - four bars from the left hand end are taken through the haunch to a position to the right of the haunch. Another four bars are started at position to the left of the haunch and goes right through the haunch to the end of the specimen at right. So that the two sets of four bars overlap each other by a length of 36 inches; it's called splice, an overlap of 36 inches.
>
> Now, we may disagree about the length of the splice but the code of Practice requires that when one bar is replaced by another it should be done in a manner which includes an overlap of splice."

Then he expands on the specimen thus:

> "A: In other words, that is with the hooks missing on one side, not actually going as far as the jacking rod, but the hooks on the

other side do go as far as the jacking rod. Some go around the jacking rod and others don't. But in terms of the way specimen B5 is loaded the maximum stress is applied to the bars on the bottom and it is the bars at the bottom that are not hooked, so maximum stress is going to be applied to the unhooked bars whereas the hooked bars in specimen B5 will not take the maximum load."

Then he said:

> "... B5, if you look at text, failed at the maximum moment of wall haunch intersection of 6.95 kips feet, less than half the value obtained in any of the other tests, and this is good quality concrete yet by virtue of the fact that the rods do not go around the jacking rod, the jacking rod at the right place, failure load is less than half the value for as designed."

Then he continued thus as far as design is concerned:

> "If we look at B3 and B3A we will find that the failure occurred - this B3 and B3A, I am reminding you, is as designed, the failure loads were - the correction is as to those failure loads from Exhibit 40A, which should read 15.91 and 12.72 and not 13.55 and 12.47. In fact, as designed load carried was not too dis-similar to specimen B1, the 15.91, that is an identical load for one of them and slightly less where the concrete is not so good, of only 12.72 kips feet."

Mr. Minor then commented on the tensile tests thus:

> "They might be failing due to the bars actually pulling out, and I would suggest that that is not the actual reason why they failed because the photographs don't tend to show the bars pulling out otherwise one would see the bars and one would see a piece of concrete - one wouldn't see a fractured piece

> of concrete. alternatively it could be due to a tensile failure in the concrete thus producing a crack straight through the specimen and the hooks just straightening after that, and it could be due therefore to the average tensile stress across the specimen. That is the value that was put in the table; you remember it aired between 173 and 73 psi, and it could be due to the average tensile stress in the concrete causing the crack and then the thing falls apart.
>
> The third reason it may be happening is that you get very high tensile stresses in the curve of the bars, at the hook and it may be at that point that crack starts propagating. This is very high local stresses that occur due to hook."

Then the following important observation was made:

> "A: On the tensile tests, M'Lord; two general observations can be made. One is that the actual stress in concrete at the time of failure does not have to get up to the modulus of rupture for it to fail, and secondly. ..
>
> Q: It does not have to?
>
> A: It does not have to get anywhere near the value of the modulus of rupture in order to fail; and the second thing that becomes clear is that the strength is determined by the amount of embedment of the bar into the specimen rather than the geometry of that embedment. So it is the amount by which the bar is embedded which determines the strength and therefore, when the bar does not go around the jacking rod, the jacking rod is 7.4 inches in haunch, if it does not go around then it is not embedded as far as it would be if it did go around the jacking rod. If it was to go around the jacking rod it must go beyond the 7.4 inches, and therefore, if

the bar does not go around the jacking rod it is not embedded so much, and therefore, it is not as strong as it would have been had it been embedded further enough to have gone around the jacking rod. So the question of the jacking rod having a purpose or being instrumental or not in collapse is purely one of the facts that if it goes around the jacking rod it has a larger embedment than if it does not go around the jacking rod."

An important comparison was made between the tests and the actual loadings condition in the silos thus:

"Q: Did any of the tests have alternating loading, first one side and then the other?

A: No, these are all loads which were applied in one direction only and they were applied until the specimen failed, so they were not put on taken off, put on and taken off, or which is even worse in the case of silos, put on one side and taken off, then put on the other side and taken off. So in these tests if the crack starts on one side it remains on that one side, whereas if you have the silos you might have crack starting on one side, one would then unload and then one would load the other way around, and then you would get crack occurring on the other side they would then migrate towards each other whereas in this case the cracks all have to start from one side only. So I would expect the values given in these tests to be - they would not be weaker than - definitely I would expect them to be stronger than the actual values at the silos because the loading is not either repetitive or from one side then the other side.

Q: What would happen if the loading did alternate?

A: Well then the cracks that are found in the specimens - quite earlier on we find the cracks - if one looks in detail at, for example, the first one, I open on page 46, table B.5, Load Stage 1, you see the applied load is 2.216 kips, and this table that we happen to have chosen, this is for specimen B3A, you will see that 2.216 is the first load, there is a maximum of 9.361 that falls just under a quarter loading, but the first crack has started at the start of the haunch, that is Mr. Cader's section CC, so with quarter of the maximum loading you see it starts cracking at one side of the partition, where the partition joins the haunch. If one were to take the load off and then turn the specimen upside down and reapply the load then the crack would then occur on the other side of the wall and one would have cracks on both sides of the wall. So because of this alternating loading that crack will very soon migrate to the centre of the wall and would crack section CC which is what I would expect, and which Mr. Cader has said would occur. The further thing, of course, when you get towards the ultimate stress - close to the ultimate strength, when the load is applied, the structure is distorted and cracks occur as has been shown in photographs, although the photographs were being taken at the time when maximum load had already been put. The cracks appear marginally from the maximum load. So the cracks would appear then if the load was taken off and is applied the other way around. A similar set of cracks would occur on the other side and it's probable that these cracks would occur one side then the other and in fact would occur at a lower load as well. I do not know how much lower then it would occur because it was only loaded from one side at one time."

All this was to culminate in the calculations of the factors of safety on the insurers' terms in contrast to that obtained by Mr. Cader. The passage reads thus:

> "MR. GEORGE: Q: Now, Mr. Minor, could one therefore compare the force in the reinforcement of the test B5 at failure with the reinforcement in the silos under the various loading conditions?
>
> A: Yes, one could.
>
> Q: To obtain the correct factors of safety?
>
> A: Yes, one could work out the correct factors of safety relative to the test that Dr. Mitchell and Dr. Cook did.
>
> Q: Did Mr. Cader do such calculations - did you hear him say he did it?
>
> A: In re-examination he said that he had done such calculations.
>
> Q: Is it here on page 3721 of the notes of evidence? Did you find them on page 3721 where he said the factors of safety as calculated by him are 4.75 for tensional load and 3.73 for bending and tension?"

Then this followed:

> "I again calculated the factor of safety of this particular loading case as compared with the test B-5, and that is 9.54 divided by 8.86, and I get a factor of safety of 1.077 at which time the collapse is imminent.
>
> Q: So, Mr. Minor, your calculations as demonstrated show that for a typical wheat under dynamic loading with the strength of the haunch as found in the Mitchell's test for

> the bars placed not around the jacking rod, you calculated factors of safety both slightly less than, and slightly above 1?
>
> A: That's correct.
>
> HIS LORDSHIP: The factor of safety above 1?
>
> MR. GEORGE: Slightly less than and slightly above 1. Mi'Lord, they were 0.91 and 1.077. I will move on to another matter."

This is a far cry from Mr. Cader's optimistic figure. Then for the record of this section it is pertinent to quote Mr. Minor's citing O.F. Thiemer on Safety Factors since this is part of JFM's particulars :

> " 'Safety and stability of a reinforced concrete structure depends on a number of circumstances.
>
> A structural unit will seldom fail because of a single defect or a mistake in the statistical analysis. Rather, it must be assumed that the failure is caused by a number of structural deficiencies.
>
> The safety factor of N=1.75 provided in most reinforced concrete specifications give enough reserve strength for small mistakes or faulty construction methods. If the safety factor is reduced however, the over pressure during emptying of bins or the shifting of underlying soil or the failure of a pile formulation may lead to complete failure of the grain silo.' "

Mr. Minor on the Jenyke & Johanson report

This report gave the opinion that there were several design features of the silos which were inadequate:

> "1) Inadequate bar anchorage to allow full fixity at end of partition walls.
>
> 2) Inadequate bar anchorage to allow proper transfer of tension force in the exterior walls through the junction to the partition wall.
>
> 3) All bar anchors in the haunch at this junction are in the same vertical line.
>
> 4) A single layer of rebars.
>
> That is reinforcement -
>
> ... in the circular walls where flexure is bound to occur.
>
> That is what they are saying. There ought to be a second layer of steel in the curved walls at certain points. Then-
>
> 5) 'Inadequate amount of reinforcement in the partition walls to resist tension and flexure.'

Then they go on to explain flexure bending. Jenkye and Johanson gave a second report in January 1993. The previous one was in January 1989. The first point they made was as follows:

> "Basically, they say that the competent silo designer working in the United States in 1966 would have used Jannsen's method - which is the method that both I myself and Dr. Zetlin used - but they say they should have chosen conservative parameters in the

equation, or should have allowed for some sort of dynamic pressure as well because dynamic pressure effects were known at the time even if they were not codified, or perhaps they should have used both conservative values and dynamic pressure as well. That is the first point they made."

As to why the silos lasted 20 years, although the design and construction was faulty, the following explanation was given:

> "Even if hooks had been allowed, the dimensions chosen by the designer were not in accordance with either British or US standards in effect at the time for end anchorage (i.e. at the end of a beam or the edge of a slab)."

They further state:

> "By not hooking many of the reinforcing bars around the jack rod in the outer haunch between silos 10 and 18, this caused an area of weakness through which a crack could easily propagate when bedding stresses were applied to the partition wall. The resulting joint between the haunch and the partition wall was very flexible. With a very low residual bending stiffness this joint carried only tensile forces between the haunch and the partition wall, which accounts for its prolonged survival, more than 20 years, from initial cracking to failure.
>
> Q: Would you explain that?
>
> A: Basically they are saying once the crack gets large enough then there is movement which could occur within the structure because of the crack width and therefore, it would not have to take so much bending moment.

Bending moment calculated, assuming that the thing is fairly rigid and once it cracks it loses its rigidity. ..

Q: It becomes more flexible?

A: It becomes more flexible; it loses rigidity at that point. Now the interesting thing is that the bending moment is resisting forces. So that although if you make it more flexible one place, that place may reduce the bending moment at that point to resist the forces. The forces are still there, the bending moment has to move to another place within the silos to continue the resistance. So by reducing the bending moment in one place you are likely to increase it somewhere else; so you may start getting cracks somewhere else as a result of it starting to crack at one point. So there may be movement of bending moment to other positions."

As for the area of failure in silos 10 and 18:

"Now if the amount of slip is enough for it to fail then you have a catastrophic failure. If on the other hand, the amount of slip at that point in order for the load to be transferred to another route or load path then if it means that, it just slips one hundredth of an inch. So each time it is loaded it might just slip one hundredth of an inch until perhaps after many years there is no more of an hundredth of an inch to go, it cracks.

They then go on to deal with the geometry of the bottom hoppers because they are talking about the outflow of grain causing very high stresses which they mentioned in their first Report. Although in the first Report they know where the hoppers were relative to bins 10 and 18 because they had pictures they didn't know where the hoppers were in relation to the remaining silos, and so they are now comparing silos 10 and 18 with the other silos in the back and the relative position of the outward channels. What they are saying is that -

> According to our knowledge of the internal frictional properties of wheat, the point at which the boundary of the flow channel struck the silo walls in the silos 10 and 18, could have been as low as close to the top of the hopper or as high as elevation 50', and it undoubtedly varied with time between these two elevations. In the other exterior silos, where the channel of flowing grain lies against the interior wall in the corner of the hexagonal shape, there is much less peak pressure applied to the opposite wall. It is evidence therefore, that the exterior walls of silos 10 and 18 and their connection to the partition wall were subjected to a far higher load than any other similar haunch connection in any other part of the structure. Therefore it was here that failure would first be expected."

So the double pressure in a narrow area in the shape of an ellipse (Minor) or a patch (Cader) due to unloading is also explained by Jenyke and Johanson. This explanation must be grasped to understand how faulty design and bad construction caused the rupture. In lawyers language this is the issue of causation.

On the adequacy of design this was said:

> "The JFM silos were not only underdesigned in comparison with today's practice, but they were underdesigned with what a prudent engineer would have done on both American and European practice that was available in 1966."

The important computation of factor of safety runs thus:

> "Factors of safety against failure of the exterior walls of silos 10 and 18 were between 1.37 and 2.70. Corresponding values for the partition wall between them was between 1.02 and 1.33."

This important aspect of their opinion is to be noted:

> "Zetlin's analysis suggests that the load which caused the failure along the junction of the interior partition wall between silos 10 and 18 and the haunch at the exterior was caused by a large shear load in the vertical direction. This is a ridiculous conclusion.
>
> We are saying that shear load would cause diagonal cracking; they were saying that the shear load caused the failure in the vertical direction, that it was a large shear load - and they say that is a ridiculous conclusion for other reasons, perhaps."

The report also has a valuable opinion on inspection. It reads:

> "A: Inspection of the inside of either silo 10 or 18 following Gilbert and before the failure would probably have revealed a well established and easily visible crack in the concrete at the junction of the partition wall with the outer haunch. As we argue above, in the sections on Force Resultants, Flow Patterns, etc., such a crack probably formed very early in the life of the silos, and had been growing wider progressively until failure occurred when the reinforcing bars were able to pull out of the concrete of the haunch. such a crack would also have been present if the failure mechanism suggested by Zetlin had occurred. However, the existence of such a crack would not demonstrate the correctness of Zetlin's theory to the exclusion of any other. Indeed,

> since it probably would have been possible to determine if this were an old rather than a new crack, the presence of an old crack would have conclusively disproved Zetlin's hypothesis."

Earlier they gave the following opinion which is important having regard to the pleaded defence on the necessity for inspection after Gilbert:

> "Following any natural disaster such as an earthquake, hurricane or other accidental loading event, it is always wise to conduct a survey of a silo or elevator structure to check its structural soundness and look for damage. The inspection made of the JFM silos was, in our opinion, inadequate."

In emphasizing the rule of Codes of Practice as standard for the engineering profession, Mr. Minor said:

> "A: It's a document which contrives or attempts to put down what the engineering profession - it might not be an engineering Code of Practice - thinks is the correct method of specifying, designing or testing an object, it's a distillation of the engineering practice of that time, but more than that, it is really used because it is necessary for there to be some measure against which the designing, construction of structures can be measured, and it's a frame of reference and more importantly I suppose from a public point of view, it is a measurement of quality and in particular a measurement of safety. If the requirements of the Code of practice have been met then it (sic) a measurement of safety, measurement of quality and it is a measurement that it's safety has been considered."

He further explained it thus:

"Well, because the concern of the Code of Practice is primarily one of safety, the values they give is one that agrees with the minimum values that have been obtained in the laboratory tests. So the values calculated from a Code of Practice would tend to be the lowest value that would obtain in practice."

The strength used to calculate the factor of safety is important. It was put thus:

"A: Well the strength you have to take is the least strength that the structure might have because if you assume that it had the average strength, or the structure might have the maximum strength, you are not really working on a factor of safety. So you have to consider the least strength the structure would have. So you are going to compare the maximum possible load with the minimum possible strength."

The haunch was critical in silos 10 and 18 so the following provision in the Code is important:

"The Clause 805(b) says -

'For splices in reinforcement in which the critical design stress is tensile ..."

And that is the case at this haunch; the critical design stress is tensile.

Q: So this is applicable?

A: It is applicable. It says -

'Splices at points of maximum tensile stress shall be avoided where possible.'

And in fact this is a point of maximum stress. So they should really be avoided if possible according to this. Then it goes on to say -

"Such splices where used shall be welded, lapped or otherwise fully developed. In any case the splice shall transfer the entire computed stress from bar to bar without exceeding three-fourths of the permissible bond value given in this Code."

The following passage reveals the design weakness:

"Now at the haunch in the actual silo, more than half of the bars are spliced within the length of 40-bar diameter. 40-bar diameter is 40 times 8. In fact all the bars are spliced and anchored at the same place, so the design should as called for splicing, if splicing is to occur at that point, then this Clause comes into effect, which says that -

'where the splices are made at points of maximum stress ..."

which it is -

'or where more than half the splice at the point ...'

which it is -

'... special precaution shall be taken such as an increased length lap.'

We know the minimum is 15 -

'... and the use of spirals or closely spaced stirrups around and for the length of splice.'

We know that there were no spirals, there were no closely spaced stirrups, so it falls down badly on this, and it should have had 15 inches lap, it didn't."

This is the evidence which satisfies a tribunal that the insurers have proved their case on a balance of probabilities.

(VI A) Professor Mitchell's evidence on the insurers' case that faulty design and construction were the cause of the collapse of silos 10 and 18.

To appreciate the role Professor Mitchell's evidence played in this case, it is appropriate to set out the grounds of appeal relating to this aspect of the case. They are as follows:

> "31. In relying on the evidence of Professor Mitchell to support the opinion of Mr. Minor that the proximate cause of the rupturing of the structure was faulty design and detailing, and deficiency in construction, the Learned Judge ignored the fact that Professor Mitchell was not consulted to investigate and did not investigate the cause of failure and therefore, not in a position to give meaningful assistance to the Court as to the cause of failure. Professor Mitchell was only consulted to conduct laboratory tests to investigate the adequacy of the hook anchorage details in the silos. The results of his tests were admitted in evidence as exhibit 40.
>
> 32. In relying on the work of Professor Mitchell to support the opinion of Mr. Minor as to the cause of failure, the Learned Judge has ignored and disregarded the powerful evidence in the case that exhibit 40 strongly supports the opinion of Mr. Cader that the strength of the Joint that failed was more than adequate to cope with the normal operation of the silos."

A few extracts from Proffessor Mitchell's curriculum vitae will demonstrate his calibre as an engineer:

> "Q: You are also Professional Engineer in the Order of Engineers of Quebec.
>
> A: Yes.
>
> Q: You are a Member of Engineering Institute of Canada; a Fellow of the Canadian Society for Civil Engineering; Fellow of the American Concrete Institute; Member of the Prestressed Concrete Institute; Member of the American Society of Civil Engineers; Member of the Earthquake Engineering Research Institute.
>
> A: Yes."

Then:

> "Q: If we turn the page, item 2, you received an Award from the American Concrete Institute, Reese Structural Research Award for co-authoring the paper entiled (sic) 'Progressive Collapse of Flat Plate Structures', presented at the Annual Convention of the American Concrete Institute in February 1981.
>
> A: Yes.
>
> Q: and going further down the page, you have membership on Technical and Code Committees. You are a Member of the American Concrete Institute Technical Committee 408 - Development of Reinforcement from 1974 to the present time, and you are currently Chairman of that Committee.
>
> A: Yes."

Then the final extract reads:

> "Q: And finally, Examples of Experience as an Expert Witness, you served as an expert witness in legal cases involving a number of structural engineering problems. Examples include a large auditorium with a cracked ring beam, a pre-stressed concrete tower, a large precast concrete warehouse structure, a multi-storey reinforced concrete core structure, and a case involving the misuse of a large amount of reinforcing steel.
>
> A: Yes.
>
> Q: In fact, Professor, you have investigated for the Government of Canada a number of failures in various parts of Canada and the world.
>
> A: Yes, that is correct."

Then turning to his specific merits in this instance:

> "Q: Now tell me, Professor, were you asked some time in January of this year by Jenike and Johanson Limited to investigate the adequacy of the hooked anchorage details used in the Flour Mills silos?
>
> A: Yes, I was."

It was necessary to advert to Professor Mitchell's qualifications to notice the calibre of witness which impressed Panton J. It should also be noted that Mr. Minor was examined on important aspects of Professor Mitchell's report. Therefore in this segment, only those areas which were not covered previously will be addressed.

The following passage is relevant because it conflicts with Mr. Cader's opinion. Having regard to the findings of Panton J, he must have accepted Professor Mitchell's opinion. Here is the passage:

> "Q: Now Professor, Mr. Cader has told us - Mr. Cader was the expert witness for the Plaintiff - Mr. Cader has told us, and we have it at page 2733 of his evidence, that where the horizontal bar goes around the jacking rod, this forms a stirrup. In fact, when I asked Mr. Cader this and he gave me his answer, and I asked him what is a stirrup and he answered and said he knew better than I did - which I have no doubt, He said where the horizontal bars go around the jacking rod this forms a stirrup - so said Mr. Cader. Do you agree with that?
>
> A: No, definitely not. There are no stirrups in this region whatsoever and you cannot count the hooks nor the jacking rod as providing any service that a stirrup can provide."

Then as the haunch was of importance in this case, it is instructive to have Professor Mitchell's words first hand as regards splicing and staggering:

> "HIS LORDSHIP: You need lapped splice there?
>
> A: Yes. Instead of hooking the bars one would lap the reinforcing bar by a sufficient length to give it a chance to transmit the load from one bar to another. And you asked about a prudent engineer: a prudent engineer would perhaps use the ACI Code as a starting point which would require the fifteen inch basic length increased by three inches to give eighteen inches, but then as well at the construction stage, and the method of construction an engineer might have accounted for as well the top bar effect

> which is the situation when you have more than twelve inches of concrete placed below a bar.
>
> So the 1963 Code at that time reduced the bond strength by multiplying by a factor of 0.7, so the eighteen inches would have had to be increased by 0.7 and that, I have done the calculations, come out to about twenty-six inches; but that would not have been enough either because a prudent engineer as you put it, would have staggered the splices. We do not like to have planes of weakness in the structure and so one would stagger the splices in different locations so that one doesn't have one single plane of weakness, so that certainly would be carried out."

As for the knowledge available on lapping and staggering, here is Professor Mitchell's account:

> "MR. GEORGE: Q: Now was any guidance on this matter for practitioners to be found in any text-books at the time when the silos were designed in the early 1960s?
>
> PROF. MITCHELL: A: Yes, there were a couple of English books out from England by two authors, Gray and Manning.
>
> Q: Gray and Manning; when did that come out?
>
> A: I am going by memory: I think the Gray and Manning textbook had a number of printings; the copy I was looking at was printed in 1953. That is one of the textbooks; another one that came out a little bit later I believe 1960, and both of these books were on the design of silos, bins, reservoir, and gave details of reinforcement."

Also there was Reinbert and the account of his work was given thus:

> "Q: There was also a textbook by a gentleman called Reinbert.
>
> A: Reinbert is a French author and I believe his textbook came out in 1965.
>
> Q: Did he recommend any types of bars or overlap?
>
> A: Yes. He gave some drawings of some tanks or bins and he uses extra reinforcement in the haunch to help transmit the forces and those extra bars are added to the haunch. First of all, the extra bars coming into the haunch go well past the haunch to the other side have hooks on them, in his case. He used 180 degrees bin hooks."

Then the Professor gave his opinion on the design of the silos. Here are his sage words:

> "A: Well, if I had to give a single word it would be 'inadequate' simply because there are no splices of the reinforcement and that is what should have been provided in this case."

There is a further defect which must be highlighted:

> "Q: And the details that you saw, could they transmit the appropriate tension?
>
> A: No, they could not. The hooks as detailed are really no replacement for splice. There is another problem: The details as indicated on the drawings with the barely overlapping hooks caused a point of high concentration of tensile stress in the concrete."

It should be borne in mind that it was the area of the haunch which was being discussed. The discussion went thus:

> "MR. GEORGE: Q: What part of the concrete?
>
> A: The concrete, for example, looking at fig. 2.1(a), the potential crack that is indicated going through the hooks, this is if they were properly placed ...
>
> Q: That is in the haunch?
>
> A: That is in the haunch. at that section the bars are delivering very concentrated force, and ..
>
> Q: You say at that section the bars are delivering a very concentrated -?
>
> A: Tensile force, and that is loading the concrete in tension and that can cause a premature collapse or failure of that section."

The significance of the absence of hooks at vital points as a probable cause of failure was examined. Here was the response:

> "MR. GEORGE: Q: I will come back to that in a moment. You mentioned misplacing of hooked bars: what effect, if any, would that have?
>
> A: Well, the misplacement of the hooked bars says, as indicated in fig. 2.1(b) would definitely lead to four problems. We have a higher tensile stress in the concrete. As you can imagine, looking at fig. 2.1(b), and realizing that the bars in the straight partition wall are say, in tension then transfer the force at the end of the hook of those bars coming from the curved wall, the concrete must resist tension.

> There is no other mechanism for transferring the force and the concrete is -- this creates a plane of weakness because the concrete is weak in tension and the tensile strength is very unreliable in actual structures."

This is a very important statement because Mr. Cader for JFM emphasized the actual structure, as if the design and construction did not determine the strength of the actual structure. It continued thus:

> "Q: What effect does that have on the haunch?
>
> A: It could fail in the haunch, and there is no staggering of hooks."

On the quality of the concrete the Professor gave this evidence:

> A: Well, the quality of the concrete is poor, very poor, and it has an unacceptably high variation. Furthermore, if we were to calculate the characteristic compressive strength from these eight samples, the characteristic strength, the one that you would use in calculating the compressive strength is 980 psi; it is a very low value."

Professor Mitchell was asked what of the consequences of loadings. Here is his answer:

> "A: Well, in the region where failure took place in the actual silo, its close to the transition between the straight wall and the haunch, and the haunch region, there is a significant number of -- in the silos in general there is significant number of what we call reversed cyclic loading, the straight wall bending one way and then the other way backwards.
>
> Q: How does that happen?

A: Well, for example, if you visualise the critical bins that we are talking about, bins number 10 and 18, if we visualise bins 10 and 18 totally full with grain, then the grain would push against the partition wall and bend the wall towards bin number 18 and this would cause ..

Q: Bin 18 would be full or empty?

A: Bin 18 would be empty, 10 would be full; 18 would be empty and the pressures from the grain would bend the partition wall towards bin 18 and could cause tension cracking on the face of the partition wall on the side of bin 10. Now if we reversed that, if we have a situation where bin 10 is empty and bin 18 is full, then just the reverse would happen: the partition wall would be pushed and it would bend towards bin 10 and you get cracking in the partition wall of the haunch region and on the side of 18; that would be one reversal of loading and of course over the years...

Q: What is actual reversed? How would you express it?

A: It is the moment and the shear that are reversed, the bending moment and the shear are reversed, first one way and then the other but this happens time and time again as the silo was used.

Q: Is the stress also reversed?

A: The stress is reversed exactly and tension stress causes cracking.

Q: So this is why it is called reversed cyclic loading.

A: Yes."

He continued thus:

> "A: Yes, it does. Cyclic loading has an effect on almost everything, including bond. If you were trying to develop a force in the reinforcing bars such as the hooked bars leading into the haunch you would have to develop bond stresses between the steel bars and the concrete, and if you cycle the load as it happens in the silos, then the bond strength would be reduced, most definitely. This is a process which is progressive; it is a deterioration process: the more you cycle it the more the strength deteriorates, so it is an ongoing process, cyclic loading."

Then the consequences are stated as follows:

> "A: Well, in this case with the hooks anchored in the haunch region the reverse cyclic loading would cause some bond deterioration; this deterioration would take place over time, the situation would get worse and worse.
>
> Q: Over time.
>
> A: Over time, absolutely, and really that is why we use very long splice lengths in critical regions like this to avoid this problem and furthermore, we stagger these splices to avoid the problem as well."

Professor Mitchell on Factors of Safety

Perhaps the most important area for a structural engineer in design and construction is the correct computation of the factor of safety. The Professor's computations were very close to that of Mr. Minor. Here is how he put it:

> "Q: My question then is, Professor, do you agree or not with the manner in which Mr. Minor determined the factor of safety in

> your test, assuming the loading he used is correct?
>
> A: Yes, I agree, I have checked over his numbers as well, I agree with the approach entirely and get nearly the very same numbers by using a computer analysis. However, none of these calculations account for the factor of the cyclic loading which was present and doesn't account for the tremendous variations in the concrete strength and quality and existing cracks and honeycombs of the structure, so these are other factors and it's very difficult to take account of those factors, but those factors would definitely be there and that reduced the factor of safety as calculated."

Zetlin Argo's contention was that it was the force of 44.84 kips which cracked the haunch. The reasoning in this judgment does not accept either the method by which that figure was computed or the figure itself. The basis of the computation was that there was differential settlement in the southeast caused by the windload generated by Gilbert. This caused a differential twist and the forces generated by the twist were locked in and caused the haunch to crack. A zipper like effect resulted and the crack extended upwards. Using the estimated differential settlement, Zetlin Argo used the process of trial and error, iteration to compute the locked in force generated by the differential twist.

Sections (1) (11) (111) and (1V) of this judgment were intended to demonstrate that, that theory was not proved by JFM. So the figure of 44.84 kips was an assumption and ought not to be regarded as a finding of fact.

It is very important to grasp that the insurers case was that, if there was proper design and construction, or if there was maintenance to bring silos up to the requisite standard to cope with dynamic forces, then silos 10 and 18 would not have failed. We now continue the Professor's account. It ran thus:

> "HIS LORDSHIP: You said none of these calculations in this document took into consideration the reverse cyclic loading and what else?
>
> PROF. MITCHELL: A: They didn't take into account the reverse cyclic loading and they did not take into account the quality of the concrete which is highly variable.
>
> HIS LORDSHIP: And you said that these additional factors would lower the factor of safety?
>
> A: Most definitely and the poor quality of the concrete such as the cracking and the honeycombing."

Then some very important questions were put:

> "Q: Professor, you have explained the necessities for proper splicing and staggering of the reinforcing steel, can you tell us the strength in tension of one foot of wall if there was proper splicing and staggering?
>
> A: Yes. If you have instead of the hooks, if you had proper splicing, and if you had the splicing staggered in order to avoid that plane of weakness, then instead of having tension failure in the concrete, in the region of the haunch, then the strength would be dictated by the reinforcement, the reinforcing bars themselves.
>
> Q: The strength of the reinforcing bars.

A: And so if you were to load it with extreme overload, for example, then the bars would -- you might get some cracks, particularly in the great wall portion, partition wall, then there would be crack in that wall probably around transition to the haunch and then the steel would yield and then further loading would bring the steel to its ultimate strength.

Q: So it would be able to bear a load right up to the ultimate strength?

A: Most, likely, yes.

Q: Now, can you calculate the ultimate capacity of those bars so that we would know what stresses the steel would stand up to its ultimate strength?

A: Yes, that would be easy to do if I could find the right figure. I am looking for the Zetlin Argo Report which gives the ultimate strength.

Q: Would you like to look at Sheet S-1, it's the calculation. Can you calculate for us the ultimate capacity? M'Lord, I think he is looking at the Wiss Janney Report. What I asked him, he wanted to look at the calculation of the Zetlin Argo calculation. Isn't that what you asked for?

A: You were asking me to calculate the tensile strength of one foot wall and I just wanted to check on one figure which is tensile strength of the reinforcement which is given in the Zetlin Argo Report. There were five tests done on the Number 5 bar, and if I take the lowest value which is the strength, ultimate strength, it's 78,150 psi, and to get the strength of the reinforcement, if you pull it in tension, if it was properly spliced and staggered it would be calculated by multiplying; if I change the stress to psi it would be 8.15 times two bars each, times two, times 0.413, and the number I got here is 64.55 kips per foot of wall.

Q: And if you look at S-1, Exhibit 18, I think it was calculated by Zetlin Argo and you came up with the same figure of 64.55 kips, is that correct?

A: Yes, using the 78,100 psi ultimate stress in steel. Down here at the bottom of the page the ultimate force, it's the same calculation, in fact, the ultimate force is 64.56.

Q: Now, would a load of 44.84 kips per foot of wall cause the wall with proper splicing and staggering of the bars to fail in tension?

A: If the load was 44.84 kips and the bars were staggered and spliced, it would carry a load bigger than 44.84, it would carry a load of 64.55 kips per foot.

Q: And so the wall would not have failed?

A: Under that load no."

To my mind, the insurers have proved convincingly that it was faulty design and construction which caused the failure of silos 10 and 18 and so the grounds of appeal considered in sections **(VI), (VIA,) (VB,) previously** cannot succeed. There is just one more area to explore on the issue of faulty design and construction. Zetlin Argo had eliminated design and construction as factors which could account for failure of the silos. So if Mr. Cader made admissions on the issue of faulty design and construction as adumbrated by Mr. Minor and

Professor Mitchell, then that would support the insurers' case. It is to that important issue we must now turn.

(V1 B) Were there expressed or implied admissions by JFM that the collapse of silos 10 and 18 were attributable to faulty design or faulty construction

In examining this issue, it is necessary to revisit the contractual terms of the insurance policies and the case of **Queensland Government Railways Electric Power Transmission PTY Ltd. v Manufacturers' Mutual Insurance Ltd.** (1969) LL Rep. 214, as the principles of law advanced in that case must govern the evidence on this issue.

To return to the Lloyd's policies again the relevant term so far as material reads:

> "2. The Underwriters shall not be liable for loss or damage occasioned by or attributable to:
>
> (a) <u>faulty design or construction</u> of, or the removal or weakening of supports to, any property described in the Policy." (Emphasis supplied)

Be it noted that there are two exemptions, faulty design or faulty construction. Therefore, if there are admissions by JFM that there was faulty design or faulty construction, then on that basis JFM cannot succeed, since the insurers would have established on balance of probabilities that it was faulty design and faulty construction which caused the rupture in silos 10 and 18. The attempt will be made in this section to show that Mr. Cader the structural engineer for JFM on this issue, made admissions which destroyed any hope that JFM had of succeeding in their claims.

In assessing Mr. Cader's evidence, the first issue to be decided is what meaning is to be attributed to the word design in the policy. Design must be related to function. The silos must have been designed to load, store, and unload grain. If therefore silos 10 and 18 were not designed to cope with these functions, then there would be faulty design. The **Queensland** case supports this stance. Here are the relevant citations bearing in mind that this case was a design case. Mr. Justice Windeyer said at p. 218:

> "... But a man may use skill and care, he may do all that in the circumstances could reasonably be expected of him, and yet produce something which is faulty because It will not answer the purpose for which it was intended. His product may be faulty although he be free of blame."

Let it be noted however that a faulty design may be the result of a blameworthy designer. That might be the situation in this case where there is evidence that some consequences of dynamic loading ought to have been known to any competent designer in 1966. Moreover, any competent consulting engineer retained to advise on maintenance would have suggested the appropriate recommendation to strengthen the silos.

Against this background it is revealing to examine the evidence of Mr. Cader on the issue of design:

> "Q: Mr. Cader, all through the history of the silos, dynamic pressure did take place, is that so?
>
> A: Yes."

Then the cross-examination mentioned:

> "Now sir, am I correct in saying that you considered the question of loading and unloading over the history of the silos in considering the factor of safety?
>
> MR. CADER: Of course, we put our consideration into this load condition in this letter and we never expressed that it was our investigation based on the dynamic load. It was very clearly shown that our investigation was based on 1966 design requirement.
>
> MR. GEORGE: So in other words, in investigating, you were looking at the design, correct?
>
> A: Yes."

That design was recognised as an issue and that it must be related to the operation of the silos was evidenced by the following passage:

> "Q: You were doing what you are now telling this court it should not do, looking at the design when you were investigating?
>
> A: We did two steps, one was design, one was as built and based on the required load ...
>
> Q: You did one as designed?
>
> A: Right.

Q: And one as built?

A: Right.

Q: Did you do one as operating?

A: No."

This admission must be fatal to JFM's case. How can there be an effective investigation into the failure of the structure, if such an investigation did not include the operations of the silos from 1966 to 1988?

It seems at one stage Mr. George for the insurers combined faulty design and construction as one issue so his question was as follows:

> "MR. GEORGE: Mr. Cader, you know perfectly well, I put it to you that you know perfectly well that when you are dealing with investigating the factor of safety, you are looking at a factor of safety not from the point of view of designing but from the actual operation and use of the silos, isn't it Mr. Cader?
>
> A: You are perfectly right. If I were asked to check the silos as exist, what safety factor they have, I would go through this exact process that Mr. George is asking about."

Then His Lordship in one of his timely interventions said:

> "HIS LORDSHIP: Let me see if I understand you correctly. You are saying that assuming nothing had happened, no disaster and you were asked to check on the safety factor, you would have approached It that way?
>
> A: Yes, I would go with the dynamic, of course."

The confrontation continued thus:

> "MR. GEORGE: I am not suggesting that you are yet. Mr. Cader, in other words, you never considered the possibility that over the years the dynamic loading would have weakened or rather not weakened but would have caused a crack and that crack would have propagated and/or bonds would come undone and collapsed, you never considered that possibility?"

Although at that stage JFM's factor of safety was the issue, it is clear from the answers that Mr. Cader admitted that the 1966 design on which the silos were built did not cater for dynamic pressures from unloading and to that extent, it was a faulty design. But Mr. Cader must have been aware of the consequences of ignoring dynamic loading in the design and construction of the silos. To be aware and not to point it out to JFM was to merit the harsh words of Panton J on Mr. Cader's conduct in the witness box.

In order to appreciate the extent of the learned judge's criticism, it is necessary to cite some passages from the agreed bundle Exhibit 34 prepared by Jenkyn and Carson:

> "**Executive Summary**
>
> 1. A competent silo designer working in the United States in 1966 would have used Janssen's method to calculate silo pressures but would have either chosen conservative parameters for this equation, included a coefficient to account for dynamic pressure conditions, or both.
>
> 2. Research conducted since 1966 has shown that much higher, localized loads can

> be exerted on grain silos of the type at JFM. Much of this work has been published, and some has been codified."

This feature has been noted previously by Mr. Cader Mr. Minor and Jenyke and Johanson.

The summary continued thus:

> "8. In exterior silos 10 and 18 and also possibly in silo 11, the channel of flowing material, since it originated close to the centre of the bottom of the silo, expanded with increasing height to the point that the boundary of flowing material struck the wall at some height. According to our knowledge of the internal frictional properties of wheat, the point at which the boundary of the flow channel struck the silo walls in silos 10 and 18, could have been as low as close to the top of the hooper or as high as elevation 50', and it undoubtedly varied with time between these two elevations. In the other exterior silos, where the channel of flowing again lies against the interior wall in the corner of the hexagonal shape, there is much less peak pressure applied to the opposite wall. It is evident, therefore, that the exterior walls of silos 10 and 18 and their connection to the partition wall were subjected to a far higher load than any other similar haunch connection in any other part of the structure. Therefore it was here that failure would first be expected."

The special features of silos 10 and 18 which made them likely to be ruptured earlier than the other silos was noted earlier by Mr. Minor. The summary further stated:

> "9. The JFM silos were not only underdesigned in comparison with today's practice, but they were underdesigned compared with what a prudent engineer would have done based on both American

> and European practice that was available in 1966."
>
> ...
>
> 12. Factors of safety against failure of the exterior walls of silos 10 and 18 were between 1.37 and 2.70. Corresponding values for the partition wall between them was between 1.02 and 1.33.
>
> ...
>
> 19. Since the imbalance load on the partition wall is at a maximum when one silo is empty and the other full, Zetlin's argument about the weakening effect of the hurricane is not credible. The imbalance load on the partition wall between silos 10 and 18 was greater the day before the accident than when the failure occurred. On the other hand, this does support our argument that, because of design and construction errors, the silos were structurally weak initially and gradually became weaker with time. Whether the failure occurred two weeks, two months or two years before or after Hurricane Gilbert was of no significance. Failure was inevitable at some time."

It is in the light of the findings by Jenkyn and Carson that the following passage from Panton J on Mr. Cader's admission must be understood:

> "In commenting on extracts from Exhibit 34, Mr. Cader said that the slope of the bottom of silos 10 to 18 was far too shallow to allow mass flow, that is, a condition in which the grain would slide continuously along the entire slope of the bottom hopper from the outlet to a point at the junction between the top of the hoper slope and the vertical silo wall."

What were some of the consequences of faulty design as stated by Mr. Cader bearing in mind that the faulty design of silos did not take into account dynamic pressure:

> "Q. Mr. Cader, do you remember saying to me -- saying to the Court on the 1st of March, or some time earlier in cross-examination that taking the dynamic pressures into account you would get cracking at the 8-inch section?
>
> A. Yes, I admitted it. The only thing you should remember is that I also qualified the dynamic pressure which is used for the design purposes.
>
> Q. You have told us, Mr. Cader, that the dynamic pressure is only for the design purposes, and I put it to you that dynamic pressure happens everyday of the operation cycle?
>
> A. Yes, from that standpoint.
>
> HIS LORDSHIP: This was cracking at what area?
>
> MR. GEORGE: The 8-inch section.
>
> HIS LORDSHIP: That's B-B, isn't it?
>
> MR. GEORGE: B-B, yes, M'Lord, and also at the 9-inch section where we have a factor of safety taking the dynamic pressure into account of 1.05, you said it was very poor?
>
> MR. CADER: A: Yes, it was my statement, yes.
>
> Q: And -- well, being very poor could crack as well?

A: Yes, under this particular condition, yes.

Q: Now, looking at the 10-inch section, Mr. Cader, that we looked at this morning in which we came up with all its controversies, we came up with a factor of safety of 1.07. We have heard your objections which boils down as Your Lordship puts it to the question of dynamic pressure, but with the factor of safety of 1.07, wouldn't you agree that that is also very poor?

A: Yes, of course.

Q: And that it would crack?

A: Under this condition, yes, it is possible.

Q: And this crack that we have been talking about would take place during as you put it over the life of the silos?

A: I wouldn't agree with the words in these circumstances; we did not prove that this double dynamic load would occur.

MR. GEORGE: Q: Mr. Cader, assuming that we took the dynamic pressure into account, based on these figures, these cracks would take place over the life of the silos?

A: Yes, right, that is if you see this assumption, what is calculated in loading, doubling the static pressure, you would expect cracking under this load condition.

Q: Over the life of the silos?

A: Yes.

Q: Now, sir, you agreed with me a while ago that although we have been talking about the 6-inch, 8-inch in the haunch, 10-inch in the haunch, and so on. The fact is

> that there are no compartments in the haunch or in the concrete in this particular way?
>
> A: We agree on that."

It is clear from these passages that because of the failure to design for dynamic loads that Zetlin Argo's calculation of a high factor of safety was based on the faulty design. When a factor of safety which took dynamic pressure into account was put to Mr. Cader, he made the remarkable admission that had he used these factors he would have found the cause of failure and not make any further investigation as to why the silos collapsed. The clear inference would be that Gilbert could not have caused the collapse. These passages are of utmost importance so that the samples of them must be cited:

> "Q: My question you have answered, namely that if you had come to the conclusion of the figure I presented to you, with the dynamic pressures and the factors of safety I put to you, which you yourself consider poor, unsatisfactory, you would not have gone further, right?
>
> A: Right."

Mr. George had put safety factors to him which included dynamic loads. His response was -

> "Q: Mr. Cader, do I understand you to be saying that even if you had come to the result that I put to you in the course of this cross-examination, with the factors of safety that you have yourself said were unsatisfactory and poor, with poor concrete, you would still have gone on to consider the other causes of failure? Can

> you answer that briefly, quickly and concisely?
>
> A: If I found the way you are presenting that the safety factor was not satisfactory for the expected loading during regular operation I wouldn't go any farther than that."

Indeed Mr. Cader demonstrated that he was unaware that dynamic pressures were recognized in the U.S.A. in 1963 but then he was in Poland at that time. Here is the relevant passage:

> "Q: Mr. Cader, have you ever seen this paper by A.M. Turitzin in 1963, Dynamic Pressure of Granular Pressure in deep bins?
>
> A: I have not seen it but let me. ...
>
> MR. GEORGE: Please, Mr. Cader, you have answered my question, you have not seen it. If you have not seen it, how are you in a position to say that the dynamic pressure of granular material in deep bin was not greater, was not known in the United States.
>
> MR. MAHFOOD: I object to this question, it is argumentative, it is not a question of fact and I object to the question.
>
> HIS LORDSHIP: Just a moment. Could you read back that question for me please.
>
> MR. GEORGE: Much obliged, yes, Mr. Cader.
>
> MR. CADER: This publication by American Society of Civil Engineering is not widely available in America. It is published by the Society and distributed

> in a narrow group, not every member of the Society is ordering it, so it is not a source that every engineer would go for to look at the design procedure."

With respect to Mr. Cader, those who specialise in the design, construction and maintenance of silos ought to know of Turitzin's article.

Was the adequacy of the design of the silos to cope with dynamic pressures part of Zetlin Argo's remit?

Panton's J strictures on Zetlin Argo and the witnesses brought to support their report was condemned by Mr. Mahfood. When the conduct of the witnesses is examined and Zetlin Argo's report assessed it is doubtful whether Mr. Mahfood's criticism of the learned judge was justified.

The first aspect to examine was how Zetlin Argo defined its investigation. Here it is again:

> "II. SCOPE AND PURPOSE OF THE INVESTIGATION AND THE ANALYSIS IN THIS REPORT
>
> Scope: to evaluate the adequacy of the original 1966-67 design of bins 10 and 18 to resist the anticipated external loads, including wind and earthquake as prescribed by the 1966 Jamaica Building Code, as well as the internal loads and forces generated by normal and the usual conditions of service and operations of the bins in loading, storing and discharging varieties of grains."

It is manifest that Zetlin Argo recognised the importance of faulty design. Did they not exhibit the articles by Safarian and Theimer? Moreover the fact that they took into account, the usual conditions of service and operations of the bins in loading, storing and discharging varieties of grains meant that they ought to have considered the effects of dynamic loading. They then referred to the Jamaican Building Code and apparently limited themselves to the provisions of that code as regards external forces.

This is how the limitation developed:

> "Purpose: to determine whether there was an inadequacy in the original design which could have been the cause of the separation of the walls between bins 10 and 18 when they were subjected to the loads due to normal and the usual operations of the bins and to the external loads as prescribed by the 1966 Jamaica Building Code"

Despite this purpose an observation was added which is misleading. That observation reads thus:

> "Observation: Bins 10 and 18 were subjected without apparent damage to all the external and the internal forces for over 20 previous years."

It was previously determined that the design did not take into account wind load of 120 lbs as prescribed by the 1966 Codes. Furthermore in the light of the cracks admitted to have existed before the hurricane, the observation that there was no apparent damage was misleading. Then an ambiguity ought to be noted in the notes appended:

> "Note: This analysis is based on the methodology of design of bins as was the accepted practice in 1966-67, as reflected in the commonly available technical literature of 1966-67."

Why speak of the accepted practice of 1966-67 and the technical literature of that period as if knowledge ceased then. They knew of the new knowledge when they penned their report and exhibited some aspects of it. Why this dissembling?

It was this duplicity which led Zetlin Argo to conclude in Part Four Summary:

> "IV. Since bins 10 and 18 have an appreciable Factors of Safety to resist the prescribed loads of 1966 and since they behaved safely under the severest loads of the past 20 or more years, it is our opinion that it could be concluded that the original 1966-67 design had no bearing on, and was not the cause of, the separation in September 1988 of the walls at the joint between bins 10 and 18."

What this summary omitted was that the cracks which appeared over the years without any repair or proper maintenance, was the cause of the rupture.

Did Mr. Cader make admissions in evidence which acknowledged that faulty construction of the silos could have and did cause its collapse?

We have seen that Mr. Cader admitted that with a factor of safety of 1.07 in the 10" section of the haunch, it would crack. Since the accepted minimum safety factor was 1.75 and good factor was 2 then a rupture was bound to occur at some time after construction in areas where the greatest stress would occur. This was especially so since JFM failed to provide either proper maintenance generally or proper inspection after the hurricane as the insurance policy ordained.

Perhaps it should be explained why in this judgment Mr. Cader is limited to his admissions in design and construction, although computer runs is also his special field. The onus was on the insurers to prove that the faults in design and construction were the cause of the rupture in the silos. Since if Mr. Cader has admissions in that area, that ought to be a sufficient treatment of his evidence.

Nonetheless, on appeal and in the court below, he was treated as the most substantial witness. So there are several grounds of appeal relating to his evidence concerning design and construction, it is appropriate to advert to those grounds now and attempt to answer them. Ground 15 reads:

> "15. The scathing description of Mr. Cader's testimony in the Judgment is clearly erroneous having regard to the finding that he was a 'model witness'. Furthermore, although the Learned Judge states that 'the case is replete with instances of situations when Mr. Cader indulged in <u>dodging, mental gymnastics,</u> and <u>plain avoidance of questions,'</u> he fails to cite a single instance of this shocking behaviour which is the exact opposite of the behaviour of a 'model witness.' If the Learned Judge observed this shocking behaviour on the part of a witness it censured the witness, which correction and censure would appear on the record. There is no evidence to be found in the verbatim record of his very long and exhaustive cross-examination to support the finding of the Learned Judge."

Then ground 16 states:

"16. In dissecting the professional integrity of Mr. Cader, the Learned Judge ignored the totally unprecedented form of his very long and exhaustive cross-examination. a large portion of this cross-examination consisted of innumerable technical questions prepared by Mr. Minor and written on sheets which were presented to Mr. Cader in the witness box. These questions were unlimited in scope, and encompassed the entire range of theoretical engineering questions involved in the litigation. The bulk of these questions had little or no relevance to the critical issues in this case. Examples are:-

i. The lengthy cross-examination of Mr. Cader based on the totally unrealistic and irrational assumption that the strength of the concrete in the silos was 986 psi or 1540 psi.

ii. The endless cross-examination about the modulus of rupture 7.5 square root of FC.

iii. The heated controversy that arose as to whether the southeast column supporting the headhouse actually existed or was merely a myth, invented by Mr. Cader.

17. Furthermore, in the very long period during which Mr. Cader testified, the Defendants generated and produced a number of very lengthy and detailed technical engineering reports which Mr. Cader had to examine and evaluate. Despite repeated complaints by Plaintiff's Counsel about the belated production of these very lengthy technical reports, the Learned Judge erred in taking the view that these new reports could not be excluded from the Trial because the Summons for Directions did not limit the

number of reports that could be produced. In these circumstances, the Learned Judge failed to appreciate that Mr. Cader performed a Herculean task of assisting the Court and expediting the Trial and was indeed, as the Learned Judge found, a 'model witness.'

19. Having found that Mr. Cader 'stuttered and stammered,' that Professor Sparks 'wished to deceive the Court' and that Dr. Oweis was 'dishonest,' it was hardly necessary for the learned Judge to address and determine the critical engineering issues in the light of the evidence, which he failed to do.

36. The Learned Judge misdirected himself in material areas of the case and came to unreasonable conclusions. For example, his conclusion that Mr. Cader 'was not speaking the truth when he said that there was no honeycomb in the haunch ..'. In coming to this conclusion he failed to appreciate that the report of the concrete tests was prepared by Wiss Janney and not Mr. Cader. He also failed to appreciate that the Wiss Janney report, as well as the testimony of Mr. Minor, supported the testimony of Mr. Cader that there was no honeycomb in the haunch/ The Learned Judge's conclusion that Mr. Cader was not speaking the truth because of 'his extreme reluctance to put a percentage figure for depreciation in the strength of the concrete given the presence of honeycomb, cold joints and delaminations' is equally unreasonable.

41. The Learned Judge erred in making a wholly imbalanced comparison of the cross-examination of Messrs. Cader and Mr. Minor in terms of length and relevancy.

> 42. The Learned Judge erred in making reference to a general observation made by Plaintiff's Counsel about the need for an engineer to exercise his Judgment in the performance of his work, and using this observation as a basis for criticizing the engineering work of Mr. Cader."

Although Mr. Cader gave evidence for JFM and therefore preceded Mr. Minor, the substance of his evidence was a reply to the opinions of Mr. Minor and Professor Mitchell. Yet so dominant he was, both in the court below and on appeal, that there were still further grounds of appeal in relation to his evidence on design and construction. Here they are:

> "46. The Learned Judge erred in criticizing the concrete tests on the ground that 'in conducting the concrete test no account was taken of the fact that the silos were subjected to cyclical loading.' The Learned Judge failed to appreciate that the taking of 'cyclical loading' into account is not the function or purpose of concrete tests and is not a basis for criticizing the concrete tests.
>
> 49. The Learned Judge erred and misdirected himself on the oral and documentary evidence by stating that 'Mr. Cader capped it all by informing the Court that locked - in stress is a personal invention of Dr. Zetlin, and that he Mr. Cader saw nothing wrong with it.' This is an unreasonable imbalanced and inaccurate summary of the oral and documentary evidence relating to locked-in stress.
>
> 50. The Learned Judge erred and misdirected himself on the meaning, purpose and effect of the evidence relating to the concrete tests conducted by Wiss Janney on behalf of Zetlin-Argo and in stating that 'Usually, the strength of a piece of concrete

> is determined by statistical calculations .. Zetlin-Argo had therefore to rely on their engineering experience and knowledge rather than on mathematics." The Learned Judge ignored and disregarded the fact that the concrete tests conducted by Wiss Janney on behalf of Zetlin-Argo were wholly appropriate, correct and thorough whereas arriving at his premature and inflexible conclusion as to cause of failure."

There were still additional grounds involving Mr. Cader's evidence on the issue of design and construction. They are:

> "52. The Learned Judge erred in applying vastly different standards in evaluating the expertise, credibility and testimony of the Plaintiff's witnesses, as compared with the standards he applied in evaluating Mr. Minor and his testimony. He came to conclusions severely adverse to the Plaintiff's witnesses, with little or no evidentiary support. On the other hand, he relied on Mr. Minor's objectivity and veracity and concluded that Mr. Minor did not take a partisan stance and 'brought an open mind to the problem of the collapse,' despite the overwhelming evidence to the contrary, clearly identified in the Plaintiff's submissions, which the Learned Judge ignored and disregarded. Furthermore, in accepting the 'expert opinion' of Mr. Minor as to the cause of failure, the Learned Judge ignored the fact that Mr. Minor is <u>not</u> a wind expert, <u>not</u> a soil expert and has very limited experience in the area of major structural failure. The Learned Judge also ignored and disregarded the powerful evidence, clearly identified in Plaintiff's submissions, of the serious errors and deficiencies in his work.
>
> 53. There is no evidence to support the harsh and severe conclusion of the Learned Judge that 'Mr. Cader did not hesitate ... to

> ... change his evidence without blinking an eye'. Furthermore, that conclusion is not warranted by the instance, which 'readily' came to his Lordship's mind, namely, Mr. Cader's 'testimony in relation to the cracking of concrete at its weakest point.' On the other hand, the Learned Judge failed to recall the dramatic shifts in the Defendant's position with regard to the weakest link' and failed to appreciate that it is the dramatic shift in the Defendant's position relating to 'the cracking of concrete at its weakest point' that was never explained."

These grounds were a powerful challenge to the learned Judge's findings against Mr. Cader. However, to reiterate, the correct approach ought to determine if there were admissions by Mr. Cader in favour of the insurers on this issue of design or construction. The onus was on the insurers to prove that faulty construction was the cause of the rupture. So it is now necessary to elicit the further admissions by Mr. Cader to complete this aspect of the case.

Mr. Cader throughout attempted to make an untenable distinction between design and actual strength. But from an evidential stance which is also a good engineering principle, the design must cater for the highest load the structure would bear. If it does not, it was faulty, and there would be cracks at critical points which would result in a rupture. Mr. Cader admits that without realizing it in the following passage:

> "Q: Yes, M'Lord. And you agree with me that a safety factor should be of the order of 2, roughly about 2, that is accepted in the literature, is it not?
>
> A: When you design, yes.

Q: And it has to be a factor of safety for the worse loading, not just any loading for the worse loading?

A: When you design, yes.

Q: And indeed, when you are considering the strength of a particular structure?

A: If I am considering, the only strength - - the safety factor is the simple relation between the strength and the expected forces due to the normal loading.

Q: And therefore you have to look at the highest loading?

A: Correct."

The crucial feature of this passage was Mr. Cader's admission that when dealing with the actual structure you have to look for the highest loading. This must be the dynamic forces released by unloading, so a good designer caters for that. So does a good structural engineer in construction of silos.

The design requirements in the Codes are minimum standards for the silos to function effectively and safely. When they are ignored and a collapse occurs, the inference must be that the design and construction faults are the cause of the collapse. So here again admissions are in favour of the insurers as they have established that design and construction faults caused the rupture.

The following admission by Mr. Cader on the Code is instructive:

"Q: It goes on: 'For contact splices spaced laterally closer than 12 bar diameters or located closer than 6 in. or 6 bar diameters from an outside edge, the lap shall be increased by 20 percent. In this case it would be a minimum of inches?

A: Yes.

Q: 'Or stirrups as prescribed in section 918 (c) 2 or closely spaced spirals shall enclose the splice for its full length.'

But there are no stirrups here?

A: No stirrups.

Q: Or spirals?

A: No.

Q: 'Shall enclose the splice for its full length.' So if you take 20 percent and you add 20 percent to the 15 inches that you told us about, you get 18 inches, wouldn't you; isn't that right?

A: It is the requirement prescribed for concrete splices placed laterally closer than twelve bars diameters .. ..

Q: Or located closer than 6 inches?

A: I am not quite sure if this applies. We have the bars spaced 9 inches in vertical plains so it may not apply for that.

Q: It satisfies both, does it not, not less than 6 inches .. .?

A: We don't have this situation in our case. we have 9 inch spaces - or how many diameters - more than 12-bar diameters obviously.

Q: It is 6 inches from the outside edge, Mr. Cader?

A: It depends on how the haunch is, it is close to 6 inches but it may be concerned ..

Q: I suggest that it is?

A: I see no objection for that.

Q: Very well. So that if you add 20% to 15 you get 18 inches, don't you?

A: Yes.

Q: So the minimum splice should be 18 inches?

A: Yes, for following this requirement, yes.

Q: 'Where more than one half of the bars are spliced within a length of 40-bars diameters; that is 25 inches, correct?

A: Yes, this is the design requirement."

Once again the design and construction requirements of the code were ignored in admissions and the inference must be that the lack of these safeguards resulted in cracks over the years especially since they were not repaired or maintained in accordance with the insurance policies.

An admission that concrete was not of the best quality must be fatal to JFM case. For the concrete takes the compressive force and the tensile forces are carried by reinforced concrete. Here is the fatal admission:

"Q: And you have told us, you admitted that this concrete was not the best quality.

A: Yes."

It was an extraordinary admission. Also it would be unusual for an expert witness to expect the court below to prefer his engineering experience to the collective wisdom of the profession as embodied In the codes. Yet that was what counsel sought to persuade the court below and on appeal to do. Here is a characteristic passage:

> "Q. Mr Cader yesterday you told His Lordship that because you were investigating the strength of the reinforcement that when you came to calculate the strength of the development length - rather, when you came to calculate the development length you did not have to multiply by 1.4 because that was a design requirement which you could ignore from your engineering experience. You remember saying that?
>
> A: Yes.
>
> Q: Well, if you were considering matters of design you would include it.
>
> A: Yes, that is correct."

Then Mr. Cader ignored the requirement of the code to multiply by 1.4 when investigating the strength of the reinforcement. The passages ran thus:

> "Q: But you didn't multiply by 1.4 there, did you?
>
> A: I did not.
>
> Q: Isn't it true, Mr. Cader, that you didn't multiply by 1.4 here or when you were investigating the strength of the reinforcement - the imbedment length, you did not require - - you did not multiply by 1.4 because you did not think that it was dealing

with a top bar, isn't that so, according to the definition.

A: Yes, it is part of the whole but it is not the whole truth. In this statement the part of it is - - we did not think it is the top bar and we also think it is the safety factor introduced in the Code to protect the bond stress for this particular occurrence, the concrete settlement during the construction.

Q: In fact, it is a factor put there for the purpose - for the reason that as in fact and in truth this requirement to multiply by 1.4 is there because, as I suggested yesterday, the higher you go in the concrete the weaker is the effect of the horizontal bar. Isn't that so?

A: It is not so exactly as you explained; it may be somebody would understand that the higher you go above the ground we should look at it as the higher you go with the core of the concrete above the certain level of the concrete which is already set.

Q: But the fact is, Mr. Cader, when you pour concrete doesn't the, what they call latence come to the surface? Water and air, does it come on the surface?

A: Right - yes, in some circumstances. If you have the certain consistency of your concrete yes, you would expect that.

Q: And isn't the latence, the scum of the water and cement that comes to the surface?

A: Yes, in some instances.

Q: doesn't it in all instances? Doesn't the water come to the surface in cement?

A: It depends on consistency of concrete."

The codes require staggering yet there was no staggering either in the drawings or in the construction. This weakness Mr. Cader admitted thus:

> "HIS LORDSHIP: The splicing was about two inches.
>
> MR. GEORGE: Two inches, yes M'lord.
>
> HIS LORDSHIP: Or a little more, I think he said.
>
> MR. GEORGE: Or a little more he said.
>
> Q: And it was all on the same plane, wasn't it, Mr. Cader?
>
> A: Yes.
>
> Q: In other words, it was not staggered.
>
> A: It was not staggered.
>
> Q: So that one hundred percent of the steel ended within the same vertical plane.
>
> A: Yes."

Mr. Cader, after admitting that there was no staggering as required by the code suggested that there could be splicing as a substitute and then made the further remarkable admission that there was no splicing either . Here is the relevant passage:

> "HIS LORDSHIP: You are saying they should be staggered?
>
> MR. GEORGE: Oh yes, and I think he agreed.
>
> A: No, I don't; we have two possibilities. There is an overlap if you have not staggered you have to provide a certain

> length and you can resolve the design purpose by having staggered or not staggered. You can move the joint away from the structure and you have the different reinforcement going into the partition and a different one which goes in.
>
> Q: Mr. Cader, isn't the real thing that you need proper splicing?
>
> A: Of course when you are creating design it is a better place to put it in.
>
> Q: But splicing is not investigated either.
>
> A: We were investigating the strength, we did not investigate the accuracy of design by the Code; we agreed that this design was not perfect.
>
> Q: Tell me something, when you come to investigate the strength of something do standards mean anything to you at all, the standards, criteria by which things are supposed to be judged?
>
> A: Of course it means a lot."

Panton J realized the effect of the admissions by Mr. Cader on the issue of faulty design and construction. Here is how he treats the admission of concrete not being of the highest quality.

> "The compressive strength of concrete is important as in order to get the bond strength of the concrete it is necessary to use the compressive strength in the calculations."

It ought to be reiterated that the insurers found the concrete awful. Then Panton J dealt with the admission of cracks. Cracks were the result either of poor concrete or inadequate reinforcement. Here is the relevant passage in the judgment:

> "Mr. Cader testified that there was a series of old cracks in the bins, and that these cracks did not arise from the collapse. He added that there were numerous narrow cracks that were not apparent to the naked eye. They were at the bottom of the curved walls of the bins and in the area of the partition. He noted that there was rusting on horizontal bars, and that this rusting resulted from old cracks from the outside migrating to the steel. Where there are old cracks, there would be no tensile strength in the concrete."

Then bearing in mind the defects namely, that there was no splicing and the absence of staggering, here is how Panton J treated the admission on construction:

> "<u>Mr. Cader on reinforcement</u>
>
> Mr. Cader testified that the reinforcement did not meet the desired requirement in that it did not reach the jacking rod. At least seven bars in one photograph of the damage that was shown to him did not go around the jacking rod. The bars were not broken; they had pulled out. This indicated that there had been bond failure. The purpose of reinforcement in concrete is to take up the tensile load. Tensile stresses are caused by tensile load, and tensile stresses cause cracks in concrete.
>
> In the haunch, there was an absence of splicing. If there had been splicing, there would have been a greater distribution of tension from bar to bar over a larger zone. That would have placed far less tensile stress in the concrete in the haunch. Proper

> splicing was needed. The design for splicing was not perfect.
>
> There was a bar anchored into the concrete at the haunch. This transmitted the tension into the concrete which then transmitted it to the next bar into the outer wall which is also anchored into the haunch.
>
> There were hooks in position. Their presence would have increased the local tensile stress distributed in the concrete in the haunch. Instead of the hooks, there should have been splicing so that the tension would have gone from bar to bar over a larger zone created by the splice. If there was splicing, there would have been a greater distribution of tension from bar to bar over a larger zone. That would have placed far less tensile stress in the concrete in the haunch.
>
> All the steel ended up in the same vertical plane, not having been staggered."

Against this background I find that the grounds of appeal under this section have not been successful. There is another general ground of appeal relating to the scope of re-examination and the challenge to the learned judge's ruling on this issue. The ground reads:

> "33. The Learned Judge erred in ruling that Plaintiff's Counsel could not re-examine Mr. Cader on matters arising out of the cross-examination, and in particular, severely restricting the re-examination of Mr. Cader on the very important Mitchell report although this report was first introduced into evidence in the cross-examination of Mr. Cader."

The purpose of re-examination is to seek clarification or explanations of matters which arose during cross-examination 17 Halsbury's Law of England 4th edition paragraph 280 and Phipson on Evidence Thirteenth edition 33-91. Once clarification or explanations are sought, the implication is that there is some ambiguity. Cross on Evidence sixth edition p. 284 does not mention the need for clarification or explanation, but that must be inferred since the authors state new matters can only be put with leave of the court. These authorities were cited by Mr. Mahfood as well as A Practical Approach to Evidence Third edition by Peter Murrary p. 460 and The Modern Law of Evidence Adrian Keaner p. 138. They restated the orthodox position.

The point raised on this appeal arose because Mr. Mahfood wished to ask Mr. Cader about the following passage on the Mitchell's report. It reads:

> "'In order to investigate the performance of the hooked details used in the silo, a series of tension (Specimens T1 to T8, T2A, T4A and T8A) and a series of bending specimens (Specimens B1 to B5, B2A and B3A) were constructed and used.
>
> The purpose of the tension specimens was to investigate the basic bond characteristics of the different types of hooked anchorage details present in the silo. In addition, the performance of these specimens are compared with the performance of specimens containing lap-spliced reinforcing bars.
>
> The purpose of the bending specimens was to investigate the performance of the different types of hooked anchorage details when the silo walls are subjected to bending. In addition, the performance of these

> specimens are compared with the performance of specimens containing lap-spliced reinforcing bars."

Mr. Mahfood concluded:

> "The fact that they did not ask Mr. Cader about it might have been a question of prudence because this test answered the question."

Then Panton J said:

> "HIS LORDSHIP: I will allow you to re-examine if I am satisfied there is really room for me to give permission for re-examination, but I have to be so satisfied. What I am saying, I cannot allow any extensive questioning whether with leave or whatever."

This ruling showed that the learned judge grasped the principle of re-examination. There was no particular merit in the ground of appeal nor in the submissions in this court as to where the learned judge erred.

So to return to Mr. Cader on the Mitchell report, how could the alleged error affect the conduct of the case? Professor Mitchell was called as witness in the case and in the narrow area on which he gave an opinion, he could have, and was no doubt cross-examined by Mr. Mahfood to the fullest extent. Also leave was granted to ask specific questions. This ground has no merit.

(VII)Did the insurers' computer runs support their case that Gilbert was not the cause of the rupture in silos 10 and 18?

Who is Mr. Cader? He is a Pole who has been working in the U.S.A. since 1981. He is a structural engineer and is employed as an engineering consultant to Zetlin Argo. He completed his studies at the Polytechnical Institution in 1966 and was awarded a Master's degree in Structural Engineering. He is also skilled in using the computer in finite element analysis as well as programming in Fotan which is computer language.

He has designed many famous buildings which include the largest department store in Poland. He has considerable experience in investigating structural failures which include Hyatt Regency Hotel, the collapse of Meinus River bridge and the Lambiance building in Bridgeport Connecticut. With this background, it can be understood why in the court below, Panton J singled him out thus:

> "Mr. Cader has to be given pride of place as
> far as this case is concerned."

This stance was continued in this court, but I disagree with it. Mr. Cader ought to be confined to the issue of design and construction where the insurers had the obligation to prove the causal relationship between bad design and faulty construction with the structural failure which culminated with the rupture of the silos. So it was Mr. Cader's task to refute the insurers' witnesses, Mr. Basil Minor and Professor Mitchell.

It has been found that the principal witness for JFM, Professor Sparks and Dr. Oweis have failed to support the Zetlin Argo's thesis that Gilbert caused a differential settlement in the southeast bank of silos. To reiterate, that thesis propounded that differential settlement produced a differential tilt which twisted silos 10 and 18 and the locked in stresses which totaled 48.9 kips. This force, it was contended, cracked the haunch and zipper effect resulted which caused a rupture in the partition between these silos. The rupture was illustrated by photographs taken on the scene by the insurers. As a contrast, Mr. Minor for the insurers, gave a different explanation but they also used metaphor of the zip to illustrate what happened. Panton J cited it thus:

> "The normal forces on the silo walls due to grain were sufficient to cause failure of the structure. Over a period of weeks, months or years and bond between the concrete and the steel reinforcement has been reducing. At some stage this probably led to the complete failure of one or two of the bars anchored across the final rupture plane. The migration of the stresses from the now useless anchors at the next loading cycle to those next above and below, resulted in these failing as well and the wall between Silos 10 and 18 opening up from bottom to top as if unzipped. From this primary failure all other damage was inevitable."

It was Mr. Cader, the structural engineer and a specialist in computers who sought to convince the court below of the validity of Zetlin Argo's approach.

Computers enable us to calculate enormous quantities of mathematical information at great speed. If the data is flawed, then the results will also be flawed. The fundamental data relied on by Mr. Cader, was Dr. Oweis' estimate of differential settlement in the southeast of 1.2". Be it recalled that Dr. Oweis relied on the flawed wind loads of Professor Sparks or Dr. Simiu. Further, the pressures given to him by Zetlin Argo to estimate the settlement used the average live loads of grain over the period instead of the loads on the day of

Gilbert and on the day of collapse. Additionally, to get accurate results , the computer must simulate the physical conditions accurately. This is done by translating the geometrical features into algebraic language. Mr. Cader relied on the process of iteration i.e. trial and error to determine stresses produced by the differential settlement. It must be borne in mind that the differential settlement relied on was estimated from data given by Dr. Zetlin to Dr. Oweis. That data was flawed.

There was no measurement before the hurricane and after which would establish with accuracy, if there was a differential settlement. Therefore to use as a base, the flawed estimated settlement of Dr. Oweis and then to rely on the method of iteration (trial and error), to determine the force which would cause the rupture, must be also flawed.

Computer results can be monitored and the insurers felt obliged to do this. They relied on Mr. Cader's formidable rival, Mr. Minor from the engineering consultants, Norman and Dawburn. It was therefore inevitable that Mr. Cader's computer results would be refuted. Perhaps the proper way to assess the evidence on this is to refer to the grounds of appeal on this issue. They are:

> "12. The Learned Judge has summarized in his Judgment that critical issues in terms of the five steps Zetlin-Argo undertook to 'calculate the cause of failure,' but failed to properly address and determine the issues in the light of the evidence. The only reasonable conclusion on the evidence is that the Plaintiff has proved, on the balance of probabilities, that hurricane Gilbert was the proximate cause of the collapse of the silos.

> 13. The Learned Judge erred in harshly condemning Mr. Cader at pages 50-53 of his Judgment starting with the observation that he had 'bouts of stammering and stuttering.' This condemnation appears to flow from the failure of the Learned Judge to understand the engineering method of 'iteration.' This was the method correctly used by Mr. Cader in carrying out his computer work, having regard to the purpose of the work, which was carefully explained to the Learned Trial Judge."

The complaint about the misunderstanding was repeated in ground 14 which reads:

> "14. To the uninformed layman, the engineering method of 'iteration' bears a superficial resemblance to 'stage management.' This was the suggestion being made to Mr. Cader in his cross-examination referred to at Pages 50-53 of the Judgment. This concept of 'stage management' was what the Learned Judge apparently had in mind in the testimony he referred to at page 54 of his Judgment. This mistaken view of the engineering method of iteration was the basis of his conclusion at page 66 of his Judgment, namely, that 'much of the investigations have been - stage managed to produce desirable results.' The harsh condemnation of Mr. Cader at pages 50-53 of the judgment and the finding of stage management at page 66 of the Judgment, appears to flow directly from the Learned Judge's misunderstanding of the engineering method of 'iteration.'"

The appellant was adept at raising the same issue under different grounds and the complaint about the learned judge's unfavourable finding with regard to the issue of computers was again repeated thus:

> "18. The Learned Judge erred in seizing on Mr. Cader acquiescence to a suggestion put in cross-examination about 'stage management' having regard to the fact that Mr. Cader's native language is not English, and that the phrase 'stage management' is meaningless to an engineer endeavoring to answer an endless barrage of engineering questions. Furthermore, Mr. Cader clearly explained the sensible and logical purpose of his computer work."

Then ground 24 was critical of the insurers' computer runs and reads as follows:

> "24. In relying on Mr. Minor's presentation of the computer work done by Strucom Structures and Computers Limited, as reflected inter alia, in exhibits 29, 57 & 57A, and in accepting Mr. Minor's position that 'the defence has done a more thorough computer analysis than the Plaintiff' the Learned Judge ignored and failed to properly address the strong evidence that the Defendant's computer work was fatally flawed. If this evidence is considered and not ignored and disregarded, the only conclusion is that the computer analysis done by the Defence, although extensive, was fatally flawed. Significantly, Strucom Structures and Computers Limited were not called to defend their work,. This was done by Mr. Minor only, who is not a computer expert."

There were yet two grounds relating to computers, one of which reads as follows:

> "51. The Learned Judge erred in stating that 'the witnesses for the Plaintiff have admitted to faulty calculations, incomplete computer runs so far as the supply of data is concerned, and in some areas the witnesses have professed lack of expertise in themselves.' He has failed to identify or evaluate the 'faulty calculations' or 'incomplete computer runs' in light of the critical engineering issues in the case."

The other, although not strictly related to computers, must have impliedly compared Mr. Cader and Mr. Minor in the area of computer expertise. It reads:

> "52. The Learned Judge erred in applying vastly different standards in evaluating the expertise, credibility and testimony of the Plaintiff's witnesses, as compared with the standards he applied in evaluating Mr. Minor and his testimony. He came to conclusions severely adverse to the Plaintiff's witnesses, with little or no evidentiary support. On the other hand, he relied on Mr. Minor's objectivity and veracity and concluded that Mr. Minor did not take a partisan stance and 'brought an open mind to the problem of the collapse,' despite the overwhelming evidence to the contrary, clearly identified in the Plaintiff's submissions, which the Learned Judge ignored and disregarded. Furthermore, in accepting the 'expert opinion' of Mr. Minor as to the cause of failure, the Learned Judge ignored the fact that Mr. Minor is <u>not</u> wind expert, <u>not</u> a soil expert and has very limited experience in the area of major structural failure. The Learned Judge also ignored and disregarded the powerful evidence, clearly identified in Plaintiff's submissions, of the serious errors and deficiencies in his work."

Perhaps it is necessary to reiterate that it has already been found that JFM has failed to prove that, Gilbert caused the differential settlement, which resulted in a differential twist. The contention was that the differential twist caused locked in forces which caused the rupture a fortnight after Gilbert. JFM failed to prove that they inspected and maintained the silos as the insurance contract required. Against that background, if Mr. Cader programmed his computers with the wrong data, it was a foregone conclusion that incorrect output would result.

Therefore it was essential to examine the computer runs by the insurers to ascertain if those runs relied on the correct geometrical forms of the silos and that the input corresponded with known data. Panton J accepted the insurers on computers and the following passage is a useful pointer to his ultimate findings:

> "The overall position of Mr. Minor is that the defence has done a more thorough computer analysis than the plaintiff, as the former has considered all the different effects the foundation conditions would have. Zetlin-Argo came to a decision first and then attempted to work towards that decision. Zetlin-Argo also attempted to use average grain loads whereas the defence used the actual grain loads. Exhibit 17 which was produced by the plaintiff does not show any input for the distribution of grain on the day of the hurricane or the day of the collapse; nor is there any input for wind or grain on the day of the hurricane or the day of the collapse. In Mr. Minor's opinion, Exhibit 17 and the other computer runs prior to it have no relevance to the circumstances of the case.

> Mr. Minor did his own calculations too. He was trying to determine the sort of order of magnitude of stresses that he would find in the silos due to grain, wind, hurricane, and earthquake. His calculations led him to conclude, in part, that the wind load itself never put any stresses in the silo at any point in an area where there was a likelihood of failure occurring; and stresses due to wind load, hurricane intensity, was a mere fraction of the stresses due to grain 'and that was just typical grain, it wasn't a particularly high granule and therefore the hurricane itself caused no damage to the silo - none whatsoever."

The critical issue therefore is whether Mr. Minor and Strucom who instituted some of the computer runs under Mr. Minor's direction adduced evidence to support the favourable finding of the learned judge. Computer runs were also done by Engineering Geology Ltd., the soil expert retained by Mr. Minor's principal. So here is the evidence from Exhibit 30:

> "C) Computer Runs
>
> Run one is an attempt to model what might have happened to the silo bank at the time of hurricane Gilbert while the wind was blowing from the North. The foundation condition assumes a regular bed of springs (fci) with long-term settlement potential. The loading applied to the structure includes the dead load, Live load 1 (a hypothetical loading case) and an approximation to Zetlin Argo's wind load at the time of hurricane Gilbert. The foundation settlements produced by this run were used as the definition of foundation case three."

Then the computer output for Run 1 was as follows:

> "The four colour plots given are titled Load Case 1. The total stress clearly shows increasing stress towards the south east corner of the bank which is the direction in which the wind load would push the structure. The principal tensile stress plot show however that the highest stresses are occurring in the silos which contain grain. The hoop stress plot shows low tensile stresses in silo bins 10, 18 and 25 with higher values being recorded in the silos containing grain, this indicates that the high wind forces due to hurricane Gilbert did not produce high tensile stresses in the joint that collapsed. Finally the vertical stress plot shows as expected increasing compressive stresses in the walls towards the south east with perhaps even slight tension at the north west."

The photographs in colour in Exhibit 30 demonstrate the degree of stress with a telling effect.

To demonstrate that Gilbert had no effect on the structure, Run 2 was done. Here is how it was stated:

> "Run two is a control case and represents the bank of silos either just before or just after hurricane Gilbert. The foundation condition and loadings are as in run one except that no wind loads have been applied."

The output was as follows:

> "Computer Run 2
>
> Consider the four colour plots titled Load case 2. The total stress plot shows slightly higher values of stress at the eastern end than at the western end. The load case is almost symmetrical except that there is the elevator tower loading at the eastern end

> which would explain the slight increase in stress in that direction. The principal tensile stress is clearly highest in the bins that contain grain, virtually no stress occurring in bins 10, 18 and 25. The hoop stress plot confirms the overriding effect of grain on the stress distribution. Vertical stresses in the fourth plot show a tendency to increas e to the East indicating the out of balance load due to the elevator tower."

Run 3 was crucial. Tthe differential settlement of 1 1/4" in the south east corner which was Dr. Oweis' estimate of the differential settlement. This was imposed and the results confirm the insurers' case, that the differential twist which resulted from the differential settlement, did not produce stresses locked in or otherwise to crack the haunch as Mr. Cader testified. The relevant passage from the report is as follows:

> "Run three is our attempt to discover what effect distortion of the foundation would have on stresses in the silo walls at the time that the silo collapsed. A dead load as well as the grain load (LL2) occurring at that time has been applied to the structure which has had its foundations distorted to the shape taken up in one. This implies that subsequent to the hurricane, and despite the wind from the south occurring after the wind from the north, there was no release or recovery of the foundations as the wind load was released. This is a very extreme interpretation of what might have occurred and can be considered as the extreme upper bound of the plausible."

Then for the output:

> "Computer Run 3

> This case is an attempt to produce the conditions which Zetlin Argo say caused the collapse of silos. The plot of total stress shows the highest visible stresses in the joint where collapse occurred with stresses increasing towards the eastern end. The maximum visible tensile stress however occurs in silo 6 which not surprisingly had the most grain in it. The walls at the bottom of bin 18 have similar levels of tensile stress. Similarly the hoop stresses are highest in bin 6 with equivalent stresses in bin 18. Vertical stresses show an increase towards the east which helps to explain why the total stress also increases in this direction."

The conclusion of all the computer runs on this aspect is as follows:

> "Conclusions
>
> The various studies carried out continue to indicate that even under extreme wind loads or substantial foundation distortion the critical tensile force that caused collapse of the silos is due to loading the bins with grain. Choosing other values for foundation stiffness or other directions for the wind forces are also going to have minimal effects although conditions can no doubt be found which will increase rather than decrease the stresses in the critical joint.
>
> It is clear that this silo failed under normal operating conditions due to the poor detailing of the reinforcement aggravated by poor construction on site. There is no indication that earthquakes, hurricanes or foundation failures contributed in any degree to the failure."

The upshot of this is that by monitoring the computer runs by Zetlin Argo and proving that they did not simulate the condition of silos, the insurers gave additional proof in their runs that the hurricane Gilbert did not cause the rupture in silos 10 and 18. Further and very importantly, they proved that the theory of locked in stress did not hold. Against this background the grounds of appeal adverted to in this section are as unsuccessful as the previous grounds that have been considered.

(VIII) Conclusion

The result of this exhaustive examination is that JFM has failed in both areas where the insurance policy obliged them to prove on a balance of probabilities that it was the hurricane which caused the rupture in silos 10 and 18. Additionally, they had not taken reasonable precautions for the maintenance and safety of the silos in accordance with the Lloyd's policies; or to keep the premises insured or containing the property in a proper state of repair as required by the collective policy of which West Indies Alliance is the lead insurer.

JFM failed because Professor Sparks' evidence did not advance Zetlin Argo's case. He exaggerated the wind speed by failing to take into account the anti-clockwise torque and resorted to the inappropriate unknown formula. Further, he failed to note the other factors which reduced the wind speed. Dr. Oweis was a vital witness. He had to prove that the differential settlement which allegedly caused the stresses to be locked in and resulted in the silos being twisted so as to cause the rupture a fortnight after Hurricane Gilbert. Yet, to reiterate, the pressures he used to estimate the settlement were not computed by him and he did not know how they were computed. They were computed by Dr. Zetlin who died before the trial. The evidence established that Dr. Zetlin used the wind loads computed by Dr. Simiu who had mean torque in the wrong direction. Further, the live loads he used were not the actual loads on the day of the hurricane but the average loads over the life of the silos. Since the alleged differential settlement was never measured but estimated with the wrong pressures, JFM was bound to fail on this aspect of the case.

The other aspect which Jamaica flour Mills had to prove was proper maintenance for safety. Mr. Ruland, who was called to establish this aspect of the case, did not even attempt to do so. The faults could have been discovered by inspecting the plans for constructing the silos. The principal fault was that they were not designed to cope with the stresses which resulted from unloading the silos. The knowledge was available in 1966 from specialist journals which the JFM exhibited as part of its particulars and evidence. Yet those features of the faulty design were never brought to the attention of JFM by its maintenance team. Further, there was no evidence to show that JFM retained specialist professional engineers skilled in the art and science of silo construction and maintenance so as to advise on what was necessary to maintain the silos in good working condition. Moreover, there was no proper inspection after Gilbert as the insurance policies required. The following response by Mr. Minor for the insurers to Panton J tells the story of what ought to have been done:

> "HIS LORDSHIP: The question is a specific one dealing with non-splicing and non-staggering. So now there are Codes

> which say, or make specific provisions that there should be splicing and staggering. The question you are being asked, 'what are those people who have been aware that there was no splicing and staggering in this case -- what should they do, or could they do as engineers'. The point was made about law, but you are not being asked a legal question here. That is the question. As engineers, what could they do?
>
> A: They could check the drawings of the old structures to see whether these specific deficiencies are included in the old structures or not, and bring to the attention of those who must make decisions those particular buildings or areas of buildings where the deficiency arises and explain to those who must make that decision how important -- there has to be a judgment, no doubt to the engineers, as to how important that failure to meet the new requirements are.
>
> Q: Are there remedial recommendations that should be made?
>
> A: Yes. If they thought that the amount by which the old building was deficient was serious enough to warrant it then they should put forward recommendations as to what could be done to remedy the deficiency."

At an earlier stage of the trial, Mr. Minor's formidable rival, Mr. Cader for JFM, acknowledged that the silos were strengthened in 1990 to cope with dynamic forces resulting from unloading the silos. In this context it must be reiterated that the effects of dynamic loading was concentrated in a narrow area. Had JFM employed skilled consulting engineers earlier to assist them with maintenance of the silos for safety, a tragedy would have been avoided.

Panton J, in this long and difficult case, prudently adjudicated without resorting to section 21 of the Judicature (Supreme Court) Act which would have enabled him to sit with assessors or an assessor. We were told that the matter was raised and the consensus was that it would not have been necessary. That was the correct decision. The evidence was within a lawyer's grasp and once it was explained to counsel by their professional advisers the necessary adjudication could take place. Further, a good judicial system must count the costs. If assessors were used, then the costs, which already were very high, might have been enormous.

It is necessary to pay tribute to counsel on both sides for the high level of advocacy in this court. As for Panton J, he was "quick, courteous and right." He saw from an early stage that Professor Sparks' critical approach to Zetlin Argo's work was bound to benefit the insurers. So it did. The insurers refrained from calling out their big battalions to give evidence on the wind, soil or maintenance. They were content to demolish JFM's case by cross-examination which brought out the necessary admissions in their favour. Then, although they were not required to prove how the rupture occurred in the circumstances of this case, they did so convincingly and here again JFM assisted through Mr. Cader's admissions. Once JFM presented their case on the basis that design criteria was irrelevant, then they were bound to fail. Faulty design was not one of the risks insured against and JFM seemed to have forgotten that if the design was faulty then the silos could not safely perform the normal functions of loading, storing and unloading grain. Without a proper design or proper maintenance a tragedy and loss of life was bound to occur.

So the appeal must be dismissed, the order below is affirmed, the agreed or taxed costs of this appeal must be borne by the appellant Jamaica Flour Mills.

Addendum

Since there are quotations from substantial numbers of the 57 volumes of evidence in this judgment, it is appropriate to give some the citations for easy reference. Here they are:

SECTIONS	JUDGMENT	EVIDENCE
(I) Introduction	pp. 1 - 17	-
(II) What was the nature of the wind pressure unleashed by hurricane Gilbert?	pp. 18- 23 Mr Calvin Gray p. 19 p. 20-21 p. 22 p. 23	 Vol. 2 pp. 440 " pp. 444-445 pp. 450-451 pp. 455
(III) The egineering evidence on the effect of the wind on the bank of silos	pp. 24 - 52 Professor Sparks p. 24 p. 25	 Vol. 9 pp. 1951-1952 " 1952-1953

SECTION	JUDGMENT	EVIDENCE
	p. 26	" p. 1954
(III) (cont'd)	p. 28	" p.
		1958
	p. 29	" p. 1985-1983
	p. 31	" p. 1991
	p. 32	" pp. 1993
	p. 33	" pp. 1995
	p. 34	" pp. 2001,2004
	p. 35	" p. 2022
	p. 36	p. 2025
		" p. 2081
		2082
	p. 37	" p. 2100
	pp. 38- 39	" pp. 2101-2103
	p. 40	p. 2119
		Vol. 10 p. 2140
		" p. 2151
	p. 41	" p. 2153
		" p. 2169
		" p. 2170
	p. 42	" p. 2172
	p. 43	" p. 2173
	p. 44	" p. 2174
	P. 45	" p. 2175
		2177-2178
		2179
	p. 46	" p. 2181-2182
	pp. 47-48	" pp. 2183-2184
		p. 2185
		2242
		2244
		2245

SECTION	JUDGMENT	EVIDENCE
(IV) Did Gilbert cause the differential settlement in the south east under the bank of silos as JFM alleged and sought to prove?	PP. 53-94	
	Dr. Oweis	
	p. 53-54	Vol.16 pp. 3222-3223
	pp. 56-57	" p. 3233
	p. 60	Vol. 16 p. 3234
	p. 61	
	p. 62	" p. 3233
	p. 63	" p. 3244
	p. 64	" p. 3250
		" p. 3254
	pp. 68-69	" pp. 3266-3267
	p. 70	" p. 3269
	p. 71	" pp. 3365
		3369
		" p. 3370
		" p. 3381
	p. 72	3398-3399
	p. 73	" p.3400
	p. 74	3404
	p. 75-76	" p. 3406
		3457
	p. 77	" p. 3459-3460
		" p. 3465
	p. 78	" pp. 3493-3498
		" p. 3499
	p. 80	" 3504
	p. 81	" p. 3508

SECTION	JUDGMENT	EVIDENCE
(IV) cont'd	p. 82-84	Vol. 17A pp. 3505-3506
		" p. 3369
	p. 85	Vol. 16 p. 3566
		3633
		Vol. 17A p. 3637
(V) Have JFM failed to exercise ordinary and reasonable precautions for maintenance of the property insured in accordance with the contract of insurers	PP. 95 - 119	
	Mr. Cader	
	pp. 114-115	Vol. 4 p. 1055

SECTION	JUDGMENT	EVIDENCE
or alternatively	Mr. John Ruland	
Have the insurers raised doubts as to whether JFM kept the premises in a proper state of repair by exercising reasonable diligence?	pp. 106 - 108	Vol. 17B p. 3777
	pp. 108-110, 112	" pp. 3779-3794
		" pp. 3803,3804
		" p. 3818
		" p. 3854
(VI) Did the insurers prove that the rupture of silos 10 & 18 was attributable to or occasioned by faulty design or construction?	PP. 119-188	
	Mr. Minor	
	p. 122	Vol. 19 p. 3982
	p. 123	" p. 3984
	p. 124	" p. 3986

SECTIONS	JUDGMENT	EVIDENCE
		3987
	p. 125	" p. 3989
	p. 126	" p. 3990
	p. 127	" p. 3991
	p. 128	" p. 3992
	p. 135	" pp. 3994-3995
	p. 136	p. 3999
	p. 137	pp. 4002-4004
	p. 138	pp. 4005-4006
	p. 139	pp. 4013-4015
	p. 140	pp. 4017-4018
	p. 141	pp. 4021-4022
	p. 142	pp. 4023,4027
	p. 143	p. 4028
	p. 144	pp. 4029-4036
		p. 4104
	p. 145	p. 4105,4117
		Vol. 20 p. 4549
(VI) (cont'd)	p. 146	Vol. 20 p. 4550
	p. 147	" p. 4553-4554
	p. 148	" p. 4555
	p. 150	" p. 4565
		4568
	p. 151	" p. 4568
		p. 4569
	p. 152	" pp. 4569-4570
	p. 153	" pp. 4571-4572
	p. 154	Vol. 21 pp. 4600-4602
		4606
	p. 156	Vol. 22 p. 5004
	p. 157	Vol. 21 pp. 4607,4612
	p. 158	p. 4613
	p. 159	pp. 4614,4621
	p. 160-161	pp. 4629-4630
	p. 162	pp. 4641-4642

SECTION	JUDGMENTS	EVIDENCE
	p. 163	pp. 4648,4657 4658
	p. 164	p. 4659
	p. 165	pp. 4660-4663
		p. 4663A
	p. 166	pp. 4668-4669
	p. 167	pp. 4671-4672
	p. 168	pp. 4674-4675
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		pp. 4679-4680
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	p. 172	p. 4796
	p. 173	pp. 4802-4803
		p. 4808
	p. 174	pp. 4804,4806
	p. 175	p. 4815
	p. 176	pp. 4818-4819
	p. 179	pp. 4822-4839
	p. 181	p. 4863
	p. 182	p. 4866
	p. 183	p. 4807
	p. 184	p. 4870
	p. 185	Vol. 22 pp. 4914
(VI) (cont'd)	p. 187	Vol. 22 p. 4924
(VI A) Professor Mitchell's evidence on the insurers case that faulty design and construction were the cause of the collapse of silos 10 and 18	Prof. Mitchell	
	pp. 188-202	
	p. 189-190	Vol. 27 pp. 5991-5992
		p. 5992

SECTIONS	JUDGMENT	EVIDENCE
		p. 5996-5997
	p. 191	" pp. 5609-5610
		p. 5611
	pp. 192-193	pp. 5613-5614
		5164
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	p. 194	p. 5616
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	p. 195	p. 5654
		p. 5656
	p. 196	p. 5657-5658
	pp. 197-198	p. 5663
	pp. 199-200	pp. 5668-5669
(VI B) Were there expressed or implied admissions by JFM that the collapse of silos 10 and 18 were attributable to faulty design or faulty construction?	<u>Mr. Cader</u>	
	PP. 202-232	
	p. 204	Vol. 6 p. 1498
		" p. 1499
		" p. 1500
	p. 205	" pp. 1501-1502
(VIB) (cont'd)	p. 206	
	p. 209	Vol. 7 p. 1665
		1666
	p. 211	Vol. 8 p. 1865
	p. 213	" p. 1866
	p. 221	Vol. 5 p. 1236

SECTION	JUDGMENT	EVIDENCE
(VIB) (cont'd)	p. 222-224 p. 225 p. 228	p. 1280 Vol. 6 p. 1311 p. 1309-1310
(VII)Did the insurers computer runs support their case that Gilbert was not the cause of the rupture in silos 10 and 18?	PP. 232 - 243	
(VIII) Conclusion	PP. 244 - 248 Mr. Minor p. 245-246	 Vol. 20 p. 4652

WOLFE J A

I have had the benefit of reading the judgments, in draft, of my learned brothers and wish to state that I agree with the judgment of Rattray P, for the reasons stated therein.

I, too, would therefore order that the appeal be allowed, that the judgment of the Crown below be set aside and judgment entered for the plaintiff appellant. The matter is to be remitted to the Supreme Court for damages to be assessed.

I consider the order for costs as proposed by Rattray P to be appropriate in the circumstances.

RATTRAY P

By a majority the appeal is allowed. Judgment of the court below set aside. Judgment entered for the plaintiffs/appellants with costs here and below to be taxed if not agreed.

We remit the matter to the court below for damages to be assessed.