NATIONAL JUSTICE COMPANIA NAVIERA SA v PRUDENTIAL ASSURANCE CO LTD ("THE IKARIAN REEFER")

QUEEN'S BENCH DIVISION (COMMERCIAL COURT)

[1993] 2 Lloyd's Rep 68

HEARING-DATES: 13, 14, 18, 19, 20, 21 May, 2, 3, 4, 8, 9, 10, 11, 12, 15, 16, 17, 18, 22, 23, 24, 25, 29, 30 June, 1, 2, 6, 7, 8, 9, 13, 14, 15, 16, 17, 20, 21, 22, 23, 27, 28, 30, 31 July, 5, 6, 7, 8, 12, 13, 14, 15, 19, 20, 21, 22, 26, 27, 28, 29 October, 2, 3, 4, 5, 9, 11, 12, 16, 17, 18, 19, 23, 24, 25, 26, 30 November, 1, 2, 3, 7, 8, 9, 10, 11, 14, 15, 16, 17 December 1992, 25 February 1993

25 February 1992

CATCHWORDS:
Insurance (Marine) -- Constructive loss of vessel -- Fire broke out on vessel -- Shipowner claimed under policy -- Underwriters alleged vessel deliberately set on fire with shipowner's' connivance -- Whether allegation proved to relevant standard -- Responsibilities of expert witnesses -- Whether underwriter liable

HEADNOTE:
The plaintiff company were the owners of Ikarian Reefer which was insured inter alia with the defendants. The vessel was insured against inter alia perils of the sea, fire and barratry. Under the policy the vessel was valued at US$3m of which 87.5 per cent was subscribed by the defendants.

The plaintiffs formed part of the extensive shipping interests of the Comninos Brothers.

On Apr 12, 1985 at about 23 00 hours Ikarian Reefer ran aground on the shoals off Sherbro Island, Sierra Leone in the course of a voyage from Kiel to Abidjan in ballast. At about 01 00 on Apr 13 fire broke out in the engineroom of the vessel and spread to the accommodation. At 01 15 the vessel was abandoned and the crew were picked up at about 03 30 by the Yugoslavian vessel Ljubljana.

The plaintiffs claimed under the policy contending that Ikarian Reefer became an actual or constructive total loss in consequence of a peril insured against ie fire (and or perils of the sea). The plaintiffs submitted that loss by fire included deliberate fire. If however the fire was accidental and if contrary to the plaintiffs' primary contention, the Court found that the fire on Ikarian Reefer was the deliberate act of the master and crew the plaintiffs claimed a loss by barratry.

The defendants argued that the vessel was wilfully cast away in that it was deliberately run aground and deliberately set on fire by or with the connivance of those beneficially interested in the plaintiffs. The defendants contended that it was to be inferred that the master, officers and crew would only have cast the vessel away on the instructions or with the connivance other beneficial owners.

The question for decision was had the defendants proved to the relevant standard that Ikarian Reefer was deliberately set on fire with the connivance of the owners.

-- Held, by QB (Com Ct) (CRESSWELL, J), that (1) before the grounding there were two impacts and the master's perception at that time was that he was in deep water and in a safe position; however the actions taken by the master were not consistent with the conduct of a master intent on deliberately grounding his ship; the master did not consider he had struck the ground; and the master's errors were a failure to use the echo sounder, a failure to alter course to starboard for a longer period of time, a failure

to slow down or stop and a failure to look at the Satnav; and the grounding of Ikarian Reefer was not deliberate but due to the negligent navigation by the master (see p 91, col 2; p 92, cols 1 and 2; p 95, col 2; p 133, col 2; p 141, col 2):

(2) the inspection of Ikarian Reefer and in particular of the quick closing stop valve and the area immediately surrounding the valve was materially inadequate; from the diesel oil service tank (DOST) diesel passed first through the valve; the source of fuel for the fire was diesel from the DOST and the valve was found to be fractured; it was not sufficient to assume that the valve had fractured as a result of the fire and a full and careful examination of other possible causes had not been carried out (see p 113, col 2; p 114, col 1; p 133, col 2; p 134, col 1);

(3) the main area of fire damage was in the generator flat in way of number 2 generator; the remaining fire damage in the engineroom spread from that area; the seat of the fire was in the vicinity of the number 2 generator although the evidence was inconclusive as to precisely where ignition first took place; there was only one seat of fire (see p 114, cols 1 and 2);

(4) the tap, which was connected to the drop line through which diesel was fed, was found to be 80 per cent open after the fire; it was likely that prior to the casualty the tap was subject to wear particularly if it had been in use since 1968 and it was possible that it vibrated open (see p 115, col 1; p 134, col 1):

(5) if a deliberate fire was started in the manner alleged by the defendants it was difficult to account for the limited nature and extent of the damage to the tap and the generator flat (see p 116, col 2);

(6) on the evidence the defendants had not proved to the relevant standard that Ikarian Reefer was deliberately set on fire (see p 133, col 2; p 141, col 2);

(7) if Ikarian Reefer had been deliberately set on fire by a member of the crew the defendants had not proved that the owners in any way consented or were privy to that action; and if the burden of disproving privity lay on the owners they had discharged it (see p 141, cols 1 and 2);

(8) the submission by the defendants that "it may be no more than standing instructions" that most Greek ship masters would know that if they had an accident their owner would far rather they had a total loss than a partial loss, would be rejected; there were no such standing instructions; and there was no evidence of any meeting between the owners and the master face to face at any time between November, 1984 and the casualty when instructions to cast the vessel away could have been given; there would be judgment for the owners (see p 141, cols 1 and 2).

Per CRESSWELL, J (at p 81, col 2): I will refer to some of the duties and responsibilities of experts in civil cases because I consider that a misunderstanding on the part of certain expert witnesses . . . as to their duties and responsibilities contributed to the length of the trial . . .

The duties and responsibilities of expert witnesses in civil cases include the following:

1. Expert evidence presented to the Court should be and should be seen to be the independent product of the expert uninfluenced as to form or content by the exigencies of litigation . . .

2. An expert witness should provide independent assistance to the Court by way of objective unbiased opinion in relation to matters within his expertise . . . An expert witness in the High Court should never assume the role of advocate.

3. An expert witness should state the facts or assumptions on which his opinion is based. He should not omit to consider material facts which detract from his concluded opinion . . .

4. An expert witness should make it clear when a particular question or issue falls outside his expertise.

5. If an expert's opinion is not properly researched because he considers that insufficient data is available then this must be stated with an indication that the opinion is no more than a provisional one . . .

6. If after exchange of reports, an expert witness changes his view on a material matter . . . such change of view should be communicated . . . to the other side without delay and when appropriate to the Court.

7. Where expert evidence refers to photographs, plans, calculations . . . survey reports or other similar documents there must be provided to the opposite party at the same time as the exchange of reports . . .

CASES-REF-TO:

Alexion Hope, The (CA) [1988] 1 Lloyds Rep 311;
Arnus, The (1924) 19 Ll L Rep 95;
Bater v Bater, [1951] P 35;
Broughton Park Textiles (Salford) Ltd v Commercial Union Assurance Co Ltd, [1987] 1 Lloyd's Rep 194;
Captain Panagos DP, The [1986] 2 Lloyd's Rep 470;
Derby & Co Ltd & Others v Weldon and Others, (CA) The Times, Nov 9, 1990.
Elias Issaias, The (CA) (1923) 15 Ll L Rep 186;
Filiatra Legacy, The (CA) [1991] 2 Lloyd's Rep 337;
Hornal v Neuberger Products Ltd, [1957] 1 QB 247;
Insurance Co of Africa v Scor (UK) Reinsurance Co Ltd, (CA) [1985] 1 Lloyd's Rep 312;
J, Re [1990] FCR 193;
Michael, The [1979] 1 Lloyd's Rep 55;
Olympia, The (1924) 19 Ll L Rep 255;
Polivitte Ltd v Commercial Union Assurance Co Plc, [1987] 1 Lloyd's Rep 379;
Popi M, The (HL) [1985] 2 Lloyd's Rep 1;
R v Home Secretary ex parte Khawaja, (HL) [1984] 1 AC 74;
Slattery v Mance [1962] 1 Lloyd's Rep 60;
Whitehouse v Jordan (HL) [1981] 1 WLR 246;
Zinovia, The [1984] 2 Lloyd's Rep 264.

INTRODUCTION:
This was an action by the plaintiffs National Justice Compania Naviera SA claiming under an insurance policy issued inter alia by the defendants, Prudential Assurance Co Ltd, in respect of the loss of its vessel Ikarian Reefer.

COUNSEL:
Mr Anthony Clarke, QC and Mr Nigel Jacobs for the plaintiffs; Mr Stephen Tomlinson, QC and Mr Stephen Kenny for the defendants.

JUDGMENT-READ:
Judgment was reserved. Feb 25, 1993

PANEL: CRESSWELL J

JUDGMENTBY-1: CRESSWELL J

JUDGMENT-1:
CRESSWELL J: I. THE CLAIM, THE DEFENCE, THE LEGAL PRINCIPLES AND THE OUESTION FOR DECISION

A. THE CLAIM

B. THE DEFENCE

C. THE LEGAL PRINCIPLES

D. THE QUESTION FOR DECISION

II. CHRONOLOGY

III. THE COMNINOS BROTHERS SHIPPING INTERESTS

IV. THE IKARIAN REEFER

A. THE CREW OF THE IKARIAN REEFER

B. A DESCRIPTION OF THE IKARIAN REEFER AND HER EQUIPMENT

C. THE ENGINE ROOM

D. THE SATELLITE NAVIGATOR

E. THE AUTOMATIC PILOT

F. DELTA ERROR

V. EXPERT EVIDENCE

A. EXCHANGE OF EVIDENCE-EXPERT WITNESSES

B. THE DUTIES AND RESPONSIBILITIES OF EXPERT WITNESSES

VI. THE GROUNDING

A. THE WATCHES

B. CHARTS

C. THE SHOALS OF SAINT ANN

D. CANARY CURRENT AND NORTH EQUATORIAL CURRENT

E. CURRENT ROSE FOR APRIL

F. TIDAL STREAMS

G. WEATHER AND SEA CONDITIONS FOR OPEN SEA OFF FREETOWN SIERRA LEONE

H. THE EVIDENCE FROM THE CREW OF THE IKARIAN REEFER AND OTHERS

I. SATELLITE NAVIGATION ISSUES

J. THE EVENTS OF APR 12 AND 13 1985

K. THE EXPERT EVIDENCE AS TO NAVIGATION

L. RECONSTRUCTION AND EXPLANATIONS FOR THE GROUNDING

VII. THE FIRE

A. THE FRACTURED VALVE AND THE OPEN TAP

B. DESCRIPTION OF THE VALVE AND THE CONNECTION BETWEEN THE VALVE AND THE TANK

C. THE RIVAL CONTENTIONS AND THE RIVAL MECHANISMS

D. THE EXPERT WITNESSES

E. THE FIRE, ANALYSIS, FINDINGS AND CONCLUSIONS

F. THE INSPECTION OF THE IKARIAN REEFER BY THE FIRE EXPERTS

G. ONLY ONE SEAT OF FIRE

H. THE OPEN TAP

I. WAS THE DAMAGE (a) TO THE TAP (b) TO THE GENERATOR FLAT CONSISTENT WITH THE DEFENDANT'S CASE?

J. HEATING THE PIPE

K. HEATING THE VALVE

L. MOVEMENT OF THE FLOOR PLATES

M. OTHER MECHANISMS OR COMBINATIONS

N. THE FATIGUE/VIBRATION MECHANISM

O. THE CIGARETTE AND RAG MECHANISMS

P. THE FIRE. CONCLUSION

VIII. MOTIVE AND CONNIVANCE

IX. OPPORTUNITIES FOR COMMUNICATIONS BETWEEN THE OWNERS AND THE MASTER

X. CONCLUSIONS

I. THE CLAIM, THE DEFENCE, THE LEGAL PRINCIPLES AND THE OUESTION FOR DECISION

A. THE CLAIM

The plaintiff company (incorporated in Panama) were the owners of Ikarian Reefer. In 1985 the plaintiff company ("the plaintiffs") formed part of the extensive shipping interests of the Comninos Brothers ("Comninos"). By a policy of marine insurance No

132875 HD Ikarian Reefer was insured from February, 1985 against inter alia, perils of the sea, fire and barratry. Under the policy the vessel was valued at US$3m of which 87.5 per cent was subscribed by the defendants (among others). (The defendants do not suggest that the placing of a value of US $3m on the vessel for the purposes of insurance was other than in the normal course of business.)

Chase Manhattan Bank NA ("Chase Manhattan") were mortgagees of the vessel. By an assignment of insurance dated Dec 5, 1983 the plaintiffs assigned to Chase Manhattan their interest in any insurance of the vessel and the benefits thereof. By a deed of assignment dated Jan 17, 1989 Chase Manhattan assigned to Den Norske Creditbank PLC ("Den Norske") their interest in any insurance of the vessel. By a deed of assignment dated Oct 24, 1989, Den Norske assigned to the plaintiffs their interest in any insurance of the vessel. The plaintiffs are accordingly entitled to claim against the defendants in respect of the actual and/or constructive total loss of the vessel. On Apr 12, 1985 at about 23 00 Ikarian Reefer ran aground on the shoals off Sherbro Island, Sierra Leone, in the course of a voyage from Kiel to Abidjan in ballast. At about 01 00 on Apr 13 fire broke out in the engineroom of the vessel. The fire spread to the accommodation and at about 01 15 those remaining on board abandoned ship. The crew were picked up at about 03 30 by the Yugoslavian flag vessel Ljubljana.

The plaintiffs' case is that Ikarian Reefer became an actual or constructive total loss, in consequence of a peril insured against, namely fire (and/or perils of the sea). The plaintiffs contend that loss by fire includes loss by deliberate fire. If, however, the fire must be accidental and if, contrary to the plaintiffs' primary contention, the Court finds that the fire on Ikarian Reefer was the deliberate act of the master or crew, the plaintiffs claim a loss by barratry.

B. THE DEFENCE The defendants' primary case is that the vessel was wilfully cast away in that it was both deliberately run aground and deliberately set on fire by or with the connivance of those beneficially interested in the plaintiffs. The defendants say that it is to be inferred that the mas1er, officers and crew would only have cast the vessel away on the instructions or with the connivance of her beneficial owners.

C. THE LEGAL PRINCIPLES

The relevant legal principles are as follows:

1. Loss by perils of the sea. The burden of proving, on a balance of probabilities, that a ship was lost by perils of the sea remains throughout on the owners. Although it is open to insurers to suggest and seek to prove some other cause of loss, against which the ship was not insured, there is no obligation on them to do so. Moreover, if insurers choose to do so, there is no obligation on them to prove, even on a balance of probabilities, the truth of their alternative case (The Popi M, [1985] 2 Lloyd's Rep 1 at p 2, Lord Brandon).

2. Fire. "Fire" in a marine policy includes, as a matter of construction, a fire started deliberately by a stranger to the insurance (The Alexion Hope, [1988] 1 Lloyd's Rep 311 at p 317 per Lord Justice Lloyd).

3. Where the owners have proved a loss by fire, the burden of proving a deliberate fire and connivance lies upon the insurers. If the evidence leaves the Court in doubt then the assured is entitled to succeed. Thus the assured in a claim for loss by fire has a lesser burden than one claiming for loss by perils of the sea (who must prove a fortuity), though he is in the same position in this respect as the claimant for loss by barratry. (The Captain Panagos DP, [1986] 2 Lloyd's Rep 470 at p 510, Mr Justice Evans.)

4. The assured must prove a loss caused by an insured peril ("fire") and the insurers

must prove, if so alleged, that there was a deliberate fire and connivance by the assured and so defeat the claim under s 55(2)(a) of the Marine Insurance Act, 1906 which provides that:

. . . the insurer is not liable for any loss attributable to the wilful misconduct of the assured, but, unless the policy otherwise provides, he is liable for any loss proximately caused by a peril insured against, even though the loss would not have happened but for the misconduct or negligence of the master or crew.

If the evidence shows a loss by fire, which was accidental rather than deliberate, the assured succeeds. If the evidence shows that the fire was deliberately caused with the connivance of the assured, the assured fails. If the evidence shows a fire deliberately caused by the master or crew (a factual situation co-existing with that required to establish a barratry claim) this is covered by "fire" and the assured need not prove absence of connivance on his part (The Captain Panagos DP sup at p 510-511, Mr Justice Evans).

5. Standard of proof. The insurers must prove that there was a deliberate fire and connivance by the assured to:

. . . the high standard required for proof of fraud in a civil case . . . a balance of probabilities appropriate to the seriousness of the charge, a standard falling not far short of the rigorous criminal standard [per Mr Justice Bingham in The Zinovia [1984] 2 Lloyd's Rep 264 at p 272].

Thus --

. . . the burden of proof, though not quite equivalent to that required in a criminal case is a heavy burden commensurate with the gravity of the matter [per Lord Justice Neill in the Captain Panagos DP, [1989] 1 Lloyd's Rep 33 at p 41].

I will refer to the standard proof set out above as "the relevant standard". See further Bater v Bater, [1951] P 35; Hornal v Neuberger Products Ltd, [1957] 1 QB 247; Slattery v Mance, [1962] 1 Lloyd's Rep 60; Reg v Home Secretary, Ex p Khawaja, [1984] 1 AC 74; The Insurance Co of Africa v Scor (UK) Reinsurance Co Ltd, [1985] 1 Lloyd's Rep 312; Broughton Park Textiles (Salford) Ltd v Commercial Union Assurance Co Ltd, [1987] 1 Lloyd's Rep 194; Polivitte Ltd v Commercial Union Assurance Co Ltd, [1987] 1 Lloyd's Rep 379; The Filiatra Legacy, [1991] 2 Lloyd's Rep 337 at pp 365 to 366 where Lord Justice Mustill said:

We ourselves are not altogether comfortable with the idea of a flexible burden of proof and would incline to prefer what we understand to be the view of Lord Justice Slade in R v Hampshire County Council, [1985] ICR 317 at p 329, that, in deciding whether a fact has been proved on balance of probabilities, the likelihood that people such as those involved would band together to commit a crime of the type and magnitude in the manner alleged is one among other factors to be weighed in the balance. We doubt whether the difference of formulation is of any real significance. The principle is clear enough.

For the avoidance of doubt the formulation in The Filiatra Legacy would not have led to a different result in the present case.

6. Barratry. Section 30(2) of the Marine Insurance Act 1906 provides:

Subject to the provisions of this Act, and unless the context of the policy, otherwise requires, the terms and expressions mentioned in the First Schedule to this Act shall be construed as having the scope and meaning in that schedule assigned to them.

The term "barratry" is defined in the First Schedule as including:

. . . every wrongful act wilfully committed by the master or crew to the prejudice of the owner or, as the case may be, charterer.

It is a necessary ingredient of the definition that the wilful act should have been committed "to the prejudice of the owner". Once the owners have proved a casting away by the deliberate act of the master or crew, it is for the insurers to establish to the relevant standard (see 5 above) that the owners consented to, or connived at, the casting away. The judgments of the Court of Appeal in The Elias Issaias, (1923) 15 Ll L Rep 186 make it impossible for any Court below the House of Lords to conclude that where a stranding was caused by a deliberate act, the onus of proving an absence of consent or connivance rests on the owners (The Captain Panagos DP sup at p 40, Lord Justice Neill).

7. Motive. Motive itself is obviously insufficient to afford proof of crime. Where the facts proved against the owner are sufficiently unambiguous it is not incumbent on the insurers to prove a motive (The Elias Issaias sup at p 192, Lord Justice Atkin and The Zinovia sup at p 273, Mr Justice Bingham).

8. The decided cases. The correct approach to the facts. In considering the approach of the various Courts in each of the cases where scuttling has been alleged it is important to keep in mind the facts of the individual case. In any particular case, while recognizing that an allegation of privity to scuttling against an owner is a matter of the utmost seriousness, it is necessary to look at all the circumstances of the case and to draw any permissible inferences (The Captain Panagos DP sup at p 41, Lord Justice Neill). Judges have long recognized the special difficulties facing marine insurers in resisting total loss claims which they believe to be fraudulent, and have defined the task of the Courts accordingly. Circumstances may exist, individually, not of decisive consequence, but in their cumulative effect establishing to the relevant standard that the vessel was dishonestly stranded or set on fire. It is not fatal to insurers that parts of the canvas remain unlighted or blank, provided only that some facts are established which are inconsistent with, or at least throw substantial doubt on, the owner's innocence. Where the facts proved against the owner are sufficiently unambiguous, his previous reputation and respectability will not save him from an adverse judgment (The Zinovia sup at pp 272-273, Mr Justice Bingham; The Olympia, (1924) 19 Ll L Rep 255; The Arnus, (1924) 19 Ll L Rep 95; The Elias Issaias sup). No Judge likes to decide cases on the burden of proof if he can legitimately avoid having to do so. There are however cases in which, owing to the unsatisfactory state of the evidence or otherwise, the only just course for the trial Judge to take is to decide the matter on the burden of proof (The Popi M sup at p 6, Lord Brandon).

9. Cases where the choice before the Court is either that the vessel was cast away with the connivance of the owners or by the crew for their own purposes. In a case where the choice before the Court is either that the vessel was cast away with the consent or connivance of the owners or it was cast away by the master and some members of the crew for their own purposes the task of the Courts is to decide on which side the balance falls (The Captain Panagos DP sup at p 41, Lord Justice Neill).

10. The approach to be adopted for determining whether a deliberate stranding was or was not carried out with the connivance of the owner. As to the approach to be adopted for determining whether a deliberate stranding or other deliberate damage was or was not carried out with the consent or connivance of the owner the following guidance applies:

(a) Though the presence of a motive is not sufficient by itself to establish guilt, it is

important to examine (i) whether the owner had any reason to destroy or damage the vessel; and (ii) whether the master or crew had any reason to destroy or damage the vessel for purposes of their own. Thus, for example, it may become apparent that the master had some financial interest in the vessel himself, or bore some ill will towards the owner, or wished to rid himself of the anxious and dangerous task of being responsible for a defective vessel.

(b) It is important to consider what opportunities there may have been during the relevant period for communications between the owner and the master or other persons whose acts led to the sinking or other casualty.

(c) It is unlikely that there will be any documentary or other direct evidence of consent or connivance and it is therefore necessary to consider what inferences, if any, can properly be drawn from the circumstantial evidence.

(d) Though it is necessary to bear in mind that the burden of proving consent or connivance must be discharged "with meticulous completeness", where the facts admit only two explanations that is, either connivance by the owners or a private venture of the master and members of the crew -- an inference of the owner's guilt can properly be drawn if the probabilities point clearly and irresistibly towards his complicity. Though a finding of complicity or other fraudulent conduct should not be made unless the scale comes down firmly on the side of guilt, the case in the end has to be decided on the balance of probabilities (The Captain Panagos DP sup at p 43, Lord Justice Neill).

Reservations in case this case goes further

Mr Tomlinson, QC on behalf of the insurers reserved a number of legal arguments in case this case goes further:

(a) Loss by the peril of fire does not include loss by deliberate fire. Deliberate fire is not the insured peril of fire because it is not fortuitous, although it may well be malicious act or malicious damage, where this is covered.

(b) Loss by fire does not include loss by fire deliberately started (or deliberately not extinguished) by the insured or his servants or agents.

(c) Where barratry is relied upon it is for the owner to prove that the wrongful act was committed to his prejudice.

(d) Where fire and barratry are both insured perils, loss caused by a barratrous fire is not recoverable as a loss by fire simpliciter.

(e) Where loss by barratrous fire is alleged, the burden of proof is on the insured to show that the act of starting and/or not extinguishing the fire was to his prejudice.

D. THE QUESTION FOR DECISION

On day 74 Counsel for the defendants conceded that the fire was the proximate cause of Ikarian Reefer becoming a constructive total loss (prior to this the defendants had reserved a point to the effect that, in certain circumstances, the fire might be regarded as merely the consequence of the grounding). In the light of the legal principles set out above the question for decision is -- have the underwriters proved to the relevant standard that the Ikarian Reefer was deliberately set on fire with the connivance of the owners? This question must be answered having regard to all the evidence. It is necessary to look at all the circumstances of the case and to draw any permissible inferences.

II. CHRONOLOGY

1985

APRIL

3rd	Time-charter round voyage concluded with Chargeurs Reunis, Paris for one round voyage via safe port(s) West Africa to Continent or West Mediterranean in charterer's option.
4th	Ikarian Reefer arrived at Brunsbuttel for bunkering Ikarian Reefer delivered on time charter to charterers Chargeurs Reunis. Ikarian Reefer full ahead towards Abidjan in accordance with instructions from the charterers: . . . after . . . bunkering . . . Please proceed bound Abidjan and adjust your speed to reach Abidjan pilot April 13th pm.
5th	Comninos received a message from the master via Athens Radio "ETA Abidjan 13/4 pm".
6th	Comninos received a message from the master via Athens Radio. Vessel will load Abidjan bananas/pineapples for Marseille/Leghorn.
7th	The Ikarian Reefer's fair deck log recorded: . . . very strong wind; very rough sea; pitching and rolling; visibility good . . . hull, engine and rudder taking punishment.
9th	Comninos received a message from the master via Athens Radio "ETA Abidjan 14/4 morning". Master of Ikarian Reefer received Saronic Reefer radiotelegram by mistake. Master spoke to Captain Christatos on

	the radio telephone.
10th	Easter greetings message sent by Comninos to Athens Radio for transmission to Ikarian Reefer.
11th	The Ikarian Reefer's fair deck log recorded "changed course (171o)".
12th	(Greek Good Friday) Comninos received a message from the master via Athens Radio as to the noon position of the Ikarian Reefer for 11th (15.39N 17.45W) with other information including "ETA Abidjan 14/4 1000".
12th/13th	GROUNDING AND FIRE -- CREW SUBSEQUENTLY PICKED UP BY YUGO-SLAVIAN VESSEL THE LJUBLJANA
13th	Comninos notified Under-writers and P and I Club of grounding and fire. Comninos appointed "ELSHIP" as agents in Sierra Leone and requested them to send a representative to look at the ship and report upon "what salvage and fire fighting facilities existing in the area . . .".
14th	GREEK EASTER
15th	Comninos instructed agents in Sierra Leone to hire a helicopter in order to determine salvage possibilities. Crew arrived in Lome from Ljubljana.
16th	Captain Katakos arrived in Sierra Leone (via London).
17th	Helicopter trip arranged for Katakos, Lloyd's Agent (Mr Floode) on behalf of the Salvage Association ("SA"), Harbour Master and Port Authority rep-resentative. Katakos reported to Comninos following the helicopter inspec-tion:

	. . . I will try and perhaps succeed in boarding the ship tomorrow for inspection together with salvage but everything here very difficult. If in the end I manage to board the only means available is a small craft distance 66 miles. I will require the whole of tomorrow please advise . . .
	Crew repatriated from Lome to Athens.
	Salvors (Vourelias and Bouras) from Starfish Navigation boarded the vessel.
18th	Comninos asked Lloyd's to provide information about salvage availability.
	Vessel reported to be afloat and drifting. Comninos notified Katakos that arrangements had been made for SA expert and two fire experts to fly to Freetown and requested him to make arrangements for an inspection on 20th.
	Lloyd's advised salvage companies of position of vessel and asked them to contact Comninos.
	Cory Ship Towage ("Cory") provided details of Rowangarth for towage.
19th	Comninos telexed Katakos . . . We clarify that you will travel jointly with the . . . experts on 20/4/85 and not prior their arrival with Lloyd's Agents as suggested in yr telex.
	Fire experts (and SA expert) arrived in Sierra Leone.
	21st
	Katakos and experts departed Freetown for vessel and arrived near vessel late pm.
	22nd

	Mr Charles Lowe of Holman, Fenwick and Willan ("HFW") (and Mr Robin Hollyhead of Burgoynes) arrived at Comninos offices for crew interviews. The interviews began on 22nd and were completed on 27th ("the first interviews"). Experts and Katakos boarded the vessel and commenced inspection.
23rd	Salvage claim for Shaw & Croft ("S & C") on behalf of Starfish Navigation (security demanded for the claim in sum of $250,000). Further inspection carried out on board the vessel by experts and Katakos. Open tap found (about 1500).
24th	Smit Int advised that they were interested in towage proposals. Expert arrived back in Freetown.
25th	Cory made proposals for the vessel to be towed to Cadiz. Salvage proposals received from Wijsmuller Salvage BV.
26th	Mr Lowe informed HFW London: Owners anxious to arrange tow with (Cory) asap because so cheap and vsl gets to a ready scrap market . . . Mr John Shearer of SA began interviewing principal engineering witnesses but stopped almost immediately when Ince & Co were instructed. Comninos decided that underwriters should have unrestricted access to the witnesses.
28th	Mr Cook arrived in Athens and replaced Hollyhead.
29th	Salvors increased demand for security to US $375,000. Brokers (Stewart & Hazell) offered tug Tamaran for tow-

	age.
	Ince & Co were instructed by the underwriters.
	Notice of Abandonment.
MAY	
1st	Mr Lowe (HFW), Mr Paul Arditti (Ince & Co) and Shearer & Bach (SA) started interviewing the witnesses. (These interviews continued on 2nd and 3rd May, 13th and 14th and 25th June ("the second (joint) interviews")).
	Master granted pension from Seamen's Pension Fund (NAT) from this date.
2nd	Starfish Navigation demanded security or threatened to tow the vessel to Freetown.
	Salvors (Vourelias and Bouras) left vessel.
	Comninos notified that underwriters declined abandonment.
	Brokers offered tug Fairplay X: DM 175,000 to Cadiz.
3rd	HFW gave S & C an estimate of salved value at $151,000.
9th	Master's Letter of Protest before Piraeus Magistrates Court.
10th	Salvage Security demand reduced to US $180,000.
13th	HFW on behalf of Comninos obtained scrap valuation with delivery at Spanish port at US $50 per long ton light displacement.
15th	HEW wrote to S & C: Your clients' present security demand doubles the likely salved value and our clients cannot . . . consider provision of security in this sum.
16th	S & C on behalf of salvors sought "open letter of guarantee.
23rd	HFW informed S & C that Comninos:

	. . . are anxious to know present position of the vessel, her condition and . . . are prepared to arrange for a guarantee in a sum which reflects present value of the ship.
JULY	
25th	HFW informed S & C that:- Our clients wish to make an inspection of the vessel and it is hoped that this can take place in the weeks beginning either the 5th or 12th August depending upon access to the vessel . . .
SEPTEMBER	
	Two Greek employees of Klonos visited Comninos offices. Klonos contacted Mr Costas Comninos ("CC") -- the taped telephone conversation. Klonos subsequently sent to CC a document in Greek containing a number of allegations. Mr Golding of Millers was informed of the above. (The defendants do not rely on the allegations in the telephone conversation or the letter.)
NOVEMBER	
15th	Writ issued with points of claim endorsed.
DECEMBER	
2nd	ASNA Tribunal found that the grounding was due to the gross negligence of the master and that the subsequent fire was due to the negligence of the Chief Engineer.
1986	
JANUARY	
13th	Negotiations with salvors recommenced with Clifford-Turner instructed on owners' behalf (in salvage claim).
16th	S & C informed Clifford-Turner that their clients: . . . are ready and willing to

	deliver the vessel into Owners' hands . . . and sought security for $250,000 -- award to be determined by Lloyd's arbitrator.
20th	Owners responded with an offer of security of 50 per cent of salved value ($70,000) and LOF arbitration. Vourelias and Bouras were paid salvage remuneration and provided affidavits.
30th	Points of defence were served.
FEBRUARY	
4th-7th	8 & C offered on behalf of the salvors to accept security of $180,000 and arbitration.
15th	Salvors threatened to withdraw services unless redelivery was accepted. Clifford-Turner informed S & C: . . . In view of your clients continued unwillingness to complete the salvage services by delivering the vessel to a safe place, our clients are now making arrangements to have the vessel towed from where she is to a safe port . . . our clients are prepared to accept delivery on commencement of the tow.
18th	Clifford-Turner said they were: . . . endeavouring to establish costs of towage to Spanish port . . . [and added] Our clients will put up security, but would prefer to explore settlement figure first to avoid expense of a bank guarantee.
26th	Clifford-Turner were notified by S & C that an order for the arrest of the vessel had been obtained in Sierra Leone and that the salvage services were deemed to be terminated. Clifford-Turner reported to P &

	I Club that it would be impossible to remove the vessel whilst she was under arrest. The owners were actively obtaining prices for towage costs because: . . . in particular it would give them access to the vessel for further investigations in relation to their claim against hull and machinery underwriters.
28th	Clifford-Turner instructed Bishop-Gooding in Sierra Leone in relation to the arrest proceedings.
MARCH	
4th	Clifford-Turner (instructed on behalf of Comninos in relation to insurance claim instead of HFW) instructed Bishop-Gooding to enter an appearance in Sierra Leone action and state that "shipowners wish to preserve the ship" notwithstanding her "little residual value".
5th	Defendants served their list of documents and list of documents sought on discovery.
6th	Comninos offered the lubes, bunkers and stores to salvors in settlement of claims.
12th	Owners advised by Solicitors and Counsel of the need to reinspect the vessel. Salvors rejected offer of lubes and bunkers in settlement.
14th	Clifford-Turner notified S & C 1st that they were prepared to offer $100,000 security and to agree LOF, with arbitration in London.
APRIL	
22nd	Clifford-Turner reported that the Judge in Freetown had still not given judgment on the application to set aside the arrest.
25th	Sierra Leone PA were unable to provide tug assistance.

30th	Sierra Leone Court refused to set aside the arrest.
MAY	
14th	Application was made in Sierra Leone for an order as to the amount of security required to release the ship.
19th/20th	Service of pleadings in Sierra Leone.
JUNE	
11th	Offer of $50,000 to S & C in settlement.
17th	Negotiations with S & C and offer of $78,000.
19th	Offer from scrap yard (Desguaces Lagoa) in Spain.
23rd	Offer from scrap yard (Hierros Novoa) in Spain.
26th	Ince & Co sought information as to reinspection of the vessel.
27th	Clifford-Turner notified Ince & Co that negotiations were well advanced for settlement of salvage claim and release of the ship from arrest in Freetown: We also confirm that arrangements are being made concurrently with settlement of the salvage claim to tow the ship to Algeciras, Spain, for further detailed inspection . . . thus enabling the ship to be brought to a more convenient and accessible location for the inspections of her engine room and the fire damage.
30th	Offer from Smit Int for towage to Port Algere or Recife ($155,000 or 90,000).
JULY	
1st	Settlement agreement alleged to have been concluded between CC and Klonos (settlement of salvage claim at $50,000 subject to confirmation that ship was in a salved condition. Salvage services to terminate on arrival of

	the tug).
	Offer of tug Fairplay X from Link Maritime.
	Offers from Remoques Maritimos and Canaria de Remolques for towage.
3rd	Negotiations with scrap yard at Algeciras.
7th/9th	Counter-offer for towage from Remolques Maritimos.
	Scrapping contract with Hierros Nova concluded.
9th	Ince & Co sought further details as to the reinspection.
10th	Finalisation of towage contract (Punta Tarifa).
11th	The tug Punta Tarffa departed Pasajes.
13th	Ikarian Reefer sank -- see further below. (There is no evidence whatsoever that the plaintiffs were responsible for the sinking).
14th	Owners gave detailed instructions in relation to the safety measures to be followed during towage of the vessel:
	Another very important point is for the towers to leave intact the areas which the fire has affected (engine room and hull), as they often tend to collect everything that can be sold, like copper, white metals, valuable spares etc.
	Local Lloyd's Surveyor (Mr Floode) agreed to make helicopter trip to locate vessel.
16th	Vessel reported to have partially or totally sunk (having taken in water for months)
	Owners sought information from Harbour Master (and others).
17th	Owners halted tug at Las Palmas and terminated its services.
	Owners advised P & I Club that the vessel sank on 13th and that

	towage contract was cancelled.
18th	Clifford-Turner notified Ince & Co of the sinking.
25th	Quotation obtained from Oceaneering International Services for diving services (@ minimum of about £30,000).
DECEMBER	
3rd	Clifford-Turner in a letter to Ince & Co referred to the difficulty in pursuing enquiries with the salvors who were in charge of the vessel at the time of her loss.
1987	
APRIL	Piraeus (vibration) tests.
SEPTEMBER	Cardington tests.
1988	
JUNE	
29th	ASNA Disciplinary Tribunal of First Instance imposed on the chief engineer a penalty of loss of his licence for fix months and dropped the disciplinary proceedings against the master because of his retirement.
OCTOBER	
25th	The Piraeus Magistrates Court found the master not guilty of causing a shipwreck due to negligence and the chief engineer not guilty of arson due to negligence.
1989	
JANUARY	
17th	Chase Manhattan assigned to Den Norske their interest in any insurance of the vessel.
FEBRUARY	
1st	Clifford Chance wrote to Ince & Co for the first time since Dec 3, 1986.
MARCH	
6th	Notice of intention to proceed.
AUGUST	
24th	Further and better particulars of the points of Claim pleaded that it was possible that the fire was

	caused as a result of the fracture of the valve on the supply line from the service tank (which led to fuel leaking onto the exhaust system of a generator).
OCTOBER	Inspection of the vessel, including two dives, by McGibbon and Palmos (who were unable to enter the vessel).
24th	Den Norske assigned to the plaintiffs their interest in any insurance of the vessel.
31st	Chase Manhattan struck out as a plaintiff by consent. Mr Justice Hobhouse directed that a summons for directions be issued.
DECEMBER	
6th	Hearing of Summons for directions before Mr Justice Hurst.
1990	
MARCH	
6th	Defendants served an amended list of documents.
27th	ASNA Higher Disciplinary Tribunal absolved the chief engineer of the charges against him.
1991	
AUGUST	
15th	Plaintiffs served a first list of documents. Clifford Chance stated in a letter: . . . it is our clients' primary case that the fire started due to the fracture of the valve on the diesel oil day tank . . . which ultimately resulted in a fire in the generator bilge, destroying the packing in the stop cock and the vibration from the generators causing it to vibrate open.

III. THE COMNINOS BROTHERS SHIPPING INTERESTS

The Comninos Brothers shipping interests (including the plaintiff company) were owned by Mr Costas Comninos and Mr Anthony Comninos. Mr Alexander Raptis was general manager and Mr Alexander Poulman was financial manager. Captain Christos Christatos

was port captain/reefer superintendent and Captain George Katakos was port captain. All the above gave evidence at the trial.

IV. THE IKARIAN REEFER

A. THE CREW OF THE IKARIAN REEFER

The crew of the Ikarian Reefer at the time of the casualty consisted of:

Capt Nicolaos Tamvakis	-- Master
Ioannis Sardis	-- Chief Officer
Ioannis Marinis	-- Second Officer
Vasilios Kollias	-- Radio Officer
Nicolaos Perdikogianis	-- Bosun
Nicolaos Assimopoulos	-- Cadet
Dionisios Staveris	-- Chief Engineer
Panagiotis Fexis	-- Second Engineer
Panagiotis Ikonomou	-- Third Engineer
Andreas Sarris	-- Reefer Engineer
Nicolaos Kanelopoulos	-- Electrician
Ioannis Marinakis	-- Oiler
Stefanos Tsakiridis	-- Oiler
Theodoros Vugiuklakis	-- Apprentice Engineer
Polidoros Annussis	-- Cook
Areti Annussi	-- Assistant Cook
Vasilios Defereras	-- Steward
Boris Vallandares	-- Assistant Steward
Pantazis Kurtis	-- Able Seaman
Athanasios Panothiokas	-- Able Seaman
Adonios Nginos	-- Able Seaman
Savvas Maheridis	-- Deck Boy
Ioannis Markantonis	-- Able Seaman

B. A DESCRIPTION OF THE IKARIAN REEFER AND HER EQUIPMENT

Ikarian Reefer was built in Spain in about 1968. Her international tonnage was 4365.82 (gross) and 2261.79 (net). Her length all over was about 440 ft. Her draft ballasted forward was about 14 ft, aft about 19 ft and mean about 16 ft. The wireless and navigation equipment included a wireless transmitter and receiver for HF Telegraphy, VHF radio telephone, direction finder, gyro compass, an Anschutz automatic pilot, a DS5 satellite navigator, echo sounder, two radars and underwater log (not in use on the last voyage). The safety equipment included two polyester boats, one with diesel motor for 36 persons, one with oars for 38 persons. The propelling machinery and auxiliary

machinery was as described below.

The refrigeration insulation included refrigeration plant, compressors, condensers and brine coolers.

C. THE ENGINEROOM

Ikarian Reefer had her engineroom amidships. The main engine was a six cylinder 2 stroke Sulzer diesel engine, directly coupled to the propeller shaft. It was located on the centre line of the vessel, in the middle of the engineroom, between frame 83 and frame 93.5. Platforms were arranged around the main engine. The rest of the engineroom machinery was arranged on three main levels.

Bottom level

To port of the main engine at the bottom level were the fuel and diesel oil purifiers (in a separate enclosure to the aft of the engine room); a small boiler (forward); and a number of pumps, including the bilge pump and the main engine cooling pumps. Also at this level, at the aft end of the port side of the main engine, was the manoeuvring stand.

On the starboard side were two large air starting cylinders with their associated compressors, together with some other pumps, including the fuel oil pumps (aft) and domestic pumps (for pumping salt and fresh water to the accommodation space above the engineroom). A large waste bin was also to be found at this level, inboard at the aft end of the main engine.

The main diesel and fuel oil settling and service tanks were also at this level, but raised above the floor plates. These were positioned aft of the main engine, athwartships, against the aft engine room bulkhead. Beneath the settling and service tanks in the middle of the aft bulkhead, was a watertight door, leading to the propeller shaft tunnel.

Middle level

The middle level platform on the port side was occupied principally by the ship's four diesel engined generators. The generators were surrounded by raised gratings and solid floor plates, about a foot above the middle level floor. Below the gratings was a bilge or saveall, surrounded by a flat bar, about 3 in in height.

The flat bar formed the edge of the, saveall. The starboard side at middle level was split into two platforms. This was where the vessel's cargo refrigeration machinery was located. The lower of the two platforms contained the compressor room, and the upper platform contained the brine room.

The main electrical switchboard was forward of the main engine at this level athwartships, between the main engine and the forward bulkhead of the engineroom.

Top level (or cylinder head level)

The top platform in the engineroom was level with the cylinder heads of the main engine.

On the port side at this level, aft and slightly inboard of the position of the generators, was the diesel oil service tank (DOST) which serviced the generator engines. At the forward end of this platform, on the port side, was the engineroom workshop. At the aft end was a refrigerated store room.

The starboard side of the top platform was occupied by the lubricating oil tanks and the

engineroom stores, forward, and a provisions room, aft.

The fuel supply to the generators

The generator engines were fuelled by diesel oil. Diesel oil would be pumped from the double bottom tanks first to the diesel settling tank at the bottom platform, where water in the oil would settle out and be drained away. For daily consumption, the diesel would then be passed through the diesel oil purifiers (also at bottom level) and pumped to the DOST at top level. From the DOST, diesel would be fed by gravity through a drop line to the generator engines at the middle level. On its way to the generator engines the diesel oil passed first through a quick closing stop valve bolted to the inboard side of the DOST, just above the top level floor plates. The stop valve was fitted with a quick release mechanism capable of being operated in an emergency from outside the engineroom. The pipework of the drop line was connected to the outlet of the stop valve. During the inspection of the engineroom following the fire, the stop valve ("the valve") was found to be fractured on its inlet side, between the flange connection to the DOST and the main body of the valve.

From the stop valve, the drop line ran a very short distance inboard before turning down to pass through the floor plates of the top level platform, and then running back under the DOST, and then forward to a vertical pillar or king post located between and slightly inboard of the forward and aft generator sets. The line passed down the outboard side of the pillar. Above the clamp, a small diesel pipe led off from the drop line to a boiler ("the boiler feedline").

Below the clamp the drop line passed through the gratings surrounding the generator engines and turned outboard towards the port side of the ship. Four branch lines led to the separate engine fuel pumps. From the pumps some of the diesel would be pumped to the generator engine fuel injectors, and the remainder would be returned via spill return lines to the DOST.

Below the clamp, and about 2 ft above the gratings, a tap fitted with a ball valve had been connected to the drop line. This was the tap ("the tap") which was found to be about 80 per cent open after the fire in the engineroom.

Access to the engineroom

There was an access door into the engineroom from the port side alleyway in the accommodation at main deck level. This led onto a small platform high up on the port side of the engineroom from which a sharply inclined stairway descended aft to the top platform, just inboard and forward of the DOST, to the port side middle level, just inboard of the pillar to which the drop line was attached. Access could be gained to the bottom level of the engineroom by walking forward, between the generators and the main engine, descending a short flight of steps to the switchboard platform, and then turning aft to another stairway to the bottom level.

There was also access into the engineroom from the officers' deck, through a door high up in the forward casing of the engineroom. From here an arrangement of ladders led down to the top level, immediately forward of the cylinder heads. At the forward end of the engineroom on the starboard side there was a second arrangement of ladders providing access from the top level to the bottom level via the brine room and the refrigerated machinery space.

The propeller shaft tunnel ran aft from the main engine to the stern of the vessel, at bottom level. Access from the engineroom was via the watertight door in the middle of the aft bulkhead. Half way along the tunnel was an access ladder leading up between Nos 3 and 4 holds, to the masthouse on the after deck.

D. THE SATELLITE NAVIGATOR

This is described below.

E. THE AUTOMATIC PILOT

The Anschutz Automatic Pilot is designed to provide an automatic facility for keeping a ship headed on a desired course. It is used in conjunction with a gyro compass that is provided with a repeater system. The course-selector knob is set for the course desired which is read off against the 360 deg card by means of the course-selector pointer. The course that is being steered is read off against the fixed lubber line. The desired course and actual course agree with each other when the course-selector pointer and lubber line coincide. As the ship deviates from the desired course the automatic pilot computes the angle of corrective rudder that is necessary to bring her back to her set course. The steering engine which depends for its control on a feedback unit is controlled accordingly. The off-course alarm rings when there is a difference of more than a preset amount (in this case 25 deg) between selected course and actual course.

F. DELTA ERROR

Delta error, known generally as course, latitude and speed error was 0.7 deg low on a course of 137 deg and 0.4 deg low on a coursMe of 115 deg. The expression low is used because the gyro is regarded as reading low compared to the true course ie it shows a lower figure than the true course. Thus the delta error was in such a direction as to tend to open up the course away from land.

V. EXPERT EVIDENCE

A. EXCHANGE OF EVIDENCE -- EXPERT WITNESSES

Section XV of the Guide to Commercial Court Practice (SCP 1993 vol 1 p 1249) summarizes the Commercial Court practice as to exchange of evidence-expert witnesses. On the hearing of the summons for directions on Dec 6, 1989 Mr Justice Hirst ordered that the parties be at liberty to call up to eight expert witnesses at the trial, provided that their reports be exchanged not later than six months before the trial, supplementary reports to be exchanged not later than one month before the trial. Throughout the trial I held regular reviews with Counsel in an attempt to reduce the extent of the expert evidence and save time. I gave a number of further directions to this end. By way of example, following the failure of a meeting between certain experts to narrow the issues in relation to the fire, on July 30, 1992 I directed the exchange of supplementary reports on any new materials which any expert wished to advance. Despite these efforts a great deal of time was taken up by expert evidence, particularly as to the cause of the fire. Although this was in part due to the complexity of certain of the evidence, other factors contributed to the unnecessary length of the trial. By way of example about seven days were spent as to the heating the valve mechanism put forward by Professor Dover on behalf of the defendants. This mechanism was not pursued in the defendants' closing submissions.

I will refer to some of the duties and responsibilities of experts in civil cases because I consider that a misunderstanding on the part of certain of the expert witnesses in the present case as to their duties and responsibilities contributed to the length of the trial.

B. THE DUTIES AND RESPONSIBILITIES OF EXPERT WITNESSES

The duties and responsibilities of expert witnesses in civil cases include the following:

1. Expert evidence presented to the Court should be, and should be seen to be, the independent product of the expert uninfluenced as to form or content by the exigencies of litigation (Whitehouse v Jordan, [1981] 1 WLR 246 at p 256, per Lord Wilberforce).

2. An expert witness should provide independent assistance to the Court by way of objective unbiased opinion in relation to matters within his expertise (see Polivitte Ltd v Commercial Union Assurance Co Plc, [1987] 1 Lloyd's Rep 379 at p 386 per Mr Justice Garland and Re J, [1990] FCR 193 per Mr Justice Cazalet). An expert witness in the High Court should never assume the role of an advocate.

3. An expert witness should state the facts or assumption upon which his opinion is based. He should not omit to consider material facts which could detract from his concluded opinion (Re J sup).

4. An expert witness should make it clear when a particular question or issue falls outside his expertise.

5. If an expert's opinion is not properly researched because he considers that insufficient data is available, then this must be stated with an indication that the opinion is no more than a provisional one (Re J sup). In cases where an expert witness who has prepared a report could not assert that the report contained the truth, the whole truth and nothing but the truth without some qualification, that qualification should be stated in the report (Derby & Co Ltd and Others v Weldon and Others, The Times, Nov 9, 1990 per Lord Justice Staughton).

6. If, after exchange of reports, an expert witness changes his view on a material matter having read the other side's expert's report or for any other reason, such change of view should be communicated (through legal representatives) to the other side without delay and when appropriate to the Court.

7. Where expert evidence refers to photographs, plans, calculations, analyses, measurements, survey reports or other similar documents, these must be provided to the opposite party at the same time as the exchange of reports (see 15.5 of the Guide to Commercial Court Practice).

VI. THE GROUNDING

A. THE WATCHES

The watches on Apr 12, 1985 were as follows:

	Deck	**Engineroom**
24-4.00 12-16	Second Officer	Third Engineer
	AB	Oiler
	(Panothiokas)	(Marinakis)
4-8.00 16-20	Chief Officer	Second
	AB	Engineer
	(Markantonis)	Oiler
		(Tsakiridis)
8-12.00 20-24	Master	Chief Engineer
	Cadet	Apprentice
	(Assimopoulos)	Engineer
		(Vugiuklakis)

B. CHARTS

The following charts were referred to during this case. Charts 1147 and 3139 are Coastal navigation charts. Chart 601 is an inshore chart. Chart 685 is an approach chart for an approach into the Sherbro River.

C. THE SHOALS OF SAINT ANN

The Shoals of Saint Ann begin near Cape Saint Ann (7 deg 34 min N, 12 deg 57 min W), 20 miles south of Shenge Point, and extend about 46 miles NW. They are very numerous and are composed of knolls of fine light-brown sand (apparently deposits from the waters of the various rivers in their vicinity). The outermost shoals are: North-west Patches (7 deg 58 min N, 13 deg 34 min W), with a depth of 5.5m over them. A patch, with a depth of 4.6m over it and whose position is doubtful, about five miles ENE of North-west Patches and Endeavour Bank (7 deg 56 min N, 13 deg 18 min W), with a least known depth pf 5.5m on its east side, 9 miles SSW of Mes-Meheux Island.

Between these patches and Turtle Islands, close NW of Cape Saint Ann, the ground is more or less covered with shoals of similar character.

D. CANARY CURRENT AND NORTH EQUATORIAL CURRENT

The Africa Pilot (13th ed 1982) p 31 stated:

The Canary Current is closely associated with the NE trade winds and flows generally in a SW direction at half a knot or less with a moderate degree of constancy. The Canary Current continues SW as far as the Arquipelago de Cabo Verde after which it tends towards the W and merges into the North Equatorial Current.

Near Cap Blanc (20o 46' N, 17o 03' W), a branch of the Canary Current turns to the S and SE as it follows the African coast as far as Sierra Leone and Liberia at about half a knot. However the constancy of this current is low and liable to seasonal variations.

E. CURRENT ROSE FOR APRIL

The Met Office have provided a current rose for the month of April for the area between 7 deg N and 11 deg N and between 12 deg W and 18 deg W and a frequency and percentage frequency table showing the distribution of current speeds versus directions. Of the 950 observations 62 per cent were of less than half a knot. 2.8 per cent of observations were of over half a knot in a northerly direction and 1.8 per cent of observations were of over half a knot in a north-easterly direction.

F. TIDAL STREAMS

The Africa Pilot (13th edition 1982) p 36 stated:

Tidal streams off the open coast.

The tidal streams throughout the area . . . are semi-diurnal, reversing their direction four times daily. The diurnal inequality is negligibly small so that the two streams running in the same direction during any particular day are of the same maximum strength and of the same duration. Off the open coast, away from the entrances to rivers, the tidal streams tend to set N or W on the rising tide, and S or E on the falling tide, parallel to the coast. These tidal streams are only appreciable close inshore and even these are usually weak. More than a few miles from the coast, the water movement is controlled by the currents and the tidal streams are negligible. Tidal streams near the

entrance to rivers

Near the entrance to any of the many rivers, a tidal stream setting towards the river mouth will be experienced while the tide is rising, and a tidal stream setting away from the river mouth while the tide is falling there. The effect is appreciable for 10 miles or more from the entrances of the larger rivers, amounting to as much as 1 knot in some cases at 10 miles distance, increasing to 3 or 4 knots at the river bar.

The Africa Pilot stated at p 232:

The tidal streams, which set into and out of the bays and inlets N of Sherbro Island, set across the Shoals of Saint Ann at rates between three quarters and one and a half knots during the dry season.

On Apr 12, 1985 low water at Banana Island and Shenge Point, two landmarks on the North side of the Sherbro estuary, occurred at 20 10 hours and 20 37 hours, respectively.

G. WEATHER AND SEA CONDITIONS FOR OPEN SEA OFF FREETOWN SIERRA LEONE

According to information from the Met Office the weather and sea conditions for sea off Freetown on Apr 12, 1985 were as follows:

```
1800 GMT   Wind NW-SW F3-4.
           Visibility moderate-poor.
           Weather Haze.
           Sea state slight.
           Swell direction confused, low.
```

H. THE EVIDENCE FROM THE CREW OF IKARIAN REEFER AND OTHERS

The following members of the crew gave evidence: the master (Captain Tamvakis), the chief officer (Ioannis Sardis), the radio officer (Vasilios Kollias), the cadet (Nicolaos Assimopoulos), the chief engineer (Dionisios Staveris), the second engineer (Panagiotis Fexis) and the oiler (Stefanos Tsakiridis).

In addition Civil Evidence Act Notices were served by both sides in relation to statements made by these and other members of the crew of Ikarian Reefer and other witnesses. (The plaintiffs and the defendants have both served Civil Evidence Act Notices in relation to extracts from the first and second (joint) interviews of the crew. In case I refer for completeness to other passages in the notes of the interviews I should make it clear that for the purpose of any findings I have relied only on extracts the subject of Civil Evidence Act Notices.)

It appears that checks carried out by the ICC -- International Maritime Bureau did net reveal any "previous involvement of any crew member in a similar incident".

The master (Captain Tamvakis)

The master first went to sea in 1955 as a cadet. He served for about 27 months in the Greek Royal Navy, completing his service in the rank of A/B. He obtained his second officer's certificate in 1962, his chief officer's certificate in 1964 and his master's certificate in 1969. In March, 1981 he joined Comninos and was appointed master of Olympian Reefer and then Ikarian Reefer. He subsequently served on Psara Reefer and Macedonian Reefer before being reappointed master of Ikarian Reefer in October, 1984, on completion of her special survey. The master attended both the first and second

(joint) interviews. In the first interview his recorded explanation for the casualty was:

. . . substantial gyro error which could have developed as a result of sand storm during bad weather on 7th-8th April . . . between 2000 and 2200.

In the second interview he is recorded as saying "have had previous gyro problems on the other vessels." The master had encountered a gyro problem earlier in his career on Tropicana. When giving evidence the master gave the following explanations for the grounding. He accepted that he had wrongly calculated the position at which he altered course. He referred to a possible error in the use and operation of the auto-pilot (having purported to alter course to 115 deg from 137 deg, he might have forgotten to reset the course-selector pointer). He mentioned the possibility of malfunction of the gyro and said he believed that some navigational equipment must have malfunctioned, but he was not able to point with certainty to a particular piece of equipment. He added that if there was an equipment failure it was his fault that he did not notice it. The master has worked part-time (onshore) for Mr Anthony Comninos since about 1989 (by which time the two brothers had separated their shipping interests). The master said that prior to 1989 he had very limited acquaintance with Mr Anthony Comninos. The master has disclosed his bank accounts. I do not consider that the late disclosure of one overseas account should be held against him.

In assessing the oral evidence of the owners, the master, the other crew members who gave oral evidence and the other witnesses from overseas I have at all times had in mind the remarks of Mr Justice Bingham in The Zinovia sup at p 278, where he said:

. . . demeanour and personal impression are, I think, an unreliable pointer to the truth, particularly where foreign witnesses are giving evidence through an interpreter in the strange surroundings of an English Court. So one must look for more reliable pointers.

I have, of course, at all times sought more reliable pointers and my detailed analysis is set out below. I should, however, state the view I have formed of the master's evidence. The master gave evidence over seven days (the evidence of the cadet was interposed for about 1/2 day). The master was cross-examined for part of Day 17, Day 18, part of Day 19, Day 20, Day 21 and part of Day 22. I formed the impression (based on seeing and hearing the master and on his demeanour) that he was a truthful witness and that he did not deliberately run Ikarian Reefer aground. He was of course in difficulty in explaining certain matters particularly as, even on the plaintiffs' case, he had been grossly negligent. At times he showed understandable frustration at his long ordeal. The master was at all times adamant in his denial of the allegation that he deliberately cast the vessel away. On several occasions his answers were to this effect:

. . . I may have made a mistake -- I have accepted that. I have never accepted and I will never accept under a penalty of my life that I did something intentionally.

My impression was of a slightly stubborn man who was proud of his sea-going career. Although he was due to retire shortly I do not think that this master would have been prepared to sacrifice his good record and reputation for a financial inducement. The master would have realized that he would probably face ASNA/disciplinary proceedings and/or criminal proceedings. Further as Captain Cockroft (the plaintiffs' principal navigation expert) pointed out it would have been dangerous to steer the vessel at 16 or 18 knots into the poorly charted shoals.

If and to the extent that the master did not take part in discussions with other members of the crew after the casualty this was a reflection not of dishonesty but of despair. I accept his evidence that the casualty had a profound effect on him. He referred to his "psychological state" and to "keeping . . . going with medication".

The chief officer (Ioannis Sardis).

The underwriters did not allege that the chief officer was in any way responsible for the fact that Ikarian Reefer ran aground or for the fact that a fire broke out in the engineroom. In my view the chief engineer was an impressive witness. He said:

. . . I did not see anything which would suggest that (the Master deliberately grounded the ship). I did not ever believe that the Master deliberately did this. I knew this Master from the past and he was a very good and conscientious Master.

Contrary to the submission of the defendants, I did not form the impression that this particular chief officer would be prepared to tell lies on oath to assist the master and others.

The radio officer (Vasilios Kollias)

The radio officer seemed to me to be doing his best to assist the Court. He contacted Captain Christatos in Piraeus through Athens Radio first after the grounding, and second after the outbreak of the fire. As to the first communication he heard everything that Captain Christatos said on the loudspeaker and added that the Athens radio operator could hear what was said. The only thing that he remembered Captain Christatos saying was "courage, lads". I find that there was no instruction from Captain Christatos to fire the ship after the grounding. I also find (contrary to the statement from the radio officer of Ljubljana) that Mr Kollias' recollection is probably correct when he said that he remembered very clearly that the radio officer of the Ljubljana told him "the (grounding) position you gave me was wrong". The radio officer also said that the third engineer had stolen five paintings or prints from his cabin on Ikarian Reefer. After a search on Ljubljana directed by the master these items were returned to the radio officer.

The cadet (Nicolaos Assimopoulos).

The defendants did not suggest that the fact that the vessel ran aground and caught fire was in any way the cadet's fault. The cadet seemed to me to be doing his best to assist the Court. He said that the thought that anybody had deliberately run the ship aground never crossed his mind. I will consider the cadet's evidence as to satfixes below.

The cadet provided important confirmation of the evidence of the chief engineer, the second engineer and the oiler as to a problem with a shaft bearing. In his statement the cadet said:

. . . I recall that Mr Tsakiridis mentioned that there had been a problem with a shaft bearing in the engine room.

When it was suggested to the cadet in cross-examination that this passage was the result of a suggestion from Mr Tsokris (a consultant employed by the plaintiffs) or the plaintiffs' solicitors, the cadet refuted this and said "I (have) a very clear picture now, Tsakiridis with some oils and a rag and something. It was (a) question of some problem in the engineroom, something they had to cool off". I accept this evidence from the cadet.

The chief engineer (Dionisios Staveris)

The chief engineer attended both the first and second (joint) interviews. There are references in the notes of both interviews to a problem with the number 11 bearing and to the chief engineer sending oiler Tsakiridis to check the generators and the DOST and to start the purifier. The chief engineer was cross-examined for two full days and part of a third day. I did not form the impression (based on seeing and hearing him and his

demeanour) that he was an untruthful witness. The chief engineer referred to an incident on a previous voyage from Cuba to East Germany when a fire broke out on the aft port generator. The cause of the fire was an indicator cock on the cylinder cover which had worked loose. From that point sparks had shot out and ignited a piece of rag which had been left there by the oilers. The chief engineer denied that he had told Mr Tsakiridis or anyone else to fire the ship. He also denied that he or Mr Tsakiridis or any other member of the crew had started a fire under the tap.

The second engineer (Panagiotis Fexis)

The second engineer had not worked for a company owned or operated by Mr Costas or Mr Anthony Comninos since the date of the casualty in 1985. The second engineer struck me as a truthful witness. His evidence provided further confirmation of the problem with the hot bearing.

Oiler (Stefanos Tsakiridis)

The defendants submitted that, on the account put forward by the plaintiffs, it was likely that it was Mr Tsakiridis who started the fire on his final visit to the engineroom, probably on the instructions of the chief engineer. (The defendants did not however tie themselves to this submission and for example referred in addition to the conflicting evidence as to the movements of the third engineer.)

Mr Tsakiridis had previously served on Aegis Prosperity and on a yacht belonging to Mr Costas Comninos, Alpega. Mr Tsakiridis attended the first and second (joint) interviews. In the first interview he referred to the number 11 bearing overheating and is recorded as saying:

Chief Engineer tells me to put purifiers on to fill DO header tank which feeds generators by gravity . . . Went back to engine room, put on purifier waited two to three minutes, walked round engine room. Heard cracks as vessel moved. Saw outside scavenge pump some oil, opened purifier valve and then left engine room.

In the second interview Mr Tsakiridis is recorded as saying:

I was last person in engine room and about 20 minutes later there was a fire in the engine room. The fire was not started by me . . . In my opinion fire could have started on the exhaust . . . My theory is that when vessel stopped because of a grounding, oil which was pressurised spewed out of the pipes into exhaust. On back part of main engine oils leaking out from top. Lubricants on port side of main engine forward. Oil on manifold ignited by sparks from scavenge . . . I had been sent down to start the DO purifier . . . Chief Engineer told me to start purifier to pump up into DO header tank . . . One month earlier there had been a previous small fire on a generator. Second Engineer and I easily able to extinguish. This from umber one generator back below floor plates.

Mr Tsakiridis denied that he had been instructed by the master or the chief engineer to go down into the engineroom to start a fire. He said he would never have accepted such an instruction. He denied that he had started the purifier in order to ensure that there was a virtually limitless supply of diesel oil to the fire. He further denied that he opened the tap in order to supply fuel to the fire.

I was particularly impressed by Mr Tsakiridis as a witness. He did not strike me as someone who would be prepared to accept instructions to fire a vessel.

[There is uncertainty as to the movements of the third engineer. In the second (joint) interview Mr Tsakiridis is recorded as saying

I was only person to enter engine room after it had been abandoned apart from Third Engineer who went down five minutes before me to stop bilge pump. This necessary because it pumping nothing ie no water. Chief Engineer had so ordered Third Engineer . . . I saw Third Engineer at door to engine room when Third Engineer reported he had switched off bilge pump. I told Third Engineer I was going to stop purifier.

When giving evidence Mr Tsakiridis said that the third engineer told him that he had been ordered by the chief engineer to go down into the engineroom to stop the bilge, but he did not know whether the third engineer went there or not. If he went down before, that was when Mr Tsakiridis was on deck carrying a television set. He met the third engineer outside the accommodation door and said that he had heard subsequently that the third engineer went into the accommodation to steal property. I find that if, which is unclear, the third engineer did go into the engineroom, he went in before Mr Tsakaridis and accordingly Mr Tsakiridis was the last person to enter the engineroom.]

I. SATELLITE NAVIGATION ISSUES

1. The expert witnesses

The expert witnesses as to satellite navigation issues were Mr Colin Beatty (called by the plaintiffs) and Mr Walter Blanchard (called by the defendants). Mr Blanchard's qualifications in this field were particularly impressive. He wrote the specifications for the first three DS models, up to the DS3, and had a major part in writing the specifications for the DS4 and DS5. Mr Beatty had had very little experience with the DS5. Most of his experience had been with Magnavox equipment which is similar to, but more complicated than, the DS5. Mr Beatty worked with Magnavox in a series of roles including service applications, engineering, fault location, installations and marketing. With no disrespect to Mr Beatty it was clear that Mr Blanchard was more experienced and knowledgeable on the technical side of satellite navigation. Nonetheless Mr Beatty made some useful contributions.

2. A description of the Satellite Navigator

The Racal-Decca DS5 satellite navigator comprises a receiver unit, an antenna and a log/gyro junction box and operates in conjunction with the US Navy Navigation Satellite System (NNSS), more usually known as Transit. This system is based on a number of satellites travelling round the earth in near-circular polar orbit at a height of about 1000 km. Each satellite takes about 110 minutes to circle the earth. The orbits pass over the poles, but the plane of each orbit tends to shift in longitude with time and the orbits are therefore not evenly spaced. The positions of the satellites are monitored by fixed tracking stations at known points on the earth located in Hawaii, California, Minnesota and Maine. The stations compile precise data on the orbit of each satellite and predict its future orbits over the following 16 hours. The tracking stations in California and Minnesota also perform the function of "uploading" the satellites by transmitting, approximately every 12 hours, a fresh set of predicted orbital data which is held in a memory on board the satellite until updated by the next such transmission. On the basis of the memorized data obtained from the tracking stations, each satellite broadcasts a navigational message every two minutes. This message, which contains 6103 digital bits and occupies the full two minute interval, gives the orbital position of the satellite together with precise time data and the satellite identity number. The navigational message is broadcast on carrier frequencies of 400 MHz. By receiving the radio signal from the satellite throughout its pass from horizon to horizon, which takes from about 10 to about 20 minutes, the shipboard receiver obtains a succession of navigational messages defining the position of the satellite in space at known times. From this information, together with a prolonged and detailed measurement of the Doppler frequency-shift on the radio signal received from the satellite, the shipboard receiver calculates the position of the ship in latitude and longitude. The interval between

position-fixes depends on the number of satellites in service and the latitude of the user ship; each of the satellites provides a minimum of four fixes in 24 hours anywhere on the earth. In mid-latitudes an average interval of about one and a half hours between fixes is typical. The Doppler frequency-shift takes its name from the Austrian mathematician Christian Doppler (1803-1853) who discovered that if there is relative motion between the source of a wave transmission and a receiver, the frequency of the received signal is shifted by an amount depending on the relative speed. The received frequency is higher than the transmitted value when the distance is decreasing and vice versa. By continuously measuring the Doppler shift on the radio signal from the satellite, the shipboard equipment is able to track the successive changes in ship-to-satellite distance as the pass proceeds; it is on these distance-difference values that the final calculation of the ship's position is based.

The accuracy of the satellite fix is degraded if the maximum angle of the elevation which the satellite reaches during the pass is less than 10 deg or greater than about 80 deg. A satellite which passes directly over the ship will in principle give an accurate latitude but a poor longitude, whereas a pass that is low over the horizon will be better in longitude than in latitude. The principal facilities provided by the DS5 as an aid to navigation include the following:

Position-fixing. The DS5 will automatically compute the position-fix yielded by each satisfactory satellite pass. The fix is displayed in lat/long to the nearest 0.01 minute.

Dead reckoning. Between satellite fixes the DS5 computes and displays the position of the ship by dead reckoning ("DR") on the basis of speed and heading inputs from external sources. The DR display is virtually continuous, being recomputed every second. (On Ikarian Reefer the speed was input manually and the heading was supplied electrically from the gyro compass.) Estimated values for tide speed (drift) and direction (set) may be entered manually to modify the DR, or computed and entered automatically as average values on the basis of a comparison between successive satellite fixes. The DR position is automatically updated by each satisfactory satellite fix.

3. Candidate Satfixes for Apr 12, 1985

Mr Blanchard put forward the following candidate satfixes for Apr 12, 1985:-

***5*TABLE 1**

No	**Rise**	**Set**	**Avlbl**	**Max**
E1				
1**	0042	0101	0103	68
2**	0102	0122	0124	76
4*	0253	0308	0310	8
5**	0533	0549	0551	17
6**	0720	0739	0741	46
7**	0753	0811	0813	20
8**	0807	0822	0824	12
9**	0938	0958	1000	33
10**	0950	1009	1011	47
12*	1114	1125	1127	4
13**	1211	1230	1232	78
14**	1257	1317	1319	79
15*	1401	1412	1414	6
16*	1450	1504	1506	6
17**	1726	1744	1746	24

18**	1914	1933	1935	36
19**	1935	1951	1953	16
21**	2120	2139	2141	41
22	2121	2140	--	77
25**	2351	0010	0012	66
26**	0040	0100	0102	76

One asterisk = Satfix but not automatic update of DR

Two Asterisks = Satfix used for updating

If Satfix 18 is taken by way of example the alarm would sound at about 19 35. A reading from the Satnav at 19 35 would indicate the current dead reckoning position updated by the last fix at 19 14. If the last fix button was pressed after the alarm sounded the latitude and longitude of the satellite fix at 19 14 would be shown.

In his first report Mr Blanchard described all the passes listed above (with the exception of No 22) as probable satfixes. He added the following commentary as to passes 21 and 22:

The NAG data shows both passes occurring at the same time and on that evidence they are so similar that it might be thought that no satfix could have resulted. However, re-computation using the correct position for the ship (Table 4) shows that satellite 21 rose 1 minute 24 seconds ahead of satellite 22 and a close examination of the Doppler-corrected frequencies shows that the two frequencies only crossed over late in the pass and for almost all the important part of the pass were separated by more than the band width of the receiver (100HZ). Fig 2 is a plot of the figures given in Table 4, showing that they are sufficiently clear of each other for the DS5 to have tracked one or the other quite successfully over the important part of the pass -- the middle. By 21.24 they are clear enough to permit correct tracking of 1, and do not approach within a 100HZ again until 21.34. This would have provided 10 minutes of clear tracking -- quite enough for the DS5 to have produced a good fix. It can do so after only 6 mins of data. It is quite likely that one of these passes was tracked successfully resulting in a good fix and one is therefore listed.

4. The operation of the satnav on Ikarian Reefer

I find that the satnav was working properly on Apr 12,1985 and that the satnav alarm was on during the last watch. The master said that he had never received any training in the theory and operation of satellite navigation. He had found out how the satnav worked by reading the instruction manual with his limited knowledge of the English language. He had had about 18 months experience of navigating with a satnav. He had learned how to switch the unit on, how to obtain a fix, how to transfer the fix and plot it on the chart, how to estimate or calculate the next pass and the previous pass and how to feed in the ship's speed. Lieutenant Commander Adrian Burnett (who gave limited expert evidence as to navigation on behalf of the plaintiffs) described his experience of the way in which different officers used the DS5. He referred to two categories --

. . . the older, more traditional officer would take . . . little information . . . he would interface as little as possible with the satellite navigator . . . if it gave him a position he would . . . get it on the chart and then forget the DS5 for as long as possible afterwards. He would leave it to go beep . . . he would keep on with manual chart work as for years and years that was how he'd been happy. He was obliged to admit the existence of it because it gave him positions that he wouldn't otherwise have, but he didn't want to know about the other ways in which it could be worked, how it could make his life easier

. . . the other category of the younger generation who were happy to use the other facilities to learn more about how the DS5 worked, . . . possibly too optimistic about it . . . obsessed with the fact that it was electronic and therefore must work. But they were prepared to integrate much better with it . . .

I formed the clear impression that the master fell into Mr Burnett's first category. I find that Mr Burnett's description is a fair reflection of the master's approach to the satnav.

5. The satifaxes received before the last watch

In the notes of the second (joint) interview the chief officer is recorded as saying:

Second Officer told me that he had not obtained a fix in his PM watch:

but the second officer is recorded as saying "At about 1430 I got a satnav fix . . ." It is thus unclear which (if any) satfixes were received during the 12 00-16 00 watch.

The defendants concede that it is possible that there was no satfix updating the DR or sounding the alarm between 10 11 (master) and 17 46 (chief officer). Passes 12, 15 and 16 (one asterisk) would not have updated the DR or caused the alarm to sound. As the defendants concede passes 13 and 14 at 78 deg and 79 deg respectively could quite easily have slipped into that category too.

In the interviews the master is recorded as saying "17.00 was the last fix" [first interview] and "last fix 4 to 5 hours before say 18.00 hrs" [second (joint) interview]. The chief officer is recorded as saying in the first interview:

. . . 1945 -- good SN fix. Speed made since previous fix was 16K and I did reprogramme . . . believe current setting easterly because last fix was slightly to the east.

In the second (joint) interview the chief officer is recorded as saying:

In my PM watch I did obtain a fix OK at 19.30 . . . My fix put me a little way to the east of my track. I drew Master's attention to that fix at 19.30 or 19.45 . . . Had programmed 16 knots into satnav.

When giving evidence the chief officer said that he believed that the fix received put the vessel to the east of the 137 deg course line by five or six miles. I find that satfix 18 was received by the chief officer (available 19 35). As to pass 17 when the chief officer was asked whether he remembered receiving a satfix OK before satfix 18 he said that he may have received one but added that during his first interview, when his memory was fresher, he had stated that he had only received one satfix during his watch. Satfix 19 may have been disregarded as it became available less than 20 minutes after satfix 18, but again it is to be noted that the chief officer said in evidence that he did not remember receiving another satfix (after satfix 18) and the notes on the interviews are consistent with this.

6. Passes 21 and 22

The plaintiffs submitted that there is no reason to disbelieve the evidence of the master that he did not receive a good fix from pass 21 (or 22) at about 21 41 on Apr 12, 1985. The defendants submitted that it is overwhelmingly probable that the vessel received a good fix from pass 21 (or 22) at about 21 41. This is an important issue because Captain Cockroft accepted that he would find the master's conduct difficult to explain if he had obtained (and perceived) a good fix from pass 21 (or 22) it would have been apparent that the vessel was running into danger.

For the reasons set out below there is considerable difficulty and uncertainty about these passes. My analysis is as follows:

(a) Mr Blanchard said that in his view the conditions for calculating a fix from the data did exist at the relevant time. He could not say that because the conditions existed at the time it necessarily followed that a good satfix was obtained.

(b) It is not without significance that Mr Blanchard found it necessary in his first report to single out passes 21 and 22 as calling for particular commentary. I have set out the full text of the commentary above but I draw attention in particular to the following --

The NAG data shows both passes occurring at the same time and on that evidence they are so similar that it might be thought that no satfix could have resulted . . . It is quite likely that one of these passes was tracked successfully resulting in a good fix.

Mr Blanchard's "quite likely" represented an important qualification.

(c) Neither Racal nor Polytechnic Engineering have retained their records so there is no documentary evidence as to the particular features incorporated in the Satnav (No 31044) on Ikarian Reefer.

(d) In a further report from Mr Blanchard (apparently handed to the plaintiffs at the start of Day 26, the second and final day of Mr Beatty's cross-examination) Mr Blanchard referred to some experiments he had been running for some weeks in order to obtain data on DS5 performance when two or more satellites are visible. In the light of these experiments Mr Blanchard sought in evidence to change his "quite likely" to "I am quite certain it tracked one of them". Mr Beatty had no or no proper opportunity to consider this new material until he had finished giving evidence. I have a number of reservations about Mr Blanchard's experiments. Mr Blanchard was not successful in finding an instance which was exactly parallel to passes 21 and 22. Mr Blanchard had no proof that the software in the DS5 on the Ikarian Reefer was the same as that in the DS5 that he was testing in his garden. Certain modifications were incorporated on the receiver which he had but he was unable to say wheher or not these modifications were incorporated in the Satnav on the Ikarian Reefer. I consider that it is safer for me to refer to the more qualified approach ("quite likely") set out in Mr Blanchard's first report.

(e) Captain Third's first report on behalf of the defendants date Dec 19, 1991 make no mention of the availability of a satfix from passes 21 and 22 (Mr Blanchard's first report was dated Nov 15, 1991). Captain Third's supplementary report dated July 3, 1992 (between Days 24 and 25 of the trial) says:

. . . the satellite navigator dead reckoning had probably been updated with a fix within the past hour.

(f) When reference was made in the course of Mr Beatty's evidence on Day 25 to the words "quite likely" in Mr Blanchard's first report, Counsel for the defendants intervened and said:

Mr Blanchard has . . . ascertained subsequent to writing his report . . . that this machine does have the facility which the witness has just described as programmed tracking. He has been able to ascertain that all the DS5s bearing a serial number in excess of 31000 did indeed have the very facility . . . known as programmed tracking and this machine . . . has . . . serial No 31044.

This intervention appeared to me to indicate Mr Blanchard would, when he gave evidence, take a slightly firmer position by reference to programmed tracking. In fact, as was clear from the supplementary report apparently handed to the plaintiffs the

following day, neither Racal nor Polytechnic Engineering had retained their records. When Mr Blanchard gave evidence he did not seek to take a firmer position by reference to programmed tracking but relied on his experiments.

(g) It is common ground that the following matters raised by Mr Beatty can now be disregarded: Radio noise, incorrectly entered antenna height, any risk of computing a fix on the wrong side of the orbital subtract, ionospheric refraction, mishandling of the high/low pass facility, satellite uploaded with faulty data and satellite not working for any reason (in which case a nanu would have been issued). Further the plaintiffs concede that passes 21 and 22 were probably not affected by scintillation (and I so find). Other possible problems were discussed. As to loss of lock Mr Blanchard said that he had seen no evidence to show that there was outside radio interference that would have produced a loss of lock. He said that there was adequate difference in frequency between passes 21 and 22. Secondary reflection off multiple surfaces could not be counted out but Mr Blanchard did not consider this would have any effect on the resulting tracking. Against this Mr Beatty and Mr Burnett described their practical experience of expected satfixes that were not received.

(h) I refer to the evidence of the chief officer and the second officer as to their watches as set out above.

(i) I consider that the only safe course is to disregard the cadet's evidence on this subject as being hopelessly inconsistent. In the first interview (at a time when his memory might be expected to have been particularly fresh) he is recorded as saying: . . . in my morning watch I heard alarm for satnav which indicated bad fix or fix OK but no way of knowing which. Can't remember whether alarm in the evening watch.

In the second (joint) interview he is recorded as saying:

. . . Heard satnav (alarm twice -- crossed out) signal twice in that watch. Could hear this from wing of bridge. Master took position and put on chart.

When giving evidence the cadet said:

I heard beeps. As I was standing on the starboard wing I assumed that these beeps were an alarm. However as I proceeded to enter the bridge I observed the Master pressing buttons . . . (I did not) see the Master . . . put a marking on the chart or go to the chart.

In the light of the analysis set out above I am not prepared to reject the master's evidence that he did not receive a good fix from pass 21 (or 22). I find that he did not receive a good fix from either of these passes. If, contrary to this finding, a good fix was received, I find, that the master did not perceive it.

7. Satfix 25

It is common ground that this satfix was received.

J. THE EVENTS OF APR 12 AND 13, 1985

I turn to consider the events of Apr 12 and 13, 1985. Two matters should be mentioned by way of introduction. First it would in my view be a mistake to regard Ikarian Reefer as an efficiently run vessel. Second Apr 12 was the Greek Good Friday, a day normally regarded as a holiday. Only minimum work was being carried out by the crew of the Ikarian Reefer and thus, for example, the master himself had to hose sand off the bridge deck during the afternoon.

I. 24 00 04 00 (The second officer's watch)

The vessel altered course shortly before 04 00hrs on Apr 12 at a time when the master was on the bridge. The vessel had been steering a course of 171 deg. The master altered course to 137 deg. The fair log records. "At position 11o00'N 17o4'W changed course."

2. 04 00-08 00 (The chief officer's watch)

The vessel was on an (intended) course of 137 deg from 04 00 to 08 00.

3. 08 00-12 00 (The master's watch)

The vessel was on an (intended) course of 137 deg from 08 00 to 12 00. The master is recorded as saying in the first interview:

. . . cannot remember when I obtained the fix but near enough on course line and speed made good fairly OK. Taking average speed between 2 fixes for SN during this watch reprogrammed SN for 18k.

During sea passages the usual practice is to record the noon position each day in the scrap log book, together with other information including the distance covered since noon of the previous day and the average speed. This information is normally copied into the fair log book but is not shown for noon on Apr 12. This probably indicates that the last time entries were copied from the scrap log into the fair log was during the 08 00-12 00 watch on Apr 12. The master is recorded as saying in the second (joint) interview --

. . . noon position on this day not entered because no transfer from scrap log which (I) left aboard vessel on bridge.

4. 12 00-16 00 (The second officer's (and the third engineer's) watch)

The chief officer is recorded as saying in the second (joint) interview "Second Officer told me that he had not obtained a fix in his PM watch". The second officer is recorded as saying in the second (joint) interview:

At about 1430 I got a satnav fix and put this on the chart. As far as . . . I remember the fix was up to 5 miles of the track because had it been any more I would have been worried. On the basis of that fix I obtained a speed made good . . . it was not so different from previous speed input that I needed to change input.

It is thus unclear which (if any) satfixes were received during the 12 00-16 00 watch. For the reasons set out above the defendants concede that it is possible that there was no satfix updating the DR or sounding the alarm between 10 11 (master) and 17 46 (chief officer). The vessel was on an intended course of 137 deg from 12 00 to 16 00.

5. 16 00-20 00 (The chief officer's (and the second engineer's) watch)

I find that there was a reduction of speed during this watch because of a scavenge fire on the main engine. The scavenge fire was referred to by the chief engineer, the second engineer and the watch oiler Mr Tsakiridis in the course of their evidence. I find that satfix 18 was received (and perceived) by the chief officer (available 19 35). When giving evidence the chief officer said that he believed that the fix received put the vessel to the east of the track by something like five to six miles. Satfix 19 may have been disregarded as it became available less then 20 minutes after satfix 18. There was no alteration of course during this watch. The vessel was on an intended course of 137 deg from 16 00 to 20 00. I find however that the vessel was in fact to the east of the track (probably in the region of five to six miles).

The plaintiffs submit that one possible explanation for the casualty is that the information obtained by the chief officer as to position and speed was not relayed to the master, who proceeded on the basis that the vessel was on her course line and proceeding at 18 knots. The plaintiffs submit that a second possible explanation is as follows. There was no satfix update of the DR until about 19 35. For a considerable period of time the chief officer may have projected forward the original DR track at 18 knots and marked the 20 00 hand over position on the chart. When the satfix was obtained at about 19 35, the chief officer may or may not have marked the fix on the chart, although it must have been some 15 miles or so further back up the track and to the east. It is possible that he omitted to erase the 20 00 hand over position based on the previous satfix. When the master came on watch, he may or may not have been told there was a recent satfix. However, the master would have looked at the 20 00 DR estimate and, knowing perhaps that there had been a recent fix, he may have felt quite confident about altering course at a position which would have been down the track and to the west of the vessel's actual position. I find that there probably was a failure of communication between the master and the chief officer at the handover in one of the ways outlined above.

6. Events after 20 00 -- the start of the last watch

20 00-24 00 was the master's and the chief engineer's watch. Cadet Assimopoulos was with the master on deck and apprentice engineer Vugiuklakis was with the chief engineer in the engineroom.

7. Reduction of speed due to a hot bearing

For about one hour shortly after 20 00 there was a reduction of engine speed due to the need to work on a hot bearing (no 11). The problem required the assistance of the second engineer and Mr Tsakiridis (the oiler on the previous watch). The chief engineer said that the previous watch should have seen this problem and should have reported it to him. He added that he reprimanded them and told them that as a result some remedial work might be necessary later on. This explains why the second engineer and Mr Tsakiridis were called back. There is reference in the interviews to the problem with the hot bearing (chief engineer, first and second (joint) interviews; oiler Tsakiridis, first interview and apprentice engineer Vugiuklakis second interview). The chief engineer, the second engineer and the oiler referred to the problem with the hot bearing in the course of their evidence. Further the cadet said that he remembered that Mr Tsakiridis mentioned some problem in the engineroom, "something they had to cool off". The second engineer and the oiler were called back shortly after the hand over. The second engineer is recorded as saying in the second interview "I did not go back to engineroom after my watch". I do not find this answer inconsistent with his evidence that he was called back almost immediately after the hand over. The question put to him is not recorded but I find that he was referring to the period of time after he was called back.

The RPM counter on the bridge was old and difficult to read. I find that the master did not observe nor was he informed about the reduction in speed. As Captain Cockroft said when giving evidence whether a reduction of speed of this order would be noticed would depend upon the characteristics of each particular vessel. Alternatively, if contrary to my finding the master did observe or was informed about the reduction in speed, he failed to make allowance for it.

8. Alteration of course from 137 deg to 115 deg.

The master purported to alter course at some time between about 20 30 and about 21 00 from 137 deg to 115 deg relying on DR on the chart. The master personally altered course at a time when the cadet was away from the bridge. The position at the time of

this alteration of course is recorded in the fair log as 7 deg 34 min N 13 deg 42 min W. This entry was made by the master several days after the grounding and does not reflect the true position of the vessel at the time of the alteration of course.

It is quite clear that the master was concerned about making Abidjan on time. He said:

It was important for us to achieve the ETA first . . . Because we had to enter port at a certain time . . . given to us by Charterers' Agents at Abidjan . . . Second . . . the shippers must know the precise time of the ship's arrival in order to start cutting and preparing the fruit for loading . . . what has remained engraved in my mind was that I was under pressure to make my ETA.

The master had originally intended to alter course to 118 deg but in fact altered course to 115 deg because he believed (in fact mistakenly) that he would gain time by altering to 115 deg (and subsequently reverting to 118 deg.).

9. Satfixes after 20 00

I find that the master did not receive a good fix from pass 21 (or 22) at about 21 41. I refer to my analysis above. If, contrary to this finding, a good fix was received, I find that the master did not perceive it.

10. The two impacts

Before the grounding there were two impacts. I accept the plaintiffs' submission that the assessment of the master's perception of the "bumps" at the time must not be made with the benefit of hindsight, in the knowledge that the vessel must have touched the bottom because of the subsequent grounding. The master's perception was that he was in fact in deep water and in a safe position at the relevant time. The master was not alone in considering that the vessel had struck a log or some other floating object. I set out below by way of example what the following members of the crew are recorded as saying in the first ("(1)") and second (joint) ("2") interviews.

Master (1):

Some 10 minutes before grounding I felt some light impact as if we hit a log but nothing to worry about.

Chief officer (1):

Don't remember any bumping prior to grounding except about 5 minutes before as if we had struck lightly. Bit of a jerk . . . Master told me we had probably touched something and asked me to sound bilges . . . took soundings, no water and as we prepared to go up second similar bump and jerk.

Chief officer (2):

Felt bump for 2 seconds, got up and went to bridge quickly. Felt second bump when . . . in engine room . . . second stronger bump. Did not fall over.

Radio officer (2):

I was playing cards . . . I felt an impact. After 5 minutes, I went to RR and put radio on and felt same again.

Chief engineer (1):

Before grounding, I detected that we touched bottom or knocked something . . . and sent Oiler to find out from other crew what happened. When he came back said crew were saying must have hit a baulk of wood.

Chief engineer (2):

Had felt one bump and then rolling within the 30 minutes and two to three minutes later grounding . . . Oiler was told by the crew on deck that vessel had hit a baulk of timber.

Second engineer (1) "I felt vessel touch twice".

Second engineer (2):

A few seconds before I had felt initial bumps v light. I paid no attention, like a swell hitting the vessel.

Electrician (2):

Had been a previous jerk about 30 minutes before when I had heard a knock forward as if bow had hit something. Also felt some vibration -- not so big. Were discussing this with others who were there and thought that we must have hit a log -- this quite common off this African coast. Nobody told us of this. There were only two knocks.

After the first impact the master checked his DR position on the chart. He did not use the satnav because he said this would have given him a DR position which he had on the chart. The master altered course (hard) to starboard for a few minutes. The chief officer reported to the bridge and was instructed by the master to take soundings. He subsequently shouted to the cadet (who was on the starboard wing of the bridge) that there was no problem with the tanks which could be sounded from the deck. The chief officer then sounded the other bilges in the engineroom. The master looked at the radar which did not reveal any problems. The master ordered the chief engineer to check the double bottoms.

The master did not use the echo sounder, an instrument which he used for "coastal navigation". The master considered (having checked the position of the ship) that he was in deep water and that he had no reason to use the echo sounder.

I accept the plaintiffs' submission that the actions which the master did take are not consistent with the conduct of a master intent upon deliberately grounding his ship. The master did not consider that he had struck the ground. The master's errors were a failure to use the echo sounder, a failure to alter course to starboard for a longer period of time, a failure to slow down or stop and a failure to look at the satnav.

By the time of the second impact, the master had received the chief officer's report of the engineroom soundings. The master took further action by again altering course to starboard. He also checked the DR position on the chart. The chief officer, who was on the bridge after the second impact, did not see anything which suggested to him that the master deliberately grounded the ship. The master's reaction to the second impact is another example of his failing to face up to the facts at a time when he was under the mistaken impression that there were logs which explained the impacts. The action the master should have taken was as set out above for the first impact. He was plainly negligent. He thought (wrongly) that he was in fact in deep water and in a safe position and had struck logs. He drew comfort from the fact that the chief officer had reported no damage following the first impact.

I was struck by a sentence in a work referred to by the plaintiffs "Strandings and their Causes" by RA Cahill:

In most (strandings) a succession of errors, oversights and miscalculations combined to produce a disastrous culmination . . .

In the same work it is stated that it is not uncommon for masters to become prisoners of pride. This master was I find a proud man who was slow to acknowledge the possibility of error.

11. The grounding

The grounding occurred at about 23 00 on the Shoals of Saint Ann. Satfix 25 was subsequently received (available 00 12).

12. Post grounding pre-fire

Following the grounding I find that there were refloating attempts/engine manoeuvres (see further below). My findings as to vibration, pounding and other observations of the crew are also set out below.

The master ordered the two lifeboats to be lowered because he was afraid the vessel would capsize. The master told about five members of the crew (including the chief officer, the chie4 engineer and the radio officer) that they were to remain on board with him to continue to try to refloat the vessel. There are references to this in the first (chief engineer) and second (joint) interviews (master and chief engineer).

13. Communications with the owners prefire

The master spoke to Captain Christatos through Athens radio at about 00 26 after the grounding (and before the fire). I accept Captain Christatos' account of this conversation.

It was not suggested to the master or Captain Christatos that the master received any instructions from Captain Christatos to cast the ship away during this first communication. The conversation was overheard by the operator at Athens Radio and by the radio officer.

14. Fire

Fire broke out on Ikarian Reefer at about 01 00 on Apr 13.

15. Communications with the owners post-fire

Following the outbreak of the fire the master spoke again to Captain Christatos through Athens Radio. I accept Captain Christatos' account of this conversation.

16. Firefighting efforts

I find that there were limited firefighting efforts but in the event, for the reasons given by the chief officer, these had to be abandoned. The chief officer was instructed by the master to open the CO2 room door but not to operate the system. This could only be done when the location of all personnel particularly personnel in the engineroom, was established and would only be effective if the ship was closed down. The smoke in the engineroom was too dense to venture down without breathing apparatus. In the chief officer's view there were, by this time, insufficient crew on board to carry out such a fire fighting operation. The chief officer became concerned that he would be cut off. The chief engineer and the chief officer discussed the possibility of going forward to let off the CO2 system even though the ship had not been shut down. This was not likely to be

very effective and it was considered too dangerous to risk going forward to the CO2 room to carry out such an attempt. At about 01 15 those remaining on board abandoned ship. The clock in the compressor room stopped at 01 25.

17. The scrap log book and charts

The master removed the fair log from the ship but not the scrap log book and the charts. This is explicable given the fire.

18. The Ljubljana

The crew were picked up at about 03 30 on Apr 13 by Ljubljana.

K. THE EXPERT EVIDENCE AS TO NAVIGATION

The two principal experts as to navigational matters were Captain Cockroft (called by the plaintiffs) and Captain Third (called by the defendants). In addition Lieutenant Commander Burnett gave limited evidence on behalf of the plaintiffs. (At time the expert evidence as to navigation went beyond what was strictly admissible). I found Captain Cockroft's evidence particularly helpful. He has greater experience than Captain Third and was in my view more balanced in his approach.

L. RECONSTRUCTION AND EXPLANATIONS FOR THE GROUNDING

1. Reconstruction -- some general comments

I accept the plaintiffs' submission that any reconstruction of the movements of Ikarian Reefer prior to the grounding must so far as possible be related to both the reported grounding position and the last recorded position before the grounding. As the 22 00 position, entered in the fair log several days after the grounding, is obviously wrong it is necessary to consider the 04 00 position on Apr 12.

2. The 04 00 position

The position recorded in the fair log (11 deg 00 min N 17 deg 04 min W) was a DR position based on a previous satfix. The experts worked on the basis that this was probably accurate to within 1 or 2 miles.

3. The grounding position

The grounding position (7 deg 38 min N13 deg 08 min W) given by the master to Captain Christatos during the first communication and included in the "XXX emergency signal" can only be regarded as approximate. There are inconsistencies with the anchorage position of Ljubijana as recorded in its log book. I accept Captain Cockroft's analysis that the grounding position was probably approximately accurate within two miles and that if the satnav position (pass 25 available 00 12) was within two miles the master would have accepted that as being generally accurate. Further Captain Cockroft referred to possible differences between satellite positions (based on World Geodetic System Datum 1972) and charted positions.

4. 19 14/19 35 Satfix position

Satfix 18 was received (and perceived) by the chief officer (available 19 35).

5. Reconstruction

The experts as to navigation have produced a number of plots, working backwards from

the grounding position, in an attempt to determine where the vessel was likely to have been at about 19 30 when satfix 18 became available. Captain Cockroft produced plots 1A and AC1 for this purpose. Both plots assume that the course changed from 137 deg to 115 deg at 21 00 and that there was some loss of speed due to a hot bearing between 20 00 and 21 00. Plot 1A assumes that the tidal stream was setting 033 deg at 1.5 knots from 21 00 to 23 00 and 0.5 knots from 19 14 to 21 00. The current is assumed to have been setting 033 deg at 0.7 knots. Plot AC1 takes account of certain points made by Captain Third (that the current was unlikely to have been setting north-east close to the shoals and that the tidal stream was probably less than 1.5 knots close to hneaps). For this plot the grounding position is assumed to be about two miles south-west of the reported position. The distance of 27 miles 19 14 to 21 00 is obtained from 46 minutes at 17K (13 miles) and 60 minutes at 14K (14 miles).

Captain Third considered four possibilities on his plots 18, 17A and 17B.

6. Tracks from 04 00 to 19 14/19 30 satfix 18 positions

Plots AC2 and AC3 show the four 19 30 positions on Captain Third's plots and the two positions shown on plots AC1 and 1A. Captain Cockroft's plot 1B shows the track from the approximate 04 00 position to be in the direction of 134.5 deg. This is also the direction to reach the 19 14 position on plot AC1. If the course steered was at 137 deg, allowing for cross-track error, the current is found to have been north-easterly about 0.7 knots. The plaintiffs submit that the current necessary for Captain Third's plots between 04 00 and 19 30 must have been greater than 0.7 knots in a north-easterly direction and that as a current of such strength is unlikely in a north-easterly direction it follows that the north-easterly component of current and tide during the period 19 30 to 23 00 was probably greater than accepted by Captain Third. Captain Third eventually accepted in cross-examination that if his plots were to be reconciled with the 04 00 position there had to be north-easterly or easterly current regardless of its statistical probability. When asked in cross-examination on Day 33 --

So on any of your plots there must have been, unless there was an alteration of course, a significant north-east going current in the period between 0400 and 1930?

Captain Third answered:

Yes, it depends on what application you put the word "significant". But there certainly would appear on that basis alone to be a set of the vessel east or north-east, certainly in an easterly direction.

The plaintiffs submit with, as it seems to me, some force, that no plan could possibly have anticipated a north-easterly current.

7. The most likely explanation for the grounding

It is probably that there was a line on the chart from the 04 00 position of 137 deg true with a projected 20 00 handover position marked. I accept the plaintiffs' submission that the most likely explanation for the grounding is that as a result of a failure of communication between the master and the chief officer at the handover (see under the heading 16 00-20 00 above) the master mistakenly thought that the vessel was making a course of about 137 deg true and a speed over the ground of about 18 knots. He failed to appreciate that the current was not a following current and no allowance for the reduction in speed due to the hot bearing was made. He relied on DR from a previous position and not on the satnav. The master was concerned about making Abidjan on time. He had originally intended to alter course to 118 deg but in fact altered course to 115 deg because he believed (in fact mistakenly) that he would gain time by altering to 115 deg (and subsequently reverting to 118 deg). He altered course to 115 deg wrongly

thinking that the vessel was to the south-west of her actual position. He also failed to give consideration to the possibility of the tide setting the vessel to the north-east. The grounding probably occurred broadly in the manner illustrated on plot AC1 (or AC2 and AC3).

8. Other possible explanations

The plaintiffs have advanced other possible explanations for the grounding. Two possible errors in the use and operation of the auto-pilot were referred to by the Plaintiffs:

(i) Having purported to alter course to 115 deg from 137 deg, the master might have forgotten to reset the course selector pointer which he would have moved out of the way of the lubber line to say 095 deg. The Anschutz Manual states:

In order to prevent unwanted course alteration after changing the mode of steering.

1) Set course-selector pointer very slowly (or step by step) for the course being steered by "hand". After that change to "automatic"

or

2) Set course-selector pointer without special regard to the rapidity of this movement for the desired course that has been set manually, wait 15 seconds and change to "automatic".

(ii) Having purported to alter course to 115 deg from 137 deg, the master might have erroneously set the course-selector pointer on 105 deg rather than 115 deg.

The plaintiffs also advanced navigational equipment malfunction as another possible explanation for the grounding.

Captain Cockroft described each of these three alternative explanations as not likely but possible.

My finding as to the probable explanation for the grounding is as set out above but I do not rule out these other possible explanations, particularly (i) above.

9. Conclusion

I find that the grounding of Ikarian Reefer was not deliberate but was due to negligent navigation by the master.

VII. THE FIRE

A. THE FRACTURED VALVE AND THE OPEN TAP

The generator engines of the Ikarian Reefer were fuelled by diesel oil. Diesel oil would be pumped from the double bottom tanks first to the diesel settling tank at the bottom platform, where water in the oil would settle out and be drained away. For daily consumption, the diesel would then be passed through the diesel oil purifiers (also at bottom level) and pumped to the diesel oil service tank ("DOST") at top level. From the DOST, diesel would be fed by gravity through a drop line to the generator engines at the middle level. On its way to the generator engines the diesel oil passed first through a quick closing stop valve bolted to the inboard side of the DOST, just above the top level floor plates. The stop valve was fitted with a quick release mechanism capable of being operated in an emergency from outside the engine room. The pipework of the drop line was connected to the outlet of the valve. During the inspection of the engine room

following the fire, the stop valve ("the valve") was found to be fractured on its inlet side, between the flange connection to the DOST and the main body of the valve. From the valve, the drop line ran a very short distance inboard before turning down to pass through the floor plates of the top level platform, and then running back under the DOST, and then forward to a vertical pillar or kingpost located between and slightly inboard of the forward and aft generator sets. The line passed down the outboard side of the pillar to a clamp which held the pipe in place against the pillar. Above the clamp, a small diesel pipe led off from the drop line to a boiler ("the boiler feedline"). Below the clamp the drop line passed through the gratings surrounding the generator engines and turned outboard toward the port side of the ship. Four branch lines led to the separate engine fuel pumps. From the pumps some of the diesel would be pumped to the generator engine fuel injectors, and the remainder would be returned via spill return lines to the DOST. Below the clamp, and about 2 ft above the gratings, a tap fitted with a ball valve had been connected to the drop line. This was the tap ("the tap") which was found to be about 80 per cent open after the fire in the engineroom.

B. DESCRIPTION OF THE VALVE AND THE CONNECTION BETWEEN THE VALVE AND THE TANK

The valve was probably a glove valve made of grey cast iron. There were three flanges on the valve body. At the outlet side there was a flange which connected with a similar flange on the drop line. At the inlet side of the valve there was a flange for connection to the service tank. The third flange was on top of the valve to which was attached the gland and the quick closing mechanism. All three flanges consisted of thick discs of cast iron (about 20mm thick), part of the single casting of the valve. The precise arrangement of connection of the valve to the service tank is uncertain. However, it is likely that the tank wall had been strengthened in way of the valve (per the plaintiffs) by welding on a steel doubler plate, or (per the defendants) by cutting out a circular section of the wall and welding a thicker steel insert in its place. A hole in (plaintiffs) the plate of the tank wall or (defendants) in the steel insert provided the outlet from the tank.

In order to effect a connection between the tank and the inlet flange of the valve, it seems that a boss ie thick ring of mild steel (perhaps 20-30 mm thick), of the same diameter as the valve flange, was welded onto the tank plate/ steel insert. The valve flange was then offered up to the boss, and the two secured together. The flange and the boss were held together with four threaded steel studs, each being about 12 mm in diameter, the studs passing through (plaintiffs) clearance holes or (defendants) bolt holes in the flange of the valve, and being screwed into threaded retaining holes in the boss. The assembly would then have been held in place by (plaintiffs) nuts or (defendants) studheads and washers. Between the boss and the flange of the valve there would have been a gasket to ensure that the connection was liquid tight. It is not known how thick the gasket would have been, although it may originally have been (plaintiffs) 1-3 mm or (defendants) 1-2 mm thick, or what it would have been made of, though it may have been graphitised asbestos. The nuts/studheads would have been tightened to compress the gasket to provide an effective seal.

C. THE RIVAL CONTENTIONS AND THE RIVAL MECHANISMS

By the start of the expert evidence as to the fire on Oct 5, 1992 (Day 40) the plaintiffs and the defendants had provided detailed written outlines of their respective contentions. The rival mechanisms sought to account for (a) the open tap (b) the fractured valve.

The plaintiffs (see the resume of the plaintiffs' physical case on fire revised 5.10.92.) contended that the fire could have occurred accidentally in a number of ways. One possibility was that the fire occurred following the fracture of the valve on the supply line for the DOST ("the fatigue/vibration mechanism"). Another possibility was that the fire

started by someone dropping a cigarette in the engineroom ("the cigarette mechanism"). A further possibility was that pieces of rag or cotton waste left on the engine could have constituted a source of ignition ("the rag mechanism"). Any one of these three mechanisms could have brought about the fire on Ikarian Reefer and, accordingly, the plaintiffs contended that the primary evidence of fact should not be rejected. As to the tap the plaintiffs contended that if partially damaged by fire, the tap could have vibrated open. The plaintiffs had carried out tests which they said showed that the tap could have vibrated open. As to the defendants' mechanisms (see below) the plaintiffs said that the defendants could not explain the fracture of the valve by reference to thermal stresses caused either by mechanical loading or thermal loading. It was, said the plaintiffs, impossible for the valve to have fractured as a result of thermal loading either along the length of the pipe or through the wall of the valve during the fire. The defendants' further mechanism based upon the relative movement between the pipe and the floor plates through which the pipe passed, was a theoretical possibility but inconsistent with the available evidence. Further, the plaintiffs submitted that the extent of the fire would have been much greater and there would have been much more widespread damage on the generator flat in the event that the tap on the drop line had been almost fully open from the beginning of the incident, given the rate of leakage from the tap and the rate of consumption of diesel by the fire.

The defendants' case (see the outline of the defendants' case on the cause of the fire dated 2.10.92 and the addendum thereto dated 9.10.92) was that the tap was opened before the fire by a member of the crew and the diesel flowing out of the tap was then deliberately ignited. The defendants contended that the valve fractured during the fire. It was, the defendants submitted, intuitively more likely that the open tap should have been the source of the fire and that the valve should have fractured as a result of the fire, than that the valve should have fractured before the fire, and that the tap should have opened during it. This intuitive assessment was, submitted the defendants, reinforced by the expert evidence which showed more scientifically the implausibility of the sequence of events proposed by the plaintiffs. The defendants' experts had considered two mechanisms by which the valve might have fractured in the course of the fire. But, submitted the defendants, there may be numerous other methods (or combinations of them) by which the valve might have come to be fractured in the course of the fire. The defendants did not commit themselves to either or any particular mechanism.

The two mechanisms by which the valve might have come to fracture during a fire were set out in appendix 2 to the defendants' outline The first mechanism focused on the effect of the fire in heating the valve. This, it was suggested, might have resulted in differential heating of different areas of the valve, setting up tensile and compressive forces within the body of the valve. This mechanism could, it was said, have caused fracture during heating, or more probably, on cooling. This mechanism was referred to during the evidence by the convenient shorthand "heating the valve". The defendants contended in their outline that this mechanism was a possible and credible explanation for the fracture of the valve in the fire. The second mechanism was as follows. During the fire the structures in the engineroom would have expanded and moved relative to each other as a result of expansion and distortion of steelwork. In particular the pipe from the valve passed through a slot in the floor plates of the service tank platform. The defendants said that the floor plates seemed to have moved against the pipe as a result of the fire. The defendants contended that it was possible, and indeed likely, that the movement of the floor plates against the pipe passing through the floor may have caused the valve attached to the pipe to fracture. This mechanism was referred to during the evidence by the convenient shorthand "movement of the floor plates". The defendants contended that both of the fire related mechanisms (heating the valve and movement of the floor plates) provided entirely credible explanations of the failure of the valve. That either one, or the other, or a combination of these two thermal mechanisms was the cause of the fracture of the valve was much more likely than the sequence of

events proposed by the plaintiffs.

In their addendum to the outline the defendants referred to a third mechanism -- stresses caused by expansion of the pipework under heat. The defendants recognized that the stresses likely to be set up in the valve in this way, would not, alone, be sufficient to cause a fracture of the valve. The defendants contended however that these stresses might contribute (together with the stresses caused by the other mechanisms, heating the valve and movement of the floor plates) to the fracture of the valve. This third mechanism was referred to during the evidence by the convenient shorthand "heating the pipe".

I will consider heating the pipe, the two mechanisms advanced by the defendants (heating the valve and movement of the floor plates) and the three mechanisms advanced by the plaintiffs (the fatigue/vibration mechanism, the cigarette mechanism and the rage mechanism) in turn. However, before I consider these mechanisms and other issues as to the fire it is convenient to refer to the expert evidence called by the plaintiffs and the defendants in relation to the fire. Any account of that evidence will inevitably be incomplete. It is however necessary to indicate the broad areas covered by the various witnesses and to state my view of the particular witnesses. This account should also serve to identify the extent of the conflict between the expert witnesses called by the plaintiffs and the defendants and how the respective cases developed (and changed).

D. THE EXPERT WITNESSES

The following expert witnesses were called by the plaintiffs:

Mr Peter Cook (fire expert);

Dr Andrew Palmer (pipe expert) primarily as to the heating the pipework and fatigue/ vibration mechanisms.

Dr Simon Walker (mechanical engineer/ heating expert) primarily as to the heating the valve mechanism.

Dr Timothy Baker (metallurgist) as to all aspects of the fracture of the valve.

Dr George Ward (naval architect with special expertise in ship vibration) primarily as to the fatigue/vibration mechanism.

Mr Christopher Fyans (ship surveyor/naval architect) primarily as to the movement of the floor plates and the fatigue/vibration mechanisms.

The following expert witnesses were called by the defendants:

Mr Brian Corlett (naval architect) primarily as to movement of the floor plates and the fatigue/vibration mechanisms.

Mr John Deegan (metallurgist) as to all aspects of the fracture of the valve.

Professor W Dover (stress analyst/mechanical behaviour of materials) as to all aspect of the fracture of the valve.

Dr Harry Taylor (fire expert).

Mr Kenneth Abel (consulting marine engineer and ship surveyor) as to the generators.

Mr Peter Cook (fire expert) was the only witness called who had inspected the fire damage to Ikarian Reefer. Dr Bound, who with Mr Cook had inspected Ikarian Reefer on behalf of the defendants in April, 1985, was not called by the defendants to give evidence. Mr Cook is a partner in Dr JH Burgoyne, and Partners. Since 1981 he has taken a special interest in maritime fire/explosion casualties and has investigated many such incidents involving vessels of many different types. Counsel for the defendants accepted that Mr Cook gave his evidence carefully and that Mr Cook's integrity is not in question. In my view Mr Cook at all times demonstrated his independence from the plaintiffs.

On Apr 18, 1985 Dr JH Burgoyne and Partners received instructions to attend Ikarian Reefer to determine the cause of the fire on behalf of the owners. Mr Cook in accordance with those instructions surveyed Ikarian Reefer on Apr 22 and 23, 1985. Mr James Kearon, a Salvage Association Surveyor and Dr Geoffrey Bound a fire expert were also present during the inspection of the vessel together with the owners' representative Captain Katakos. Subsequently Mr Cook attended in Piraeus between Apr 28 and May 4, 1985 to be present at, and assist with, some of the crew interviews. In April or May, 1985 Mr Cook provided an undated manuscript report to the owners which read:

The vessel had suffered extensive fire damage to both the accommodation and the engine room. Within the engine room, which was essentially arranged on three main levels, nothing combustible remained above the middle (generator) level. Below the generator platform, on the bottom level, were two further areas of severe but localised fire damage. One of these was on the port side almost directly beneath the inboard aft generator in way of the main engine manoeuvring station; the other was at the aft starboard corner of the main engine where a large container of waste had been located. The remainder of the bottom level was unaffected by fire. Within the accommodation the fire had burnt itself out and practically all the combustible materials originally present had been consumed. The above-mentioned damage can all be accounted for in terms of fire spread from a single source of fire in the engine room in the vicinity of the aft inboard diesel generator. The damage patterns in that area indicated that a liquid fuel had been burning in the bilge beneath the generator. No mechanical defect likely to have resulted in such a fire was found in this area. In way of the generator a side-arm had been fitted to the main diesel supply line from the daily tank for the purpose of providing a convenient means of drawing off small quantities of diesel fuel. The valve in this side-arm was found to have been almost fully open during the fire. In my opinion, human intervention offers the only plausible explanation for this valve being open and, on the basis of the crew evidence, no explanation involving accidental human agency can be proffered.

Mr Cook modified the conclusion in his manuscript report in the light of certain experimental work. When giving evidence he explained his reasons for modifying his earlier conclusion as follows:

At the time of the original inspection, it seemed to me that it was incredible that a tap of this type could have come open by any other means other than somebody deliberately opening it . . . Subsequently some experimental work was done and I had to review that opinion in the light of the experimental results . . . I was present at the experiments in Piraeus . . . I had given some advice prior to the test being carried out and I went along to monitor and to improve the test procedure where I could . . . I was convinced and I am still convinced that the critical factors that play a part . . . were tested in a valid way and the tests demonstrated that at frequencies that are commonly encountered on a working generator platform a slightly damaged or partly fire damaged (tap) of this type is susceptible to rotational movement as a result of forced vibration . . . in the face of that evidence it was absurd to continue with the view that there was no other possible explanation other than human intervention and it was on that basis that I changed my view . . . The other explanation being the possibility of vibrationally induced rotation.

In April, 1987 the tests were carried out in Piraeus to determine under what conditions, if any, a tap of the type found on Ikarian Reefer might come open accidentally. In September, 1987 tests, which were performed at the Fire Research Facility at Cardington, were carried out to monitor the effect of a diesel oil pool fire on duplex filter units of the type found on the auxiliary generators, and also on a tap of the type found open on Ikarian Reefer.

Mr Cook's first report (for the purposes of the trial) summarized the physical evidence with a description of the damage, reported the results of the Piraeus Tests, the Cardington Tests and referred to failure mode mechanisms.

The conclusions to Mr Cook's first report were as follows:

Following the preliminary inspection of the vessel off Sierra Leone in 1985, it was felt that the fire evidence, and in particular that relating to the open valve could only be accounted for satisfactorily in terms of human intervention. While such an explanation still cannot be excluded, subsequent experimental work has demonstrated that a valve of the type in question can be susceptible to vibration-induced rotational movement at the sort of frequencies to be expected on a working generator flat. Moreover, if the tap had been open as found from the beginning of the event, for the reasons given in the previous section considerably more damage to that valve would have been expected.

Even if it is argued that the tap was in the position found as a result of human intervention, an explanation is still required to account satisfactorily for the broke stop valve on the header tank, which a stress analysis indicates is unlikely to have been thermally induced. What is evident, of course, is that if the stop valve had fractured during the postgrounding conditions experienced by the vessel then there would have beesubstantial release of fuel almost directly above the generator flat and in close proximity to a viable ignition source in the form of the generator exhaust system.

In addition to the above, reference was made . . . to another possible source of ignition which does not involve a deliberate act, namely that of careless smoking activities . . .

Mr Cook's second report commented on the first (joint report) by Dr Taylor and Dr Bound. Mr Cook's third report concerned further tests carried out in Piraeus in June, 1992 on flow from a fractured valve. Mr Cook's fourth report dated Sept 28, 1992 referred to vibration tests and other matters.

When giving evidence Mr Cook said that the seat of the fire was in the vicinity of number 2 generator. He did not think the evidence was at all helpful as to precisely where ignition first took place. Mr Cook said that he found cotton waste residue close to the aft end of number 4 generator, perhaps a little more than half a metre away from the tap very close to two dipstick pipes. Mr Cook added that cotton waste is ordinarily used for wiping an oily dipstick.

As to the valve Mr Cook said that he had not seen a cast iron valve of the type in question fractured in a fire before and that so far as the surrounding temperature was concerned this was not an area where there had been particularly severe heating, so the fracture was a little surprising. He had not had any experience before or since of a cast iron valve fractured as a result of thermal stress.

In his first report Mr Cook stated that it was anticipated that a return visit would be made to Ikarian Reefer to complete the inspection once further details concerning the circumstances surrounding the casualty had been obtained from the crew. By the summer of 1986 it was envisaged that the vessel would be towed to a yard in Spain where it would be more practical for a further detailed survey and examination to be

carried out. Before final arrangements for the inspection could be made the vessel, which was still in the hands of salvors, sank. One of the features which merited further investigation was the valve. Mr Cook described the inspection in April, 1985 as a preliminary inspection. Once the tap had been found on the second day the further investigation was to see whether all the other physical evidence could be accounted for in terms of fire spread from that area. Mr Cook was satisfied that the evidence that he found was consistent with a fire burning from the generator bilge. It was probably in the course of the exercise to examine the fire patterns that the broken valve on the DOST was found. There was not a rigorous scrutiny of the broken valve and the area surrounding it. Mr Cook added that he did not give due consideration at the time to the possibility of the fracture of the valve being the initiating event. He did not consider at the time of the inspection the possibility of diesel oil escaping from the valve and finding its way to hot areas of the exhaust system of the aft inboard generator and becoming ignited. He did not expressly apply his mind to the question how the fire could have caused a fracture to the valve. He had not seen this sort of damage on a cast iron valve before and further consideration of the problem raised rather more difficulties in explaining that particular piece of evidence. He did not have any relevant experience at the time that could have led to the conclusion that the fracture to the valve was caused by thermal stress. He was more concerned now than he was at the time of the inspection as to whether the fracture of the valve was the result of thermal stress. The temperatures that were present around the valve did not seem to have been excessive.

Mr Cook was cross-examined as to whether the patterns of fire damage were more consistent with the tap or the valve being the source of fuel for the fire. Mr Cook said that he considered that the patterns of damage were more consistent with the tap as opposed to the valve having been the source of fuel for the fire. He did not consider however that the burning patterns were inconsistent with the other mechanism. He thought it more likely that the fire which started on Ikarian Reefer was a fire which was fuelled by the tap than a fire which was fuelled from the broken valve above but did not think that the fire evidence was inconsistent with the fatigue/vibration mechanism. At the time of his inspection the evidence of the open tap seemed rather overwhelming and to that extent he said that perhaps he did not give due consideration at the time to the possibility of the fracture of the valve being the initiating event. In the course of cross-examination on day 44 Mr Cook said:

The possibilities are these and the evidence that has to be accounted for is as follows: that, first of all, the fire damage has to be accounted for, the open tap has to be accounted for, the broken valve at the DOST has to be accounted for, and clearly there has to be a viable ignition source to start the thing going . . . I can't deal entirely with the mechanism by which the DOST valve might have broken and clearly that is something which so far as my assessment is concerned is a weakness in assessing probability from that point of view. So far as the fire evidence is concerned, the fire evidence which would follow as a consequence of the valve at the DOST breaking first, is certainly not impossible and is not inconsistent with the fire evidence in my view but there are a number of fairly complicated steps and conditions which make that particular mechanism, as far as the fire evidence is concerned -- my assessment is very unlikely. So far as the other possibilities are concerned, for deliberate ignition that is very attractive in many ways because, on the face of it, it seems a simple explanation, but that explanation does have to account satisfactorily for the broken valve at the DOST, so whilst from a fire mechanistic point of view I would regard that as rather more probable than the other mechanism, the order of probability would change if there was no satisfactory mechanism by means of which the broken valve at the tank could be accounted for. So, in a sense, there is an inter-dependence so far as probability is concerned with all of these mechanisms . . . The other basic mechanism that we considered was the cigarette or rag ignition theory. There is absolutely no difference between the manifestations of the fire that would have resulted from those mechanisms as compared with the deliberate ignition and I don't think the fire evidence helps us at

all in distinguishing between those . . . So far as both the cigarette theory and the ignition of rag on the engine theories are concerned, clearly there is an additional component in that mechanism involving damage to the tap ball valve and rotation of that valve open and to that extent that mechanism is less rather than more likely, but certainly not impossible.

In his first report Mr Cook said that if the tap had been open from the beginning considerably more damage to the tap would have been expected. When giving evidence he said that the tap had been in the area of a severe fire but had not been subjected to the most intense fire. During the time that oil would have drained through the tap there would be a cooling effect, but once the tank was empty Mr Cook found it inconceivable that there would be no further significant fire in the area of the tap for the sort of quantity of fuel in question coming from the tank. If the valve fractured before the fire he would expect the majority of the diesel oil to go into the main engine bilge, though some would go into the generator bilge. If all of the oil came out of the tap Mr Cook said that it was quite difficult to account for three tonnes being deposited into the generator bilge. Although he accepted that some of it may have gone over the saveall edge into the engineroom bilge, it was still a very large quantity of fuel to dispose of. From the manifestations of the fire damage it had not all been consumed.

If all of the oil came through the tap and was located in the generator bilge during the fire and burnt there it was very difficult to account for the absence of further more widespread damage in the generator flat. If someone started a fire immediately under the tap and then opened the tap 80 per cent, with the diesel below its flash point it would almost certainly put the fire out.

As to a source of ignition for diesel oil from the DOST Mr Cook said that it was almost inevitable that any significant amount of diesel leaking onto the generator would find an ignition source on the exhaust system. The temperature of the exhaust system would be very considerably in excess of the auto-ignition temperature of diesel fuel and this is a very common source of ignition where diesel oil has leaked from a generator or a fuel supply system. Where you have that combination it is almost impossible not to get ignition. If there was a fracture in way of the valve the prospects of diesel oil getting onto the exhaust manifold were quite high.

As to the Piraeus Tests Mr Cook said that the only conclusion he could draw from those tests was that a partly fire-damaged tap of the type in question could be subjected to rotational movement as a result of vibration induced at the sort of frequencies and at the sort of amplitudes that one would expect to find on a working generator platform. Mr Cook added that it seemed to him that this introduced a very realistic possible alternative explanation for the tap being open, contrary to the initial view that he formed that there was no credible explanation for the tap being open.

Mr Cook was asked whether, when he formed the view in his manuscript note that "human intervention offers the only plausible explanation for this (tap) being open", he gave any consideration at that time to a possible motive for the fire. Mr Cook's answer was as follows:

Yes, I did. It occurred to me after . . . speaking to crew members in Piraeus during the interviews, the impression I got was that they were all very, very scared after the grounding and it was also apparent that when . . . at least five of them had been ordered to remain on board, I think the impression I got was that they might have been reluctant to do so and that the fire would have given them . . . a cast iron excuse for abandoning the vessel. . . . The impression I received during the interviews was that the crew were very scared and were reluctant to stay on board and they had been ordered to do so, and clearly if they were reluctant to stay on board, it required a further excuse to abandon the ship and clearly a fire would be a justifiable reason for abandoning.

When asked "did you at that time say to yourself 'if this fire was started deliberately, the owners must have encouraged it?' "Mr Cook answered "No, that never occurred to me."

Dr Palmer (pipe expert) was an extremely impressive witness. His first report presented the results of a stress analysis of the valve and associated pipework. He subsequently performed an analysis using an extended model of the piping system which encompassed both the boiler feed pipe and the oil tank. His second report presented the results of a finite element modal extraction analysis and an assessment of the stresses induced under the calculated vibration modes. Dr Palmer's conclusions were as follows. As to heating the pipework, small stresses were generated in the valve due to the thermal loads occurring during the fire and it was unlikely that these were of a sufficient magnitude to have fractured the value. As to vibration, the stresses at the valve due to displacements of 50 mm in leg two of the pipework were much higher than those caused by the fire. To generate stresses at the value of 100 MPa in need displacement of 108 mm at Mode 17 Mode 1 and 159 mm at node 17 in Mode 2. Displacements of 50 mm represented vibrations with an amplitude of approximately one diameter (60 mm). Mode 1 frequency in the second report demonstrated that for an oil filled line the lowest vibration frequency was 5.91 Hz (the corresponding figure for Mode 2 was 8.59 Hz). This frequency was within the possible range of excitation frequencies caused by rotating machinery.

Dr Walker (mechanical engineer/heating expert) was a careful and extremely impressive witness. As will be seen below the defendants eventually accepted that Dr Walker's evidence was correct but only after a great deal of time and money had been expended in an attempt to prove the contrary. In his first report following a one dimensional analytical study Dr Walker concluded that plausible, best estimate parameters in the heat transfer calculations caused stresses of about 1 per cent of the failure stress. Even physically impossible (and thus upper bound) values of the parameters left stresses at about 8 per cent of the failure stress. Thus he concluded that thermal stress (heating the valve) was not the cause of the valve failure. Dr Walker stated in his first report that the expected range of the heat transfer coefficient would be about 10 to 30 and that for conservatism, to overestimate thermal stresses, a temperature of 900C was used.

Dr Walker carried out a finite element analysis after receiving Professor Dover's finite element work. The same thermal boundary conditions were used (a heat transfer coefficient of 40 and a gas temperature of 900C). Dr Walker's first four cases were as follows:

Case 1 (infinitely stiff and infinitely frictional gasket);

Case 2 (removal of radial restraint);

Case 3 (only outer peripheral node pinned radially and axially) and

Case 4 (free axially and radially)

Dr Walker concluded that the stress levels predicted by Professor Dover were a consequence of his treatment of the gasket as being infinitely stiff and infinitely frictional and of his use of a geometry with sharp corners. Allowing even only radial motion, and treating the gasket as still infinitely stiff in the axial direction, reduced calculated stresses in the fracture region to levels about one fifth of those required to fracture the valve. Use of best estimate rather than extreme values for air temperatures (600C instead of 900C) and heat transfer coefficients (20 instead of 40) would reduce stresses in the valve to below 1/10th of the fracture stress (assumed to be of the order of 200MPa). Accordingly Dr Walker reasserted his earlier conclusion that the valve did not fail through thermal stress. Dr Walker's earlier conclusions remained unaltered following

two further case studies provided in the course of his evidence:

Case 5 (restraint over an annular region extending from a radius of 54 mm to 61 mm) and

Case 6 (analysis of two single thickness flanges, both modelled as glued to a 1 mm thick gasket).

Dr Walker's analysis of the maximum stresses in the region of the fracture (which he took to be between 47 mm and 57 mm) is set out in Table 2 below:

***5*TABLE 2**

	Case 3	**Case 4**	**Case 5**	**Case 6**
Outer Surface axial stress	30/40 MPa	-30 MPa	150 MPa	-32 MPa
Inner Surface axial stress	-100 to + 70 MPa	35 MPa	90 MPa	37 MPa
Outer Surface Princi-pal stress	120 MPa	10 MPa	220 MPa	18 MPa
Inner Surface Princi-pal stress	150 MPa	48 MPa	200 MPa	51 MPa

Of his six cases Dr Walker said that the most realistic estimate of the stresses was found in case 6. This was because the geometry was the most appropriate with the gasket in its real life position. Dr Walker stressed that case 6 embodied several deliberate conservatisms (the heat transfer coefficient, the temperature, a 1 mm thick gasket and the modulus (the stiffness) at 1 per cent of that of cast iron). Dr Walker stated that the outer surface axial stress and the inner surface axial stress were the most relevant in causing a crack. The values for stresses produced in case 6 were a small fraction of the fracture stress and these stresses were obtained using a series of conservatisms and upper bound figures. The three principal points of difference that emerged in cross-examination were the heat transfer coefficient, the external gas temperature and the effect of the gasket. As to the heat transfer coefficient Dr Walker took 40 although his own view was 10 to 30. As to the external gas temperature Dr Walker took 900C although he had reservations about this figure. As to the effects of the gasket Dr Walker reflected his best view of this in case 6 subject to the conservatisms. (On day 51 Counsel for the defendants said that the defendants no longer pursued the case put in cross-examination to Dr Walker as to 20 per cent restraint and indicated that the defendants accepted Dr Walker's broad approach to the gasket.) Dr Walker added that his highly conservative model was many times stiffer than required to reproduce the effect of the studs. Dr Walker's two principal criticisms of Professor Dover's work were first that it did not include any of the effects of the gasket and as such the stresses that it calculated

were not relevant and second that the absence of the rounded corner made the outer surface stresses have no real meaning. Dr Walker disagreed with Professor Dover's suggestion in his fifth report that heating the valve, leading to thermal gradients, could not be ruled out particularly from the moment when the oil ran out and transient conditions leading to higher temperatures all over the valve existed. Dr Walker said that the stresses were being driven by temperature gradients and that when there ceased to be relatively cold oil on the inside of the valve, temperature gradients would get lower rather than higher so that the stresses would become zero.

Dr Timothy Baker (metallurgist) was a careful and impressive witness. Dr Baker was cross-examined at very considerable length. He showed himself ready to concede a point when it should be conceded and to acknowledge errors. It was to Dr Baker's credit that he enlisted the assistance of other experts when appropriate. In his first report he concluded that it was most unlikely that the valve had failed as a consequence of the effects of the fire because no source of adequate thermally induced stress could be identified. Following the suggestion made in Professor Dover's third report he accepted that mechanical loading of the valve due to fire-induced distortion of the structure was possible in principle but concluded that this failure mechanism was not supported by the geometry of the fracture surface or the photographic evidence. He reviewed the potential loading on the valve due to vibration of the pipework and maintained this was a possible mechanism of failure, under conditions of resonant vibration.

In oral evidence Dr Baker emmsized the principal uncertainties as to the valve (the dimensions; the geometry -- particularly the local arrangement in way of the neck; the tensile strength; the fatigue strength; the ratio of the outside area to the inside area; whether the valve was subject to casting defects and corrosion, a low possibility) and as to the pipework (how the pipework was supported -- particularly whether it was pinned or clamped; the boiler feedline connection particularly the nominal stress and the stress concentration at that point). Dr Baker concluded from the evidence in the photographs that the upper bound temperature at or around the area of the valve was 600C.

As to the movement of the floor plates mechanism Dr Baker's principal objection was that the fracture of the valve started on the aft side and then propagated forward (as shown in Mr Deegan's Figure 3). In order to get a fracture starting on the aft side and going forward the valve had to be displaced relative to the tank in a forward direction, whereas the only evidence (in photograph F) indicated that the floor plates moved forward to aft. Dr Baker also maintained a further objection that the floor plates and/or the pipe at the point of contact would deform rather than loading the valve to the point of failure.

Dr Baker identified four conditions that would have to be satisfied before it was possible to add together the effect of two more of the mechanisms heating the pipe, heating the valve and movement of the floor plates. First, they must be coincident in time. Second, the valve must be at the same temperature for the three sources of loading. Third, the stresses must be at the same location in the valve. Fourth, the stresses must act in the same direction. Dr Baker concluded that heating the valve could not be added to movement of the floor plates or heating the pipework because the maximum stresses were in different positions.

As to the fatigue mechanism Dr Baker said that fatigue accounts for the greatest proportion of failures that occur in ships' engine rooms and that although there are a greater number of fatigue failures in steel components than in cast iron components there are situations in ships' engines which are particularly susceptible to fatigue in cast iron. Dr Baker mentioned his experience of two valves in the case of the St Constantine (one of which had broken by fatigue and had caused a fire and another which had cracked at an earlier stage and had been weld repaired) and a valve on another ship which had failed (not by fatigue). Dr Baker put forward the following in relation to the

valve: tensile strength 200 plus or minus 60MPa; fatigue strength 62 to 131MPa (drawing on Angus p 92) and 1 X 104 for the cycles which would have arisen from the operation of the main engine. Dr Baker referred to a document entitled "Valve failure due to vibration" (see Table 3 below) which analysed "pipe fixed at clamp" (drawn from Professor Dover's second report as subsequently recalculated) and "pipe pinned at clamp" (drawn from Dr Palmer's second report) and stated that the displacements shown could have caused the valve to fail without a fracture of the pipework at the butt weld or elsewhere. He said it was possible that a fatigue failure could have occurred elsewhere before it occurred at the valve but if regard was had to Table 3 and to scatter, a fatigue failure could have occurred in the valve without the steel pipe failing in fatigue. Dr Baker said that he did not know what stress was acting on the valve when the main engine was operating and what stress was acting on the valve when the main engine stopped. If the stress in the second phase fell below the stress available in the first phase by an appropriate factor you would get below the threshold at which there would be further propagation. Any calculations based on the Paris law would be speculative without knowing th cyclic stress acting on the valve and the crack length. If there was a large crack you would need a small cyclic stress to continue propagation. If there was a small crack you would need a large stress.

Dr Baker's conclusion was as follows. The probability of the heating the pipework and the heating the valve mechanisms was so low that he discounted them. He acknowledged that there was problems with the fatigue mechanism. In particular it was difficult to deal with crack propagation after the main source of vibration had gone and he recognized that there were points of high stress elsewhere in the system. However in his view the fatigue mechanism was more likely than the movement of the floor plates mechanism. The problems with the fatigue mechanism were questions of degree whereas the movement of the floor plates mechanism faced an insuperable problem -- the movement was in the wrong direction.

(Dr Baker had to be recalled to deal with Professor Dover's residual stress theory referred to for the first time in relation to the movement of the floor plates mechanism in Professor Dover's seventh report dated Nov 16, 1992 (day 64 of the trial). Dr Baker's principal answers to the residual stress theory were set out in his fourth and fifth reports.)

Dr George Ward (naval architect with special expertise in ship vibration) was a quiet but impressive witness. In his third report Dr Ward concluded that the operation of the propeller in the grounded condition with the propeller only partly submerged, would set up exciting/periodic tilting moments in the propeller shaft at blade passage frequency (the shaft speed times the number of blades) and twice this. Such moments would be transmitted along the shaft to the engineroom structure and would then excite resonant vibration in the DOST pipe in its second mode. Because of the difficulty in calculating the exciting forces and moments and then of calculating the effects of those on elements of the structure, such as the DOST pipe, it was not possible to state the resulting vibration amplitudes of the DOST pipe. However Dr Ward said that it was possible that the refloating attempts created vibration at about the resonant frequency of the pipework attached to the DOST.

In his third report Dr Ward also concluded that there would in practice be exciting forces transmitted to fuel pipes connected to the engines at 10, 20 and 30Hz. In particular a faulty fuel injector would excite resonant vibration in the DOST pipe in its first mode. Because of the difficulties in calculating the exciting force it was not possible to state the resulting vibration amplitudes of the pipe.

Dr Ward said that if the possibility of a faulty fuel injector was excluded there would be some excitation from the generators but he was not sure what the subsequent stress would be and whether or not the stress would propagate a crack. The exciting force and

the damping properties of the final element of the piping were unknown factors. There would be stresses set up in the pipe due to the excitation of the generators but he did not know what value they would have and hence whether there would be any crack propagation. There would be a noticeable increase in vibration from the engine with a faulty fuel injector.

As to the tap Dr Ward stated in his second report that he considered that the tests undertaken at Piraeus satisfactorily simulated the transmission of vibration energy to the tap and that the range of frequencies used covered those that would have been experienced in the vicinity of the auxiliary diesel engines in Ikarian Reefer.

Mr Fyans (ship surveyor/naval architect) also gave evidence on behalf of the plaintiffs. The plaintiffs did not rely on Mr Fyans' first report and only relied on one paragraph in his second report. Reliance was placed on Mr Fyans' third report and fifth report but not on his fourth report. In particular the plaintiffs did not allege that the cause of any relevant vibration in the engine spaces of Ikarian Reefer was cavitation.

When giving evidence Mr Fyans suggested that pounding may have occurred sufficient to propagate a crack in the valve. He did not know whether a single shock impact or pound would be sufficient to make the valve part or whether it would require two or more such pounds. He said that structures that have been subjected to a pounding force will often experience a reactive failure remote from the actual point of pounding due to the transmission of shock forces through the structure. If the vessel was aground in a rising tide it is often the case that the worst point as regards pounding on the ground is as it lifts off the bottom. If there was pounding then the nature of the structure would permit it to be transmitted to the area of the valve and if such shock loading was transmitted to that area there was a possibility of it being significant in the final failure of the valve.

The expert witnesses called by the defendants

Mr Brian Corlett (naval architect) was an articulate witness but I felt that at times he was inclined to express opinions beyond his area of expertise. Mr Corlett conceded that he was not as knowledgeable and as experienced in the investigation of vibration as Dr Ward. He did not profess the same level of expertise as Dr Palmer in the field of pipes. He was not a specialist in fracture mechanics or in metallurgy and he had not previously investigated fire cases on ships.

Mr Corlett produced four reports and a supplementary note on pounding. In his third report he asserted that in photograph F it could clearly be seen that the forward floor plate on which the ladder landed had been pushed aft under the aft section of floor plate. His fourth report dated as late as Nov 2, 1992 (day 56 of the trial) dealt inter alia with propeller excited vibration, pounding, the generators, structural movements due to heat (movement due to the ladder and general movement of the platform on the main engine) and pipework fatigue calculations.

As to movement of the floor plates Mr Corlett said that he could not see any evidence of any movement from aft to forward and he was not aware of a mechanism to produce a movement from aft to forward. If he had hen able to think of a sensible mechanism to produce a movement from aft to forward he would have advance it. He added that it was very clear there were two plates which overlapped with the forward one underneath and slightly inboard of the after one. He referred to a square in photographs F1 and F2 and stated that he was absolutely certain that there was an athwartships movement. As to the section in his fourth report entitled "movement due to ladder" this presupposed that the ladder was attached to the floor plates. Mr Corlett acknowledged that it was unclear how the ladder was attached. As to the section in his fourth report entitled "general movement of the platform on the main engine" (racking with rectangles becoming parallelograms) Mr Corlett conceded in cross-examination that he only worked out this

particular mechanism at the beginning of November. Mr Corlett said that he did not see any buckling at the point where the plating would be restrained by screws and added that this was a very difficult phenomenon to analysis with any degree of confidence.

As to the fatigue mechanism Mr Corlett did not disagree with Dr Ward that propeller excited vibration would cause bending moments in the tail shaft. In particular he agreed with Dr Ward that a blade going into the water would show a discontinuity in she thrust developed by that blade (relative to a fully submerged case) and that a blade coming out of the water would show a similar discontinuity. Such discontinuities in a periodic function are the cause of harmonics. Mr Corlett's principal reservation in this connection was as to the extent of attenuation of the forces before they reached the engineroom. In evidence he maintained the view expressed in his fourth report that it was unlikely that any significant excitation due to out of plane forces and moments would be transmitted to the engineroom because of its distance from the aft end. Mr Corlett said that his assessment was slightly different to Dr Ward's, that this was a question of degree and that he could not prove that Dr Ward was wrong in his opinion. Mr Corlett also maintained the view set out in his fourth report that the generator diesel engine would not have provided a source of significant non-resonant vibration excitation for the pipework and that any forced vibration would not have been of a significant amplitude such as to cause the alleged fatigue crack in the valve to propagate.

As to pounding Mr Corlett agreed with Mr Fyans that as the tide rises the risk of pounding increases. He said that the factors relevant to pounding included the state of the tide, the particular swell conditions, the nature of the bottom and the position at which the ship was in contact with the ground. Mr Corlett's view was that pounding was extremely unlikely. He added that he would not rule it out completely but did not believe that it would have produced severe impacts even if it occurred. He asserted that the photographic evidence tended to confirm that any pounding, if it occurred, was not severe. As to the Pireaus tests in relation to the tap Mr Corlett said that the range of frequencies used covered those that could be experienced in the vicinity of the auxiliary diesel engines on Ikarian Reefer but it had not been satisfactorily demonstrated that the transmission of vibration energy to the tap in the circumstances on board the ship would cause it to vibrate open. He accepted that the opposite had not been demonstrated. It emerged for the first time in the course of cross-examination of Mr Corlett (day 61) that an enargement of photograph N showed that the clamp on the boiler feed pipe had come away.

Mr John Deegan (metallurgist) has had very considerable experience and often acts in cases on the other side to Dr Baker. I was concerned about Mr Deegan's change of view as to the probable initiation region of the fracture path in the valve. This was shown in Figure 3 to his first report dated Nov 29, 1991 as on the aft side of the valve. On day 52 (Oct 26, 1992) Counsel for the defendants stated that Mr Deegan now did not know whether the initiation region was on the aft or the forward side of the valve.

Mr Deegan produced three reports. In his first report he concluded that the fracture of the valve had not been by a fatigue process. The position and the path of the fracture were not consistent with fatigue propogation. The fracture was consistent, in his opinion, with an overload failure. The most likely source of the overload stress necessary to fracture the valve was associated with heating and cooling during and after the fire. Figure 3 to the first report showed the probable initiation region of the fracture path on the aft side of the valve, with the probable final failure region on the forward side of the valve. (Mr Deegan in this report made a general reference to the movement of the floor plates mechanism).

In his second report Mr Deegan stated that he did not agree that the probable cause of failure of the valve was by progressive fatigue cracking. This was in his opinion highly improbable. In his third report dated Nov 3, 1992 (day 57 of the trial) Mr Deegan stated

for the first time in writing that the aft location of the fracture of the valve could be the end point of a fracture which started at the forward side by an overload mechanism. Mr Deegan added that the photographic evidence suggested that the movement of the floor plates mechanism probably operated by movement from forward to aft and concluded that if this interpretation of the photographic evidence was correct the valve probably fractured from forward to aft rather than aft to forward. Mr Deegan's third report concluded with his current opinion that the fatigue mechanism was extremely improbable and the movement of the floor plates mechanism was distinctly feasible and likely.

In evidence Mr Deegan said that if it was suggested that the valve was crucial to the case then he would want to visit the ship with Dr Baker, take photographs of the structure around the valve, take photographs of the valve in situ and then unbolt the valve and bring it home and carry out a thorough metallurgical examination of it. At one point he referred to the foolishness of relying too much on photographs and not doing a proper investigation.

Mr Deegan said he had never seen a fatigue fracture in a cast iron valve but nor had he seen a cast iron valve fractured by fire. In his first report Mr Deegan had stated that the tensile strength of a cast iron valve might be about 140 MPa. In evidence he said that Dr Baker's 200 MPa plus or minus 60 represented the extreme limits. It seemed likely from the work carried out since his first report that 200 MPa was right but 140 to 260 probably encompassed the whole range.

As to the probable initiation region of the fracture path of the valve Mr Deegan said in evidence that he did not have any photograph or any other evidence which was not available to him when he wrote his first report. Mr Deegan said he changed his mind a week or two weeks after receiving Dr Baker's third report (dated Sept 28, 1992). He agreed that the fracture path ran from side to side (rather than from top to bottom or bottom to top) and said that the question was whether it ran from forward to aft or aft to forward. When asked what led him to his original opinion as to the probably initiation region of the fracture path Mr Deegan said that he made the judgment that the casting was probably thinner and smaller in diameter close to the run-out of the fillet and that the fracture face was in thicker material on the forward side. Mr Deegan said he had looked at the photographs again and again. He thought he might be mistaken as to the initiation region of the fracture path on the aft side but he might still be right. He added:

I might very well have come to the conclusion that it was still as I show it in Figure 3, but the point is that I didn't consider it as deeply as I should have done in terms of a differential thermal movement theory.

He recognized that he may have been right as to initiation on the aft side and concluded that the fracture path may have gone from forward to aft and may have gone from aft to forward. He was not certain which way it went and was not saying that it was more probable that it was forward to aft than aft to forward.

As to photographic evidence of movement of the floor plates Mr Deegan said that he was clear that there was an athwartships movement of the plate and probably an aft movement although the evidence was inconclusive. Mr Deegan also stated that if his Figure 3 was correct and the fracture path initiated on the aft side of the valve and any floor movement was forward to aft, not aft to forward, then (excluding any other mechanisms) movement of the floor plates could not have caused the fracture.

Mr Deegan's principal objections to the fatigue mechanism were as follows. First, the very short period of time which implied very high stresses. Second, the fillet weld was more likely to fail by fatigue and there were very much higher stress points in the piping system. Third, if a fracture was initiated in a very short time and the fracture stopped

and there was then a very much lower stress regime, the crack would either stop propagating or would propagate at a very much slower rate.

(Mr Deegan was recalled as to limited aspects of Professor Dover's residual stress theory which were the subject of his fourth report dated Nov 19, 1992. At no stage prior to this had Mr Deegan suggested the possible significance of residual stress as advanced in Professor Dover's seventh report.)

Professor W Dover (stress analyst/mechanical behaviour of materials) is very distinguished in his field but had not given evidence before as an expert witness. For the reasons set out below I regret that I have a number of reservations about Professor Dover's approach and evidence.

Professor Dover produced seven reports. In his first report he said that:

. . . the thermal stress . . . for a uniform cross-section of the valve between main body and flange, would be given simply by EaT where E = Youngs Modulus, a = coefficient of thermal expansion and T = temperature difference between inside and outside. Choosing appropriate values of these constraints for cast iron gives a stress of 517 MPa well above the yield stress for the material.

The conclusions to the first report were as follows --

1. Thermal loading can arise due to restraint of expansion either along the length of the pipe or through the wall of the pipe or the valve. Calculations show that the stresses due to thermal loading, in both cases, were high and that for through wall exceeded the yield stress of the material. 2. Mechanical loading can arise due to vibration transmitted from the main engine, auxiliary engines, grounding and slashing of fuel oil in the tank. In all these cases the stresses produced were insignificant . . . 4. The cause of failure of the quick acting valve attached to the diesel oil fuel tank is thermal loading and the valve probably fractured after the fire.

In his second report Professor Dover stated that finite element analysis had been conducted on an improved model containing a radius at each pipe corner and the boiler feedline. A dynamic analysis of the improved model of the pipe system between the DOST and the lower clamp (including the boiler feedline) showed that the resonant frequency was 52 per cent higher than the same model omitting the boiler feedline. Following this further work Professor Dover's conclusions remained as stated in his first report.

In his third report (served on or about June 15, 1992) Professor Dover reported on specimen tests, material examination, mechanical test fatigue, mechanical tests at 700 deg C (including a test conducted to determine the possible temperature distribution) and further finite element stress analysis. The summary to the third report concluded:

. . . the measurements of temperature distribution on a valve heated externally and cooled internally showed differences of 171oC. This is far in excess of that predicted with simple models by Walker (14oC) and shows that a thermal loading constraint failure is possible. The conclusions from my earlier reports remain unaltered.

Professor Dover's fourth report dated Sept 29, 1992 reviewed the findings of two studies, a theoretical thermal analysis leading to temperature distributions (attempted by Professor Collins) and a thermal and stress analysis using finite elements in order to give typical stress distributions. Professor Collins was not called to give evidence on behalf of the defendants. The report stated at the outset that the results of the two studies fully supported the laboratory measurements and showed that failure due to thermal loading was likely.

On day 48 of the trial (Oct 19,1992) Counsel for the defendants stated that Professor Dover as a result of his various experiments inclined to the view that it was probably unlikely that heating the valve alone caused the fracture but that the process of heating the valve was capable of producing very much greater stresses than the plaintiffs' experts were prepared to countenance. On day 51 of the trial (Oct 22, 1992) Counsel for the defendants stated that Professor Dover had in his first report (in introducing the heating the valve mechanism) put forward conclusions that were based on a temperature difference of 300 deg C. That difference was (at day 51) accepted to be an unsustainably high temperature difference. Again on day 51 Counsel for the defendants stated that Dr Walker's basic approach in relation to the gasket was accepted and that the case put in cross examination to Dr Walker as to a 20 per cent restraint was not a case which the defendants now pursued.

Professor Dover's fifth report dated Oct 27, 1992 (day 53 of the trial) reflected a number of important changes. Professor Dover's revised views as to the gasket were set out. As to his first report Professor Dover said:

I was focusing on thicker sections where T does not strictly apply but where the thermal gradient was greatest. In order to use T I had to consider the area between the main body and the flange, where T can be more reasonably applied, but I incorrectly used the extremes of temperature that could be found in the vicinity of the valve. I failed to consider whether those temperatures could exist in the valve at the same time. I now accept that it is not possible to have a temperature difference of 300oC in the neck of the valve . . . Dover once suggested that thermal gradient was a possible cause of the fracture of the DOST value. Subsequent work has shown that significant stresses can occur due to thermal gradient but that these are less than the failure stress at say 250oC (with oil in the valve).

Professor Dover added:

I have always said that thermal fractures are to be expected to be initiated in thicker sections such as the flange or the central body. If the fracture initiation site is at the expected fatigue fracture initiation site then I would agree that failure due to thermal gradient is unlikely. Due to problems in interpreting the photographs I cannot be sure of the location of the fracture initiation site . . . I do not believe heating of the valve, leading to thermal gradients, can be ruled out particularly for the moment when the oil runs out and transient conditions leading to higher temperatures all over the valve exist.

Professor Dover's sixth report dated Nov 6, 1992 (between days 59 and 60 of the trial) dealt with remaining life after postulated large amplitude vibration (including in particular application of the Paris law), failure of pipe system during alleged vibration, floor plate movement, ductility and thermal gradient.

On Monday Nov 16, 1992 (day 64 of the trial) Counsel for the defendants, in seeking leave to introduce Professor Dover's seventh report, stated that Professor Dover had pointed out to the defendants' legal advisers on the previous Friday that residual stress was relevant to the movement of the floor plates mechanism. Counsel said that since nobody on the defendants' side had hitherto realized that residual stress was of any significance in relation to the movement of the floor plates mechanism (as opposed to the heating of the valve mechanism) Professor Dover had been asked to provide a seventh report. In his seventh report Professor Dover said:

. . . compressive loading leading to residual stress on cooling and ultimately fracture is applicable to the structural thermal distortion mechanism.

A flow-chart was attached to Professor Dover's seventh report. Professor Dover amplified

his views as to residual stress in a subsequent document entitled "Residual Stress due to Compressive Yielding".

In evidence Professor Dover said that he had had very little experience of working in cast iron and did not know an enormous amount about cast iron.

When giving evidence as to the heating the pipe mechanism Professor Dover was referred to the conclusions in his first report "Calculations show that the stresses due to (heating the pipe) were high" and conceded that he had only done "a few simple sums" (see further his fax dated June 2, 1992). Professor Dover agreed that his first report should have contained reservations and that despite his first conclusion (which included heating the pipe as well as heating the valve) he did not have the level of constraints needed to investigate the heating the pipe mechanism. Professor Dover said that having read the first reports of Drs Baker and Palmer he thought their conclusions were probably right as to heating the pipe. In particular he said that since receiving Dr Palmer's first report he accepted that the stress in the pipe was probably small (and that converted to an even smaller stress of the valve). He agreed that his second report did not accurately or fairly set out his then view as to heating the pipe and that heating the pipe could be disregarded unless there was an additional clamp. In his second report Professor Dover in commenting on Dr Palmer's first report had referred to:

. . . possible causes of higher thermal stress which have not been considered [-- and added --] the study would appear to be incomplete and has consequently led to the wrong conclusions being drawn.

In evidence Professor Dover said:

. . . I was listing the possibilities there and I think I have listed some which are rather trivial . . . I think there is only one of those possibilities which could give rise to anything of significance and we don't have firm evidence of that . . . all the others . . . are negligible.

Professor Dover accepted at the end of cross-examination as to heating the pipe that this mechanism could be disregarded, alone and in combination, as a cause of the fracture of the valve.

When giving evidence as to the heating the valve mechanism Professor Dover accepted that his first report should have contained reservations and that he was in error in saying:

. . . choosing appropriate values of these constraints for cast iron gives a stress of 517 MPa well above the yield stress for the material.

In his first report he had taken 300 as the appropriate value for T (temperature difference between inside and outside) but accepted that that temperature difference was not possible. Professor Dover agreed that he should have taken account of the stiffness of the restraint in his fourth report. The gasket was the principle difference between the results from Dr Walker's work and from his work. Professor Dover accepted that Dr Walker had led him to review his position on the restraint. Professor Dover acknowledged that Dr Walker's intervention was extremely helpful and agreed that it was possible that but for Dr Walker he would have adhered to the conclusions in his fourth report. Although it was put to Dr Walker in cross-examination (on the advice of Professor Dover) that the restraint offered by the gasket was of the order of 20 per cent, Professor Dover agreed that he was confused on this point. Dr Walker's work dated Oct 18, 1992 contained most of the information needed to make a decision about what would happen in the subject valve. Professor Dover accepted that he had not been able to show that the failure of the valve was caused by the heating the valve mechanism

either in its steady state or thereafter. For the steady state condition the stresses, whilst in Professor Dover's view significant, were insufficient for failure.

When giving evidence as to the movement of the floor plates mechanism Professor Dover accepted that, in so far as he considered the mechanism in his first report, he did not reach the conclusion that it caused the fracture of the valve. Professor Dover accepted that a passage in his third report could be read as indicating his agreement with Mr Deegan's Figure 3 (with the probably initiation region of the fracture on the aft side of the valve) but he said that he did not have a firm view as to which way the crack ran. Professor Dover added that he had been content to accept Mr Deegan's opinion as to the probable initiation region and that it was not until his fifth report that he said:

. . . due to problems in interpreting the photographs, I cannot be sure of the location of the fracture initiation site.

As to any movement of the floor plates Professor Dover agreed that it was quite unsafe to draw a firm conclusion from photograph F. Critical factors in the analysis were the gap that might exist and the amount of movement that might take place during the fire. Professor Dover agreed that if any movement was from forward to aft and if Mr Deegan's Figure 3 was correct as to the probable initiation region, the movement of the floor plates mechanism would not work unless his residual stress theory was correct. Professor Dover had stated for the first time in his seventh report dated Nov 16, 1992 (day 64 of the trial) that compressive loading leading to residual stress on cooling and ultimately fracture was applicable to the movement of the floor plates mechanism. He accepted that he had not put compressive loading leading to residual stress together with the movement of the floor plates mechanism until his seventh report. He said that it had not occurred to him that residual stress might account for a fracture aft to forward when in early October he saw Dr Baker's third report. When asked to explain why it was that he did not come up with the residual stress point until day 64 Professor Dover said:

I don't think one can explain things like that. For me it requires some sort of input and in this case it was Mr Deegan's evidence which sparked off the idea or the thought that I should consider the mechanisms for cracking from left to right or right to left and it was at that stage that I felt I should mention those possibilities.

Professor Dover expressed the opinion that there would only be significant residual stresses if unloading occurred below 400 deg C. If unloading occurred at higher temperatures residual stresses could well disappear. Professor Dover added that he could not say that unloading would have occurred below 400 deg C because he did not have the necessary expertise. Accordingly he accepted that he was not able to express any view as to the likelihood of the residual stress theory because he did not know one of the essential factors. He had not referred to this gap in the analysis in his seventh report. Professsor Dover acknowledged that he could not say that there was probably compressive loading leading to residual stress on cooling and ultimately fracture. He could see the circumstances under which it could arise. The amount of force applied to the valve was unknown. If that force was released at high temperature then the theory became unlikely. Professor Dover had not done any analysis in relation to the residual stress theory.

Professor Dover's conclusion was that the valve probably failed due to thermal loading. He did not know how the valve failed. The most likely looking area was thermal distortion of the structure.

When giving evidence as to the fatigue mechanism Professor Dover stated two main objections to that mechanism. First in order to produce damage in the valve a very large amplitude of vibration was needed. He said that although he was not an expert on vibration of pipes in ships it seemed to him that an extraordinary amplitude was needed

and that once that amplitude was obtained he assumed something else would have happened before the valve failed (see the section in his sixth report entitled "Failure of pipe system during alleged vibration"). Professor Dover's second main objection was based on the application of the Paris law (see the section as to this in his sixth report). If there was a reduction in stress Professor Dover could not see how the crack could start growing again -- a second phase when the loading was again quite severe would be needed. Professor Dover also relied on a number of subsidiary points. These included the point that the distribution of bending moments along the section of the pipe for the thermal mechanism favoured the inlet side of the valve, but for the vibration mechanism favoured the outlet side.

Professor Dover said that one would expect a fatigue fracture to start in a site of stress concentration such as the toe of the fillet (see Mr Deegan's Figure 3). The initiation site shown on Figure 3 was where he would expect a fatigue fracture to begin. He could not tell whether the fracture was a fatigue fracture or not simply by looking at the fracture path. Fatigue fractures from low cycle, high stress conditions were not unknown. Professor Dover had produced one himself.

Professor Dover's flow-chart (produced as late as Nov 16, 1992 and without any accompanying text) stated that other parts could (not would) fail in mode 2. He accepted that any such analysis could be affected by defects and scatter. As to the application of the Paris law Professor Dover accepted that without knowing the amplitudes from any propeller excitation any application of the Paris law would be speculative. All he could say from the Paris law was what would happen if there was a change of magnitude. From what he had heard he thought the differences were significant. Further any stresses due to pounding would have to be comparable to those that produced the initial crack.

Professor Dover also accepted that it could not be said that because the stress might be higher at point A rather than point B, a fracture would take place at A rather than at B. This could be affected by a number of factors including the stress amplitude, the stress concentration position, a particular defect or a slightly different wall section.

Professor Dover said that it was surprising, given that the valve was on the same pipeline as the tap, that the valve was not closely inspected and removed by the fire experts.

When giving evidence Professor Dover referred to the "ill-defined problems that we are solving" and added:

. . . we are never quite sure that the problem we have solved is directly relevant to the Ikarian Reefer, so we learn something from each problem that we solve but we don't know exactly how to apply it . . . we are searching for answers to problems but we are never 100% sure that we have defined the problem properly.

Professor Dover listed some of the uncertainties as to the valve, the pipework, the floor plates etc. These included the geometry of the valve; the strength of the cast iron; whether the valve was subject to any defects; the fracture initiation site; the fracture surface; the strength of the pipe; the quality of the welds in the pipework; the strength of the other components in the pipeline; the fixity of the clamp (although it appeared to be common ground that this was somewhere between pinned and fixed); the resonant frequency of the pipework; the magnification factor; whether damage had occurred to any other components in the pipeline; the flexibility of the tank; whether the floor plates had become detached due to fire or whether they were generally loose; whether there was any permanent deformation of the floor plates; the definitions of loading and the heat transfer coefficient.

Although Professor Dover at all times supported the thermal mechanisms as opposed to the fatigue mechanism he said when giving evidence:

I still would find it difficult to know what caused the failure of the valve . . . I do not see the fatigue vibration (mechanism) as possible, but the other thermal mechanisms are all possible to some extent . . . I don't know how the valve failed . . . the most likely looking area is the thermal distortion of the structure . . . I cannot prove how the valve failed . . . it is beyond all of our powers because we don't have the full information . . . we can conduct stress analysis and it will point to possible modes of failure. It will even in some cases suggest more likely ones than others but it won't tell us how the valve failed . . . it is because we have so little information that we have quite a few avenues of investigation . . . we have seen one side produce some work, the other side mentioned something about it and the first side would change it again.

Dr Harry Taylor (fire expert) gave evidence further to two joint reports by Dr Taylor and Dr Bound. Dr Bound (but not Dr Taylor) had inspected Ikarian Reefer with Mr Cook in April, 1985. Dr Bound was not called to give evidence by the defendants. Dr Taylor is a very experienced fire expert. When asked whether he regarded himself as at a disadvantage by reason of not having himself inspected the ship he said:

. . . yes, I think I have to say that . . . to a limited extent and I couldn't quantify it. It's a feeling I have rather than anything I can put into a rational expression.

I was surprised that the defendants did not call Dr Bound as a witness.

Dr Taylor was careful to point out that he was simply a fire expert and not an expert in vibration, metallurgy, stress analysis, fracture mechanics or naval architecture.

The conclusions to Dr Taylor's first (joint) report were as follows:

The pattern of fire damage is not consistent with the Plaintiffs' case that the fire possibly resulted from a fractured valve . . . leading to fuel leaking onto a generator exhaust . it is concluded that the fire on board the Ikarian Reefer started in the engine room on the port side at the generator flat, between numbers (2) and (4) generators. The fuel for the fire was diesel oil, released from the generator supply pipeline via an open tap. No accidental source of ignition was observed within the immediate area of the seat of the fire and no remote source of ignition appeared probable. It is concluded, therefore, that the oil was ignited deliberately, probably utilizing cotton waste -- residues of which were found -- as a "wick", to facilitate ignition . . .

Dr Taylor's second (joint) report commented on Mr Cook's report of his shipboard inspection, on the Piraeus and Cardington tests and on Mr Cook's conclusions. At p 15 of the second report Dr Taylor stated --

. . . fatigue failure (of the valve) is very improbable and the most likely mechanism is through thermal effects, ie after the fire started.

Dr Taylor agreed when giving evidence that the words "fatigue failure is very improbable" should not have appeared in the second report because he was not qualified to propound upon that. The first report stated that:

. . . the phenomenon of a fractured valve body has been observed in other instances, involving tanks at middle or upper parts of engine room where a fire of some severity has occurred at lower levels. There was no evidence of direct human intervention and it has been concluded that the damage resulted from the effects of the fire at the level below.

Dr Taylor said in evidence that on the two occasions (out of between 130 and 140) he had found fractured valves he did not seek to determine the material of the valves and he could not remember the names of the ships. Unlike Dr Baker he was unable to refer to any documents in this connection. Dr Taylor agreed that with hindsight it would obviously have been a great advantage if the valve had been removed from Ikarian Reefer.

As to the cotton waste residues found on the ship Dr Taylor accepted that these were found in the sort of area where you might expect to find cotton waste -- close to two dip sticks. In the first report it was stated that "it is extremely unlikely that the valve fractured before the fire". Two matters were relied upon in support of this contention:

(a) soot generally on the fronnne of the DOST in places adhering to paint which is itself still adhering to the tank . . . (b) an early fire at the front face of the DOST would have led to an early failure of the improvised sight glass on the tank . . .

In evidence Dr Taylor accepted that (b) was a neutral factor. He also accepted that (a) may have been premised on a rather larger fire in the saveall than was now being envisaged. There was a discontinuity in the saveall at about the valve so that if oil came out of the gap much of it would flow down the hole under the valve. It was a matter of speculation what if any oil would remain in the vicinity of the valve. There would only be significant damage to the side of the DOST if a significant pool of oil developed and caught fire in this vicinity. Because of debris it was not possible to tell by looking at the area of the saveall whether there had been a fire. Thus the reasoning put forward in the first report in support of the contention that it was extremely unlikely that the valve fractured before the fire was confined to the tank wall. Dr Taylor agreed that photograph L was not inconsistent with the possibility of some flame impingement in that area. He could not say that there was not a little flame impingement looking at photograph C. If there was only thin films of oil (as suggested to Mr Cook in cross-examination) then there would only be small flames in that area.

When giving evidence Dr Taylor put forward additional reasons in support of the contention that it was extremely unlikely that the valve fractured before the fire (in addition to reason (a) in the first report). In particular he said that he would have expected to see signs of staining by diesel or signs of burning of diesel or both in two places, first the stairway down to the next level below (as shown in Mr Cook's photograph 50) and second the floor plates roughly midway between the saveall and the main engine (Mr Cook's photograph 46). As to the first point Dr Taylor agreed that there was a certain amount of burning near the support at the side of the staircase and that there were very distinctive individual streaks at the bottom of the staircase which suggested that something had run down there vertically in a liquid form. As to the second point Dr Taylor agreed that there was a great deal of debris on the floor plates and that one could not tell whether there was any oil under that debris. On the left hand side signs of burning could be seen and he accepted that it could have been diesel burning. He agreed that he could not really tell anything one way or the other from photograph 46. Dr Taylor said that he did not know why he did not focus on the route of the oil in the first report.

As to the tap Dr Taylor agreed that in principle it was possible to damage a tap of this type so that in its damaged condition it would be susceptible to rotation induced by vibration and that given appropriate conditions the tap could have vibrated open. In the second (joint) report it was stated:

In our view the Piraeus tests are of no scientific value and did not fulfil Mr Cook's stated objectives. The Piraeus tests were markedly deficient, not least in the following respects: . . .

In evidence Dr Taylor accepted that he ought to have said that he was pointing out certain differences but it was not for him to say whether they were significant. Further he ought not to have used the word "deficient" but should have said "markedly different". Paragraph 3.17 (which was fractually inaccurate) should have been omitted because it dealt with vibration and Dr Taylor claimed no expertise in vibration. Dr Taylor conceded that he would not wish to contradict Dr Ward's conclusion that the tests undertaken at Piraeus satisfactorily simulated the transmission of vibration energy to the tap and that the range of frequencies used covered those that would be experienced in the vicinity of the auxiliary diesel engines on Ikarian Reefer. When giving evidence in relation to the tap Dr Taylor introduced as a principal consideration the force imposed by a head of liquid in the pipe on the ball valve. This represented a development in his thinking between the time when Mr Cook gave evidence and his own evidence. Dr Taylor put forward some brief calculations (which had not been set out in the joint reports and which had not been put to the plaintiffs' witnesses in cross-examination). Dr Taylor agreed that the tap might have had some wear in it. Dr Taylor referred to some tests that he had carried out in November, 1992 (but not at the request of the defendants). He accepted that no conclusions whatever could be drawn from these tests. As to whether the tap might have vibrated open under vibration he pointed out that in an ideal world it would be necessary to produce a tap showing the degree of fire damage that could be achieved during the period the generators were still running. Although in Dr Taylor's view it was extremely improbable that the tap rotated open in the fire he said that he could not totally exclude the possibility that the tap might have rotated open in the fire if the conditions were appropriate. Dr Taylor said that as a fire expert he always tried to establish the cause of a fire even if only to the extent of finding the source of the fuel, but not finding the means of ignition. Given exactly the same evidence (but with the tap closed) he would have found the evidence conflicting and returned an open verdict.

In the first report it was stated:

It is difficult . . . to envisage a route for oil leaking from the valve to a point of accidental ignition . . .

whereas the second report stated "ignition of oil leaking from the fuel tank valve is not inevitable". In evidence Dr Taylor accepted that if the valve fractured it was possible that oil would escape onto the generator. Dr Taylor was asked about the possibility that oil might have been ignited on the aft inboard generator. He said that the only way that oil could have got onto the generators and then ignited would have been on the exhaust manifolds of that generator. He (and Dr Bound) had any number of experiences of this sort of ignition taking place on generators. On the hypothesis that the valve fractured and some diesel oil got onto the generator there were parts of the generator which would have been hot enough to ignite the diesel. There were six exhaust outlets from the six cylinders of the generator. A length along each of these tubes of about an inch was uninsulated and in principle available as a hot spot. Diesel oil could be ignited if it came into contact with one or more of these hot spots. Without an inspection on site Dr Taylor could not be sure whether there had been any fire between the rocker covers on the generator. If oil had come from the fractured valve it might have gathered between the rocker covers and in a subsequent fire it might have burned. On the basis of the photographic material available it was very difficult to tell. In the conditions that obtained on Ikarian Reefer it was quite difficult to follow such a route of fire if one existed. Dr Taylor accepted that on the hypothesis that the valve fractured there was an explanation for burning diesel arriving in the saveall beneath the generator and this could account for the beginning of a fire.

Dr Taylor accepted that subject to the number of steps to which he referred the cigarette mechanism and the rag mechanism could produce a fire. As to the latter he added that he did not disagree with Mr Cook's description of the mechanism which would load a rag,

having been ignited on the manifold, to cause a fire in the saveall beneath. Because of the number of steps required he regarded this as possible but very unlikely.

As to fire fighting he said that if there was an absence of fire fighting this should be disregarded as a factor because he had come across an absence of fire fighting in cases where the casualty had been beyond question accidental.

Mr Kenneth Abel (consulting marine engineer and ship surveyor) gave evidence pursuant to a report dated Nov 6, 1992 in response to certain matters raised by Dr Ward as to the operation of the generator. The chief engineer said when interviewed:

. . . experience usual problems with blocked injectors on diesel generators. Fuel dirty 2/3 times each trip -- cleaned all injectors after leaving Hamburg [according to Mr Arditti] [and] some regular problems with generator fuel injectors because dirty [according to Mr Lowe].

E. THE FIRE. ANALYSIS, FINDINGS AND CONCLUSIONS

I set out below my analysis, findings and conclusions as to the fire under the following headings.

F. THE INSPECTION OF THE IKARIAN REEFER BY THE FIRE EXPERTS

In accordance with what I was told represents current practice in claims of this type, the defendants were afforded an opportunity to inspect Ikarian Reefer and to interview the crew. Mr Cook and Dr Bound inspected Ikarian Reefer on Apr 22 and 23, 1985. The open tap was found at about 15 00 on 23rd and the experts left Ikarian Reefer at about 19 55 on the same day. Mr Cook gave evidence but the defendants did not call Mr Bound as a witness although he had prepared two joint reports with Dr Taylor.

My findings and conclusions as to the inspection are as follows. Mr Cook regarded the inspection as a preliminary inspection. At the time of the inspection he had no information from the crew. I accept that he anticipated returning to the ship once he had spoken to the crew (but this was apparently not something that was discussed with Dr Bound). After the open tap had been found the experts jumped to one conclusion and did not consider other possibilities. The further investigation was confined to seeing whether the other physical evidence could be accounted for in terms of fire spread from the generator platform. In the course of that further investigation the fractured valve was found. There was not a rigorous scrutiny of the broken valve and the area surrounding it. Mr Cook (and I suspect Dr Bound) did not give due consideration at the time of the inspection to the possibility of the fracture of the valve being the initiating event. Mr Cook said he did not expressly apply his mind to the question -- how could the fire have caused a fracture to that valve? He had not seen this type of damage on a cast iron valve before. I am not prepared to accept that Dr Bound had any relevant previous experience either.

I am clear in my conclusion that the inspection of Ikarian Reefer, and in particular of the valve and the area immediately surrounding the valve, was materially inadequate. From the DOST diesel passed first through the valve. From the valve the drop line ran a very short distance inboard before turning down to pass through the floor plates of the top level platform, and then running back under the DOST, then forward to a vertical pillar or kingpost located between and slightly inboard of the forward and aft generator sets. The line passed down the outboard side of the pillar to a clamp which held the pipe in place against the pillar. Below the clamp, and about 2ft above the gratings, the tap had been connected to the drop line. The tap was found to be about 80 per cent open on the second day of the inspection. The source of fuel for the fire was diesel from the DOST. Given that the diesel passed first through the valve and given that the valve had

fractured, the fracture of the valve cried out for careful investigation. It was not sufficient to assume that the valve had fractured as a result of the fire, take a few photographs and pass on. It may be said that it is easy for me with the benefit of hindsight to be critical of the nature and extent of the inspection of the valve and the area immediately surrounding it, but the underwriters make very serious allegations in this case. They had an opportunity to carry out a full inspection. Many of the difficulties and uncertainties that gave rise to protracted conflicting expert evidence would have been avoided if the valve and the area surrounding it had been fully and carefully inspected. The tap was removed from Ikarian Reefer and equally the valve could have been removed from the vessel. It was not enough to see whether all the other physical evidence could be accounted for in terms of fire spread from the generator platform (an exercise which I find occupied the remaining time spent on Ikarian Reefer on the second and final day of the inspection). Had the valve and the area immediately surrounding it been carefully inspected it would have been far easier for the Court (with the assistance of the expert witnesses) to get to the truth of the matter. A full and careful inspection (including probably the removal of the value) would have thrown considerable further light on the competing mechanisms. Several of the expert witnesses referred to the uncertainties as to the valve, the pipework, the floor plates etc (see the summary of the expert evidence set out above). Captain Katakos' contemporary report to the owners stated:

. . . whilst I objected as to the cause of the fire and that they (the experts) must consider other causes, they insist on departure.

I consider that Captain Katakos was entitled to call upon the experts to consider other causes. Mr Cook regarded the inspection as a preliminary inspection and intended to return. It is very difficult to judge Dr Bound's approach to the matter as he did not give evidence. In my view however it is elementary that however compelling one piece of evidence may seem, an expert in Dr Bound's position should carry out a full and careful examination of other possible causes. I find that in relation to the valve and the area immediately surrounding it, there was a failure to do this.

G. ONLY ONE SEAT OF FIRE

I accept Mr Cook's evidence that the main area of fire damage was in the generator flat in way of the number 2 generator. The remaining fire damage in the engine room can be explained in terms of fire spread from that area. The seat of the fire was in the vicinity of the number 2 generator, but the evidence is inconclusive as to precisely where ignition first took place. I find that there was only one seat of fire.

H. THE OPEN TAP

Mr Cook's first report referred to some experimental work undertaken in April and September, 1987. The April tests, carried out in Piraeus, were designed to determine under what conditions, if any, a tap of the type found open on Ikarian Reefer might come open accidentally. The September tests, carried out at Cardington, were designed to monitor the effect of a diesel oil pool fire on duplex filter units of the type found on the auxiliary generators, and also on a tap of the same type as the tap which was found open.

The section in Dr Taylor's second (joint) report, which commented on the Piraeus Tests, was unsatisfactory in a number of respects. Instead of saying "The Piraeus Tests were markedly deficient, not least in the following respects:- . . ." Dr Taylor (as he accepted) ought to have said that he was pointing out certain differences, but it was not for him to say whether they were significant. He ought not to have used the word "deficient" but should have said "markedly different". Paragraph 3.17 (which was factually inaccurate) should have been omitted because it dealt with vibration and Dr Taylor claimed no

expertise in vibration.

The defendants in their closing submissions advanced a number of criticisms of the Piraeus vibration tests drawn largely from points that Mr Cook accepted in cross-examination. These included the following. Mr Cook was not present when the damage to the packing was produced. The extent of flame impingement was different in the case of the two taps. This particular series of tests was initially envisaged as a preliminary series. (One of the matters that Mr Cook wanted to examine in more detail was the manner in which the tap had been damaged and it was to that end that part of the Cardington Tests was devoted.) Mr Cook did not know whether the rig construction, the engine speeds and the frequencies of vibration were realistic. (In fact the vibration frequencies that were generated during the tests were in precisely the right sort of range for a working generator platform.) A number of movements back and forth had taken place at the handle before the tap vibrated open from the fully closed to the fully open position. The tap was tested cold. The nitrile rubber packing was not likely to be in exactly the same condition when it had been heated and subsequently allowed to cool as it would have been in when it had heated but had not yet cooled. Mr Cook did not know to what extent the brittleness would be the same. The test rig had no oil in the down pipe. Mr Cook did not attempt to measure the force that was required to open the tap.

Mr Cook emphasized that the most important factor was the extent of damage to the packing. The yardstick he used was the degree of damage to the packing and regardless of the type of flame that was used to produce it, the end result was in his view very similar. Dr Taylor pointed out:

. . . I know it is impossible to do this but what you should in an ideal world be trying to produce is a tap showing the degree of fire damage that could be achieved during the period the generators were still running.

In the course of his evidence Dr Taylor introduced as a principal consideration the force imposed by a head of liquid in the pipe on the ball valve of the tap. This represented a development in his thinking between the time when Mr Cook gave evidence and when he gave evidence. When Mr Cook was cross-examined he was asked:

. . . if there had been liquid in the pipe impacting on the ball valve, the head of liquid would have imposed a force -- it may be a small force -- on the ball valve which would create resistance to rotation.

Mr Cook's answer was "it is possible that that is the case". Dr Taylor's second report had referred to the fact that the vibration tests were conducted with the drop line empty (par 3.12). I am confident that Dr Ward had this point in mind when he prepared his second report.

The plaintiffs pointed to the fact that no tests were carried out at the instance of the defendants by way of answer to the Piraeus vibration tests. Dr Taylor referred to some tests that he carried out in November, 1992 (but not at the request of the defendants). He accepted that no conclusions whatever could be drawn from these tests which were relevant to the question whether the tap might have vibrated open.

My findings and conclusions are as follows:

1. It is likely that the tap prior to the casualty was subject to wear, particularly if it had been in use since 1968. The Piraeus vibration tests show that it is possible for a tap of the type in question to be damaged in such a manner as to render it susceptible to rotation induced by vibration. Mr Cook said that this was the only conclusion he had drawn from the Piraeus Tests. Dr Taylor recognized that a tap could be so damaged that it might vibrate open under appropriate conditions. Mr Corlett accepted that the Piraeus

Tests demonstrated that it was possible to damage a tap in such a way that under certain circumstances it would vibrate open.

2. I accept the conclusion to Dr Ward's second report that the tests undertaken at Piraeus satisfactorily simulated the transmission of vibration energy to the tap and that the range of frequencies used covered those that would be experienced in the vicinity of the auxiliary diesel engines on Ikarian Reefer (see in this connection the fax from MAN B & W dated 21.7.92). Dr Taylor, having recognised that certain parts of his second report went beyond his expertise, said that he would not wish to contradict Dr Ward's conclusion.

3. The plaintiffs accepted in their closing submissions that the Piraeus Tests did not prove that the tap probably vibrated open. It would be extremely difficult to reproduce the precise conditions that obtained on board Ikarian Reefer at the material time.

4. Mr Cook put the matter fairly when he said:

. . . the only conclusion that I can draw from (the Piraeus) Tests is that a partly fire-damaged (tap) of the type that was on board the vessel . . . can be subjected to rotational movement as a result of vibration induced at the sort of frequencies and at the sort of amplitudes that one would normally expect to find on a working generator platform . . . Clearly the relevance is this; that if there had been a pre-existing fire close to that tap prior to the major incident such that the tap would be damaged, then clearly there is a possibility that the tap could have vibrated open under the influence of the generators whilst the generators were still running . . . It seems to me that it does introduce a very . . . realistic possible alternative explanation for the tap being open, contrary to the initial view that I formed that there was no credible explanation for the tap being open.

5. To the extent that there is a conflict on this subject between the expert evidence on behalf of the plaintiffs and the defendants I prefer the evidence of Mr Cook and Dr Ward to that of Dr Taylor and Mr Corlett.

I should add one footnote as to the tap. Diesel for the lifeboat engine if needed could have been drawn from the tap. The second engineer is recorded as saying in the first interview:

I last checked if (tank and can) were full in Panama last Christmas. Took no additional can . . . I am confident nobody else picked up more diesel and put into port boat . . . To obtain diesel from (DOST) we draw from (the tap).

There was no evidence that any member of the crew drew fuel for the lifeboat engine on Apr 12.

I. WAS THE DAMAGE (a) TO THE TAP

(b) TO THE GENERATOR FLAT CONSISTENT WITH THE DEFENDANTS' CASE?

In his first report Mr Cook expressed the opinion that if the tap had been open from the outset (to fuel a fire deliberately started, as alleged by the defendants) he would have expected considerably more damage to the tap. When giving evidence Mr Cook said that the tap had not been subjected to the same sort of fire as was produced by a metre square pool of diesel in the Cardington Tests. When subjected to that sort of heating the valve packing of the test tap had completely disintegrated. The tap on Ikarian Reefer had been in the area of a severe fire but had not been subjected to the most intense fire. During the time that oil drained through the tap there would be a cooling effect but once the tank was empty it was inconceivable that there would be no further significant

fire in that area.

On the assumption of a deliberate fire, Mr Cook said that for the quantity of fuel coming from the DOST he would have expected a very much more intense and severe fire in the area around the generator, on the generator flat. The fire on the generator flat, although intense and localized at low level, had not been a fully developed fire (compare the fire at the forward starboard corner of the engineroom). Mr Cook said that if about three tonnes came out of the tap it was quite difficult to account for that quantity being deposited into the generator bilge. He accepted that some of it may have drained away over the saveall edge into the engineroom bilge, but it was still a very large quantity of oil to dispose of. From the manifestations of the fire damage it had not all been consumed. With the tap almost fully open, a large quantity of oil would have been deposited per minute in the bilge. Not all of that could have been consumed, given the fire evidence, at the same rate as it was being discharged into the generator bilge, over the area where there was clear evidence of fire damage. If all the oil came through the tap and was located in the generator bilge during the fire and burnt there, it was very difficult to account for the absence of more widespread damage in the generator flat. Mr Cook added that if a person started a fire deliberately immediately under the tap and then opened the tap 80 per cent, with the diesel below its flash point he would expect it to put the fire out.

If a deliberate fire was started in the manner alleged by the defendants, I find that for the reasons given by Mr Cook it is difficult to account for the limited nature and extent of the damage (a) to the tap (b) to the generator flat.

I will now consider the mechanism which the defendants' experts have (at different times) put forward in attempts to explain the fracture valve.

J. HEATING THE PIPE

By the addendum to the outline of the defendants' case on the cause of the fire dated Oct 9, 1992, the defendants recognized that the stresses likely to be set up in the valve by expansion of the pipework under heat would not, alone, be sufficient to cause a fracture of the valve. They submitted however that heating the pipe could contribute to failure of the valve. Professor Dover's evidence as to heating the pipe (and heating the valve, see below) was most unsatisfactory, inter alia for reasons referred to in the summary of his evidence at D above. I prefer the evidence of Dr Palmer and Dr Baker as to this mechanism. As Professor Dover eventually accepted at the end of cross-examination as to heating the pipe, this mechanism can be disregarded, both alone and in combination, as a cause of the fracture of the valve. As Dr Baker put it --

. . . heating the pipe has always been low, stays low in terms of stress and . . . I cannot see (this mechanism) either in combination or alone as providing a credible explanation . . . or contributor to the failure of the valve.

K. HEATING THE VALVE

In the outline of their case on the cause of the fire dated Oct 2, 1992 the defendants contended that:

. . . both of the . . . fire related thermal mechanisms (heating the valve and movement of the floor plates) provide entirely credible explanations of the failure of the DOST stop valve. That either one, or the other, or a combination of these two thermal mechanisms was the cause of the fracture of the valve is much, much more likely than the sequence of events proposed by the Plaintiffs. The Plaintiffs' case should therefore be rejected.

On Oct 19, 1992 (Day 48) Counsel for the defendants stated:

Professor Dover, as a result of his various experiments, inclines to the view that it is probably unlikely that heating the valve alone caused the fracture, but that the process of heating the valve is capable of producing very much greater stresses than the experts on the Plaintiffs' side were prepared to countenance . . .

On Oct 22, 1992 (Day 51) Counsel accepted on behalf of the defendants that the sentence in the outline of the defendants' case quoted above overstated the matter and reiterated what he had said on Day 48. Counsel for the defendants also accepted that in his first report, which introduced the heating the valve mechanism, Professor Dover put forward conclusions which were based, as Dr Baker had rightly pointed out, on a temperature difference of 300 deg and that that had proved to be an unsustainably high temperature difference. Counsel for the defendants also conceded that the case that had been put in cross-examination to Dr Walker as to the 20 per cent restraint was not a case which the defendants now pursued. On Nov 2, 1992 (Day 56) Counsel for the defendants referred to a passage in Professor Dover's fifth report dated Oct 27, 1992 (Day 53 of the trial) which read:

I do not believe heating of the valve, leading to thermal gradients, can be ruled out particularly for the moment when the oil runs out and transient conditions leading to higher temperatures all over the valve exist . . .

and stated that he was not sure that the Court could rule out heating the valve. He added that in any event the underwriters did not adduce a positive case as to the manner in which the valve fractured. After a short adjournment Counsel for the defendants stated that he was not seeking to run a positive case based upon what Professor Dover said in his fifth report about the transient conditions. He was not in a position to say or to agree that on the balance of probabilities it would not happen, but he would not be seeking to suggest that on the balance of probabilities it did happen. On the next day Dr Walker was recalled to give evidence. Dr Walker's fifth report was put in evidence by way of response to Professor Dover's fifth report. Counsel for the defendants referred to the 20 per cent figure that had been previously put to Dr Walker in cross-examination and very properly accepted that that was a wrong basis and that it was plain that what Dr Walker was saying about the gasket was entirely right. As to transient conditions Dr Walker said, when giving further evidence in chief, that the stresses were being driven by temperature gradients and that when there ceased to be relatively cold oil on the inside, temperature gradients would get lower rather than higher, so that the stresses would become insignificant. Dr Walker was not cross-examined as to this. On Nov 17, 1992 (Day 65) Counsel for the defendants stated that the production of a flow-chart prepared by Professor Dover did not alter any concession as to the inability of the defendants to prove on the balance of probabilities that the failure of the valve was caused by the heating the valve mechanism. A sixth report from Dr Walker dated Nov 17, 1992 commented on those parts of Professor Dover's seventh report and flowchart which referred to this mechanism. On Nov 19, 1992 (day 67) Counsel for the defendants said that he would not be able to suggest that there would be any reason for rejecting Dr Walker's evidence as to transient conditions, since he did not challenge it and that the Court could only reach one conclusion on the matter.

In their closing submissions on the technical evidence in relation to heating the valve the defendants stated "this mechanism is not pursued. Although it is clear that cast iron can be subject to cracking caused by internal temperature gradients, the defendants are not able to show that it would have done (so) in this case".

Professor Dover's evidence on this subject was most unsatisfactory, inter alia for the reasons referred to in the summary of his evidence at D above and for the reasons set out above. There are many further points which could be made in support of this conclusion. By way of example, as Counsel for the plaintiffs pointed out in his final

submissions on the fire, Professor Dover's fourth report was expressed in quite strong terms and was dismissive of the work of Dr Walker. However, at the end of the day Dr Walker's evidence was unchallenged. Counsel for the defendants conceded that Dr Walker gave his evidence most effectively and he was proved to be right. He was, as Counsel accepted, obviously a man of immense learning. Thus as a result of the impressive work and evidence of Dr Walker, I find that the fracture of the valve was not caused by the heating the valve mechanism. I pay tribute to Dr Walker who was cross-examined for over two days and had to be recalled to give further evidence. A calculation prepared by the defendants showed that about seven days of the trial were devoted to this mechanism.

(I regret that I have come to the further conclusion that it would be unsafe for me to rely upon any of Professor Dover's evidence as to any other issue in this case, where his evidence conflicts with that of Dr Walker; Dr Palmer or Dr Baker.)

L. MOVEMENT OF THE FLOOR PLATES

Dr Baker's principal objection to the movement of the floor plates mechanism was as follows. The fracture of the valve started on the aft side and then propagated forward (as shown in Mr Deegan's Figure 3). In order for a fracture to start on the aft side and go forward the valve had to be displaced relative to the tank in a forward direction, whereas the only evidence (in photograph F) indicated that the floor plates moved (if at all) forward to aft (ie in the wrong direction).

It is necessary to set out an account of the changes of position by the defendants' expert witnesses as to the movement of the floor plates mechanism. These changes of position caused me considerable concern.

Figure 3 to Mr Deegan's first report showed the probable initiation region of the fracture path on the aft side of the valve, with the probable final failure region on the forward side of the valve. In his second report Mr Deegan referred to his Figure 3 without qualifying the view expressed in his first report. In so far as Professor Dover considered the movement of the floor plates mechanism in his first report, he did not reach the conclusion that it caused the fracture of the valve. Although it is clear from Professor Dover's second report that he had considered Mr Deegan's first report, Professor Dover did not express a different view in his second report to that reflected in Mr Deegan's Figure 3. A passage in Professor Dover's third report can be read as indicating his agreement with Mr Deegan's Figure 3 (although Professor Dover said in evidence that he did not have a firm view as to which way the crack ran, but had been content to accept Mr Deegan's opinion as to the probable initiation region). In his third report Mr Corlett asserted that it could clearly be seen in photograph F that the forward floor plate on which the ladder landed had been pushed aft under the aft section of floor plate.

When commenting on Mr Deegan's first report Dr Palmer said:

The "possible initiation region" marked in Figure 3 is exactly where one would expect a fatigue crack to start from, a stress concentration in a thin section, a particularly probable site for a defect.

Dr Baker stated in his third report dated Sept 28, 1992:

In Figure 3 of Deegan 1 . . . the region where the crack runs out of the minimum cross-section is identified as the probable final failure region. If the fracture had been produced by mechanical loading caused by either vibration of the pipework or relative movement between the floor and the pipe, I would agree with Deegan and Dover that the crack region outside of the minimum cross-section could not be the site of fracture initiation . . . if the crack did run from side to side, as proposed by Dover, it must follow

from the arguments presented above that it initiated on the aft side of the valve and propagated to the forward side . . .

On days 48 and 51 Counsel made the statements as to the heating the valve mechanism referred to above. On day 52 Counsel for the defendants, in the course of cross-examining Dr Baker, stated:

. . . whilst Mr Deegan says that the probable initiation region shown in Figure 3 was his first thought, he would not wish (the Court) to think that he still regards that as a reliable conclusion. He . . . says that it is not possible on the basis of the photographic evidence alone to draw a conclusion as to which is the side of initiation.

On day 53 Counsel for the defendants stated:

. . . the only evidence indicates the floor plates moving from forward to aft. It is agreed that that direction would be inconsistent with the initiation of the fracture at the point shown in Figure 3 produced by Mr Deegan.

Professor Dover's fifth report dated Oct 27, 1992 (Day 53 of the trial) stated for the first time --

. . . due to problems in interpreting the photographs I cannot be sure of the location of the fracture initiation site.

On days 56 and 57 Counsel for the defendants made the further statements as to the heating the valve mechanism referred to above. Mr Corlett's fourth report dated Nov 2, 1992 (Day 56 of the trial) dealt inter alia with structural movements due to heat (movement due to the ladder and general movement of the platform on the main engine). As to the section entitled "general movement of the platform on the main engine" (racking with rectangles becoming parallelograms) Mr Corlett conceded in cross-examination that he only worked out this particular mechanism at the beginning of November. On day 57 Counsel for the defendants again confirmed that the only evidence indicated the floor plates moving from forward to aft. In his third report dated Nov 3, 1992 (Day 57) Mr Deegan stated for the first time in writing that the aft location of the fracture of the valve could be the end point of a fracture which started at the forward side by an overload mechanism. Mr Deegan added that the photographic evidence suggested that the movement of the floor plates mechanism probably operated by movement from forward to aft and concluded that if this interpretation of the photographic evidence was correct the valve probably fractured from forward to aft rather than aft to forward. On Monday Nov 16 1992 (Day 64 of the trial) Counsel for the defendants, in seeking leave to introduce Professor Dover's seventh report, stated that Professor Dover had pointed out to the defendants' legal advisers on the previous Friday that residual stress was relevant to the movement of the floor plates mechanism. Counsel said that since nobody on the defendants' side had hitherto realized that residual stress was of any significance in relation to the movement of the floor plates mechanism Professor Dover had been asked to provide a seventh report. In his seventh report Professor Dover said:

. . . compressive loading leading to residual stress on cooling and ultimately fracture, is applicable to the structural thermal distortion mechanism.

Professor Dover amplified his views as to residual stress in a subsequent document entitled "Residual Stress due to Compressive Yielding". (When giving evidence Professor Dover agreed that if any movement of the floor plates was from forward to aft and if Mr Deegan's Figure 3 was correct as to the probable initiation region, the movement of the floor plates mechanism would not work unless his residual stress theory was correct. He accepted that he had not put compressive loading leading to residual stress together

with the movement of the floor plates mechanism until his seventh report. It had not occurred to him that residual stress might account for a fracture aft to forward when in early October he saw Dr Baker's third report.) On days 65 and 67 Counsel for the defendants made the further statements as to the heating the valve mechanism referred to above.

It will be seen from the above that the attempts by the expert witnesses called by the defendants to explain the fracture of the valve were far from consistent. As the defendants' experts reluctantly abandoned the heating the valve mechanism they sought to overcome a fundamental inconsistency in the movement of the floor plates mechanism.

My findings and conclusions as to the movement of the floor plates mechanism are as follows:

1. As Dr Baker accepted, mechanical loading of the valve due to fire-induced distortion of the structure is theoretically possible in principle.

2. There is no evidence of any movement of the floor plates forward (see the statements by Counsel set out above and the defendants' closing submissions where it is asserted that the only evidence is of movement of the floor plates aft. Mr Corlett said that he was not aware of a mechanism to produce a movement from aft to forward; if he had been able to think of a sensible mechanism to produce such a movement he would have advanced it). It is difficult and unsafe to draw any firm conclusion from photograph F in the absence of a thorough examination of the area in question. It is possible that there was movement aft and/or athwartships

(but not forward).

3. The probable initiation region of the fracture of the valve was on the aft side as shown in Mr Deegan's Figure 3. I refer in this connection to the account of the changes of position by the defendants' expert witnesses as set out above. I find that Dr Baker's view as quoted above from his third report was justified for the reasons which he gave. As Professor Dover accepted if any movement was from forward to aft and if Mr Deegan's Figure 3 is correct as to the probable initiation region, the movement of the floor plates mechanism would not work unless his residual stress theory is correct (and as will be seen below I do not accept that theory). In his third report Professor Dover stated that:

. . . at 700oC . . . the required displacement (at the point of contact between the pipe and the floor) is only 1.6mm.

There are, I find, a number of factors to be taken into account. 700 deg C is too high. There was probably a gap between the pipe and the floor plates (see photograph C). When that gap had been closed it would be necessary for the pipe to be moved several millimetres because of the plastic deformation of the floor (at 600 deg C 2 Imm according to Professor Dover and 2.8mm according to Dr Baker) and because of the ductility of the valve.

5. As to residual stress it was not until day 64 that the defendants sought leave to introduce Professor Dover's seventh report as to the alleged significance of residual stress in relation to the movement of the floor plates mechanism. At no stage had Mr Deegan suggested the possible significance of residual stress in this connection. According to Professor Dover there would only be significant residual stresses if unloading occurred below 400 deg C. Professor Dover could not say that unloading would have occurred below 400 deg C because he did not have the necessary expertise. Accordingly he accepted that he was not able to express any view as to the likelihood of the residual stress theory because he did not know one of the essential factors. He had

not referred to this gap in the analysis in his seventh report (see further the summary of Professor Dover's evidence on this subject set out above). The defendants stated in their closing submissions "residual stress cannot be said to be a probable mechanism, although it might be". I prefer Dr Baker's evidence as to residual stress and in particular the following extract from his fifth report (as amended in the course of his evidence):

Professor Dover's evidence relating to his proposed residual stress model implies that the valve would be exposed to load-controlled loading in response to the fire-induced displacement of the floor plates, ie he assumes that the loading and resultant stresses in the valve would be maintained throughout the period of the fire. This is not correct. The displacement of the floor plates which is responsible for the proposed loading, as set out in Dover 3, would be dictated by the product of the thermal expansion coefficient a, the temperature difference T and the extent of the heated structure. Because the stiffness of the platform structure is likely to be greater than that of the pipe and the valve, the resulting displacement of the floor plates would be fixed during the period of high temperature exposure, ie the loading is predominantly displacement-controlled. Under these conditions, as described above, the loading on the valve must relax during the fire. At the end of the heating period, the valve would be stress relieved and it would be impossible for residual stresses to develop during the subsequent air cooling.

Accordingly I reject Professor Dover's residual stress theory.

6. Where there is a conflict between the expert evidence called by the plaintiffs and that called by the defendants on this subject I prefer the evidence of Dr Baker to that of Mr Deegan, Professor Dover and Mr Corlett. In particular I prefer Dr Baker's evidence on the matters referred to above and as to expansion of the ladder, racking and increased ductility of cast iron at high temperatures. I consider that Mr Corlett was prepared to deduce rather more from photograph F than was justified.

7. The changes of position by the defendants' expert witnesses as to this mechanism have caused me considerable concern.

8. The difficulties with this mechanism provide another illustration of why it was essential that the fire experts should conduct a thorough investigation of the area around the fractured valve.

9. On the material available to me I find that the movement of the floor plates mechanism is subject to a fundamental objection. There is no evidence of any movement aft to forward. If (as I find) any movement was from forward to aft and if, (as I find) Mr Deegan's Figure 3 shows the probable initiation region, the movement of the floor plates mechanism does not work (save for Professor Dover's residual stress theory, which I reject).

M. OTHER MECHANISMS OR COMBINATIONS

In the outline of the defendants' case on the cause of the fire it was stated:

. . . for completeness the Defendants' experts have considered in detail two mechanisms (heating the valve and movement of the floor plates) by which the valve might come to be fractured in the course of the fire . . . But there may be numerous other methods (or combinations of them) by which the valve might have come to be fractured in the course of the fire. The Defendants do not commit themselves to either or any particular mechanism.

I accept Dr Baker's evidence as to the four conditions that would have to be satisfied before it would be possible to add together the effect of two or more of the mechanisms heating the pipe, heating the valve and movement of the floor plates. The defendants'

closing submissions did not develop any detailed case as to combination of heating the pipe and/or heating the valve and/or movement of the floor plates. For the reasons given by Dr Baker in the course of his evidence I do not consider that a combination of any of these mechanisms explains the fracture of the valve.

In their final submissions the defendants stated that they could not rule out the possibility that the valve cracked because the salvors applied cold water to it. As it was not known whether the salvors did any firefighting the defendants "put it no higher than that". I regard this reference to cold water as a reflection of the difficulties the defendants faced in explaining the fracture of the valve. I have, no doubt whatsoever that if any other mechanism existed to explain the fracture of the valve the defendants' experts would have advanced it.

I will now consider the mechanisms advanced by the plaintiffs.

N. THE FATIGUE/VIBRATION MECHANISM

It is common ground that there are nine steps involved in this mechanism. I will consider each of the steps in turn.

STEP 1: The refloating attempts must create vibrations at (per the defendants precisely/about the resonant frequency of the pipe work attached to the DOST.

(a) Refloating Attempts

There are references to refloating attempts/ engine manoeuvres in the first and second (joint) interviews of the master:

Full astern immediately. Helm port and starboard personally . . . efforts to unground without result [-and-] Using engines ahead/ astern and with helm tried to free the vessel from ground . . . engine room responding, to telegraph. I operated telegraph . . . engine also responded. If ordered fast got fast . . . O to 60o after manoeuvring.

There are also references to refloating attempts/ engine manoeuvres in the first and second (joint) interviews of the chief engineer:

Manoeuvred for about 20 minutes and probably remained for a further 20 minutes. After grounding, manoeuvred with LFO for about 20 minutes astern and ahead . . . at one stage propeller racing to 130. This while vessel being worked ahead [-and-] Manoeuvring according to engine telegraph movements. Started with Full Ahead, but engine did not start. Close valve and then reopen fuel valve. On this occasion engine started to pick up slowly but not up to required revs of 100 or so. Only picked up to 50 or 40 rpm. Order to stop. 2 or 3 more orders for Ahead and then one Astern but I do not remember exactly. Never achieved normal revs -- never more than 60 . . . I was manoeuvring for about 20 minutes . . .

In addition there are references to refloating attempts/engine manoeuvres in the first ("(1)") and second (joint ("(2)")) interviews of the following members of the crew:

Second Officer ((2) -- no first interview);

AB Nginos ((2) -- no first interview);

Cadet ((1) and (2));

Apprentice Engineer ((1) and (2));

Cook ((2) no first interview);

Steward ((2) no first interview).

I accept the oral evidence of the master, the chief engineer and the second engineer as to the fact that there were refloating attempts/engine manoeuvres. I reject the submission on behalf of the defendants that there were no refloating attempts. There was confusion and panic following the grounding. Some members of the crew (eg chief officer who saw wash from the propeller had other tasks to perform (eg taking overside soundings and dealing with the boats).

It is not possible to be precise as to the detail of the refloating attempts/engine manoeuvres. The evidence indicates that there were a number of different manoeuvres ahead and astern. Some manoeuvres were missed. Engine manoeuvres lasted for about 20 minutes (although any estimation of time is particularly difficult). There was some fluctuation in the rpms that were achieved. The main engine was operating during the manoeuvres at about 60 rpm. No steady speed higher than about 60 rpm could be maintained.

(b) Vibration, Pounding and other observations of the crew

It is useful to refer to the contemporary accounts of the crew as to vibration, pounding etc.

The master is recorded as saying (1):

Listing 12-14o either side very quickly. I was frightened -- we might capsize . . . This happening suddenly . . . 3-4 minutes but flopping rapidly. Irregular but I think fire followed one flop . . . No pounding . . . Still flopping even after engine stopped . . . Flopping not a result of helm action or engine action . . . Still flopping from port to starboard when we alongside lifeboat.

and (2):

Vessel stopped . . . Vessel rolling. Lost my balance fwd. Feared we might capsize . . . Rolling thro' 12-15o either side. V. quick internal rolling. Had to hold on. Otherwise might fall. No pitching . . . Next ordered because of fear of rolling heavily that both lifeboats be lowered and brought to starboard side. I gave this order to Chief Officer. I feared vessel would capsize.

The chief officer is recorded as saying (1):

immediately vessel began to loll over very quickly from side to side thro' about 10o each side but very jerkily and quickly.

and (2):

Vessel stopped and began to roll quickly for 30 minutes or so. Less thereafter . . . Master told all crew to go to boats because vibrating and shuddering heavily.

The second officer is recorded as saying (2):

Vessel rolling from side to side. Seemed to be balanced on something. Some of movements slow. Others a quick trembling from side to side -- unpredictable. Not banging but vibrating. Swd up fwd. Lolling through an angle less slightly than roll in a rough sea. Never felt this motion before . . . When I was still aboard vessel I remember her lolling.

The chief engineer is recorded as saying (1):

Very heavy vibration. Got to hold on v abnormal motion -- shocks . . . Much heavy vibration while aground and moving on bottom . . . Vessel flopping from side to side . . . Vessel continued to loll over rapidly one way and then the other . . . Plenty of vibration

and (2):

There is some swell and pounding . . . During the rolling, vessel rolled to port and starboard rapidly 2-3o either side . . . During grounding, heard scraping revs decrease and then race . . . Vessel in dangerous position because vessel bumping1 from side to side after grounding. Necessary to hold on very much. Lifeboat swinging and banging at one stage. Sea condition slight with slight swell. Was very frightened and trembling with fear. Vessel banging on bottom and I feared capsize. I had to remain on board if that is what Master required but certainly did not wish to go in engine room . . . After grounding, I was manoeuvring for about 20 minutes. Don't remember any vibration during this manoeuvring.

The second engineer is recorded as saying (1):

Went at once to engine room because propeller thrashing out of water . . . everybody running with personal effects to lifeboats because vessel listing.

The third engineer is recorded as saying (2):

Vessel vibrating and while dressing felt a shock . . . Spoke to some people but everybody in a panic . . . Still some shocks on vessel, vessel stopped and thereafter no more "shocks" . . . Had some difficulty because vessel vibrating which totally unusual -- forward and aft movement. Had to hold on . . . Forward and aft movement but no rolling.

The cadet (Assimopoulos) is recorded as saying (1):

Big vibration on grounding . . . Immediately after grounding lolling over rapidly. Felt like an earthquake . . . As boat lowered into water vessel still rolling irregularly. Not continuously but jerkily.

and (2):

After grounding . . . went to my cabin to collect personal belongings -- difficult to walk at that time. Like an earthquake. Not rolling, stuck and vibrating heavily.

The oiler (Tsakiridis) is recorded as saying (1):

Vessel moving so badly had to hold on to walk round . . . Walked round engine room. Heard cracks as vessel moved. [Emphasis added.]

and (2):

While vessels aground all crew afraid because vessel shuddering and needed to hold on and we frightened she might capsize over on top of us.

The apprentice engineer (Vugiuklakis) is recorded as saying (1):

. . . a knock big one and then vibration . . . Vessel aground and with swell vessel was knocking to port and starboard . . . As ship knocking badly we . . . left engine room.

and (2): "Banging forward may be on bottom".

The AB (Nginos) is recorded as saying (2):

On final grounding can't remember if swd up forward or aft but began taking in the swell and bumping on bottom. Because of bumping I was frightened. Rolling through 5o either side and difficult to move around because of bumping. I was not in least surprised to hear Master say he thought a risk of vessel breaking up . . . I was not personally very frightened . . . until vessel started bumping . . . bumping still continuing but I not so frightened.

The deck boy (Maheridis) is recorded as saying (2):

Returned to middle and heard conversation that we might abandon because possibility of vessel breaking . . . Vessel moving up and down. Difficult to move because bumping, thought vessel would break in two. Collected our effects because heard vessel might break up. No question of vessel banging from side to side.

The cook is recorded as saying (2):

Looking after my wife remember vessel moving up and down and difficult to stand. Hitting bottom aft. Not rolling . . . Master came down and said that because vessel's motion of bumping so violently some risk of vessel breaking and therefore go to boats as would be necessary to abandon the ship. This was after 0000 . . . After grounding trimmed substantially by head and then after prop stopped regained even trim and then pounded aft.

The assistant cook is recorded as saying (2):

Vessel moving suddenly and then from side to side. Jerky and strong shuddering, gentle] rolling. Difficult to walk around vessel when this strong shuddering taking place.

The steward is recorded as saying (2):

Vessel rolling from side to side. At beginning aft pounding on bottom and began to roll when we had got back to even keel. Big rolling.

The AB (Panothiokas) is recorded as saying (2):

Ship was moving from side to side. Movements not slow but sudden and sharp.

The electrician is recorded as saying (2):

Vessel knocking aft . . . Vessel unsteady . . . As I understood it there was a fear that vessel might break or capsize. There was panic.

The first and second (joint) interviews were not altogether satisfactory in terms of translation, recording and verification. Further there are differences between the notes taken by Mr Lowe and those taken by Mr Arditti of the second (joint) interviews. For convenience I have generally referred above to Mr Lowe's notes. It is not always easy to determine the particular point of time which a crew member is referring to or to distinguish between vibration created by the refloating attempts, pounding shuddering of the vessel as it moved on the ground (not mechanical vibration) etc.

Having considered all the relevant evidence my findings and conclusions as to vibration, pounding and other observations of the crew are as follows:

1. I accept the evidence of Dr Ward (who I found to be the most highly qualified and reliable witness as to ship vibration) that the operation of the propeller in the grounded condition with the propeller only partly submerged, would set up exciting/periodic tilting moments in the propeller shaft at blade passage frequency (the shaft speed times the number of blades) and twice this. Such moments would be transmitted along the shaft to the engine room structure and would then excite resonant vibration in the DOST pipe in its second mode. Because of the difficulty of calculating the exciting forces and moments and then of calculating the effects of those on elements of the structure, such as the DOST pipe, it is not possible to state the resulting vibration amplitudes of the DOST pipe. However, I accept Dr Ward's evidence that it is possible that the refloating attempts created vibration at about the resonant frequency of the pipework attached to the DOST. One of the most impressive features of Ward's evidence was that he was careful to indicate when it was not possible to answer a question with any certainty. Save where otherwise indicated I prefer the evidence of Dr Ward and the other expert witnesses called by the plaintiffs to the evidence of Mr Corlett and the other expert witnesses called by the defendants on the subject of vibration.

2. The evidence of Dr Ward provides independent support for the oral evidence of the master and the chief engineer that the refloating attempts created vibrations. I accept this evidence of the master and the chief engineer. The master said in evidence that while operating the main engines the vibrations "were very, very strong". The chief engineer said in evidence:

. . . The vibration was stronger when we were moving astern . . . the vibration during the grounding was something I have not come across before . . . It was not the usual vibration you have with ships, this was impacts with shaking . . . I got very scared manoeuvring astern, so much so that I had to force myself to see it through and not to stop the engine and abandon the engine room . . .

The chief engineer added --

. . . the highest point of these vibrations was with the manoeuvring astern.

(In making the above finding as to the evidence of the chief engineer I bear in mind the answer he is recorded as having given as to vibration in the course of the second (joint) interviews. As to this the chief engineer said "it is not conceivable that I ever said that there was no vibration". This answer probably resulted from translation or other difficulties in relation to those interviews.)

3. I find that there was significant pounding. The factors relevant to pounding include the state of the tide, the particular swell conditions, the nature of the bottom and the position at which the ship was in contact with the bottom. I reject Mr Corlett's view that pounding was extremely unlikely. (I do not regard the position of certain objects in the photographs as inconsistent with pounding -- the photographs were taken after "salvors" had been on board).

(c) The natural frequencies of the pipework

The first mode of vibration obtained by Dr Palmer was at 5.91Hz. The second mode of vibration was at 8.59Hz. Dr Palmer said that he would expect these calculated frequencies to be within perhaps 2Hz of the measured frequency on the Ikarian Reefer. A number of factors were relevant (the dimensions of the pipe, how the pipe was supported, the material properties, etc). In his second report Dr Palmer stated under the heading "Boundary Conditions":

The clamp at B has been treated as pinned; this means that the pipe is fully constrained

against translation, and unconstrained against rotation. Any constraint against rotation increases the natural frequencies in the system, it will also induce increased bending stresses at the clamp. The true clamp condition is likely to be somewhere between pinned and fixed.

Dr Palmer said that the pipework on Ikarian Reefer was not very finely tuned so there was a resonance peak around the natural frequency If the system is less highly tuned, the response peak is lower but the peak is also broader so if you fall away from the natural frequency, the amplitude will be less. The pipework has one natural frequency but resonance does not only occur at that natural frequency. There is a band of excitation frequency over which resonance will occur. Dr Palmer said that he would expect that band to correspond to a band width of perhaps 2Hz, ie plus or minus one Hz. In addition I refer to the summary of Dr Palmer's evidence set out at D above. Dr Palmer was an extremely impressive witness and to the extent that there is any conflict between his evidence and that of the expert witnesses called by the defendants, I prefer the evidence of Dr Palmer.

The defendants submitted that the plaintiffs could not prove that any exciting vibration would exactly or nearly coincide with a natural frequency of the pipework. It might, possibly. But in all probability it would not. The defendants further submitted that if the rpm of the engine fluctuated, then the amplitudes of vibration proposed by the plaintiffs, even if they were possible, would not be uniformly sustained. Thus the number of stress cycles available to cause fatigue damage at the requisite level would be significantly fewer than the total number of possible vibration cycles.

The plaintiffs submitted that it was likely that there would have been a coincidence between the natural frequency of the pipework and the likely frequency of vibration. The natural frequency of the pipework could well have been coincident with the frequency of vibration induced by the propeller at twice blade rate. Thus a propeller excitation could readily have caused resonant vibration in the pipework. The plaintiffs further submitted that there would no doubt be some fluctuation of vibration, but Dr Palmer's work had shown that resonance will occur either side of the resonant frequencies. Thus resonance can occur even if there is some fluctuation. It follows (submitted the plaintiffs) that the fact that there was some fluctuation of rpm will not prevent the pipework from vibrating in resonance at about its natural frequency.

My findings and conclusions as to (c) are as follows. The refloating attempts created vibrations (see above). It is possible that the refloating attempts created vibrations at about the resonant frequency of the pipework attached to the DOST. Dr Ward's and Dr Palmer's evidence provides material support for the plaintiffs' case as to this step.

Step 2: The resulting vibration must be of an amplitude sufficiently large to impose a stress on the valve which is equivalent to the fatigue strength of the valve relative to the number of stress cycles caused by the refloating attempts.

The defendants' submissions as to this step were as follows:

(i) If the mean, best estimate fatigue strength of the valve is 100MPa over 20,000 cycles, failure in less than 20,000 cycles is at best a less than a 50 per cent chance.

(ii) It is also not likely that the fatigue strength of the valve in 20,000 cycles was less than 100MPa; and very unlikely that the fatigue strength of the valve in 20,000 was less than 80MPa.

(iii) It must be entirely speculative as to whether there was any corrosion or defect in the inlet neck of the valve; but it would be unlikely (to say the least) that this particular valve had a weakness of the right kind and in the right place (ie in the inlet neck), to

weaken it against this particular form of loading.

(iv) Attempts to argue from the fact that the valve was broken to the conclusion that the valve was unusually weak in fatigue strength are unjustifiable.

(v) There is no basis for attempting to assess the amplitudes of vibration needed to create failure stresses from the Palmer 1 and Baker 2 analyses. The most realistic working model (as both the pipework stress/FEA experts agreed) is Palmer 2 -- though it must be recognised that the "pinned at the clamp" assumption can only be a (close) approximation to the real condition. The defendants submitted that while these points are by no means decisive, they do affect substantially the probability of fatigue being the cause of the fracture of the valve.

The plaintiffs submitted that the amplitude of vibration which the propeller excitation would have caused at the pipework was unknown. It was to the credit of Dr Ward that he recognized that it was not possible to put numerical values upon the vibration amplitudes. As to attenuation the plaintiffs submitted that Dr Ward's evidence should be preferred to Mr Corlett's evidence. It is not the plaintiffs' case that there must have been an amplitude of as much as 159mm, which Dr Palmer described as "large but possible". Plaintiffs relied on the table below.

The plaintiffs submitted that the purpose of Table 3 was to present various different possibilities in recognition of the fact that Palmer 2 gave a large amplitude of 159mm for failure at 100 MPa. The plaintiffs did not accept the defendants' objection that Dr Baker was advancing a different case in Table 3 from that previously put forward based on failure at 100MPa at 20,000 cycles. The plaintiffs referred to a number of uncertainties and other matters including scatter, defects, the nature and extent of the stress concentration at the initiation site, the ultimate tensile strength, the fatigue strength, the stress concentration factor and the geometry of the valve.

My findings and conclusions as to this step are as follows:

***7*TABLE 3**

***4*VALVE FAILURE DUE TO VIBRATION**

***5*A. PIPE FIXED AT CLAMP (Dover 2) (Recalculated 28/10/92)**

Mode	Max Pipe Displ Node 63	Stress at Valve	'Elastic' stress at Clamp	Strain at Clamp (see Note)	'Elastic' stress 1st Bend	Strai at 1s Bend
	mm	MPa	MPa		MPa	
1	84.3	124.2	545	2.63E-03	306	1.48E-
1	68	100	439	2.12E-03	245	1.18E-
1	51	75	329	1.59E-03	190	9.18E-

*2*E = 207,000 Mpa

*3*PINNED AT CLAMP (Palmer 2)

Mode	Max Pipe	Stress at	'Elastic'	Strain at	'Elastic'	Stra at 1

	Displ Node 17 mm	Valve	stress at Clamp MPa	Clamp (see Note)	stress 1st Bend MPa	Bend
1	108	100	286	1.43E-03	343	1.71E-03
1	81	75	215	1.07E-03	257	1.28E-03
2	159	100	456	2.28E-03	310	1.55E-03
2	119	75	342	1.71E-03	233	1.16E-03

E = 200,000 Mpa

*Note

For mild steel having a 0.2% yield stress of 250 MPa the corresponding plastic yield strain is approximately 3 X 10-3.

1. I refer to my findings and conclusions in relation to Step 1 above. In particular I accept the evidence of Dr Ward that the operation of the propeller in the grounded condition with the propeller only partly submerged, would set up exciting/periodic tilting moments in the propeller shaft at blade passage frequency (the shaft speed times the number of blades) and twice this. Such moments would be transmitted along the shaft to the engineroom structure and would then excite resonant vibration in the DOST pipe in its second mode. Because of the difficulty in calculating the exciting forces and moments and then of calculating the effects of those on elements of the structure, such as the DOST pipe, it is not possible to state the resulting vibration amplitudes of the DOST pipe. It is possible that the refloating attempts created vibrations at about the resonant frequency of the pipework attached to the DOST.

2. As to attenuation I prefer the evidence of Dr Ward to that of Mr Corlett. In fairness to Mr Corlett it should be pointed that he said that although his assessment was slightly different to Dr Ward's, this was a question of degree and that he could not prove that Dr Ward was wrong in his opinion.

3. There are a large number of uncertainties as to the valve, the pipework etc (see the list set out in the summary of Professor Dover's evidence at D above).

4. The circumstances that obtained on the Ikarian Reefer during the refloating attempts were highly unusual and are particularly difficult to assess. The evidence of Drs Baker, Palmer and Ward provides material support for the plaintiffs' case as to this step.

Step 3: Vibration at (per the Defendants precisely/) about the resonant frequency must be sustained for a sufficiently long period of time for there to occur sufficient stress cycles, generating sufficient stress in the valve, to cause a fracture to initiate.

I refer to my findings and conclusions in relation to Step 2 above.

The defendants raised one further point for consideration, namely whether, in the event of vibration of the kind suggested by the plaintiffs, other parts of the pipework system would have failed first. The defendants submitted that under vibration of the kind suggested by the plaintiffs, the pipe would have buckled, leaving a permanent and visible set in the pipe. In addition the defendants' expert witnesses also considered the

likelihood of fatigue failure in the welds in the pipework, and in the pipework at the clamp. The defendants submitted that the butt weld between the weld neck flange and the pipe itself, the boiler feedline connection and the pipe at the clamp had shorter predicted fatigue lives than the valve, and that it was highly unlikely that the valve would have failed in fatigue before all of them.

The plaintiffs submitted that the defendants' whole analysis was somewhat artificial since it depended upon the assumption that Palmer 2 Mode 2 represented the real situation. The pipe was not fully pinned (although this was one of the assumptions upon which Palmer 2 was based). The analysis was largely irrelevant because, submitted the plaintiffs, it is likely that the failure stress was less than 100MPa and that the maximum pipe displacement was less than 159mm. The plaintiffs referred to Table 3 above. The plaintiffs further referred to the likelihood of a defect in the cast iron and to the fact that the valve failed at a site of stress concentration, ie the toe of the fillet.

My findings and conclusions as to this step are as follows:

1. It is necessary to refer again to the uncertainties as to the valve, the pipework etc Professor Dover listed some of these as follows: The geometry of the valve; the strength of the cast iron; whether the valve was subject to any defects; the fracture initiation site; the fracture surface; the strength of the pipe; the quality of the welds in the pipework; the strength of the other components in the pipeline; the fixity of the clamp (somewhere between pinned and fixed); the resonant frequency of the pipework; the magnification factor; whether damage had occurred to any other components in the pipeline; the flexibility of the tank; the definitions of loading and the heat transfer coefficient. It emerged for the first time in the course of cross-examination of Mr Corlett (Day 61) that an enlargement of photograph N showed that the clamp on the boiler feed pipe had come away.

2. I prefer the evidence of Dr Baker to the evidence of the experts called by the defendants. In particular I accept Dr Baker's evidence as follows. Dr Baker referred to Table 3 above and stated that the displacements shown could have caused the valve to fail without a fracture of the pipework at the butt weld or elsewhere. It was possible that a fatigue failure could have occurred elsewhere before it occurred at the valve, but if regard was had to Table 3 and to scatter, a fatigue failure could have occurred in the valve without the steel pipe failing in fatigue.

Step 4: The crack must propagate to a sufficient extent at the moment when the refloating attempts come to an end.

Step 5: Thereafter the vibration caused by the generators alternatively shock-loading caused by pounding, must be sufficient to cause the crack to propagate to failure.

It is convenient to consider Steps 4 and 5 together.

(a) Generator induced vibration

The defendants submitted that it is more unlikely that the vibration of the pipe induced by the ordinary operation of the generators would be greater than 2mm but even if vibration of 5mm amplitude had been set up in the pipe by the operation of the generators, still the (presumed) crack in the valve would not propagate to failure, or at all. The defendants further submitted that the fact that the fatigue/ vibration mechanism, so far as it relied on ordinary operation of the generators to propagate the crack to failure, was unsustainable, was demonstrated by the introduction by the plaintiffs at a very late stage of faulty operation of the generators and pounding as possible means whereby completion of the crack might have occurred.

The plaintiffs submitted that the true position was stated by Dr Ward when he said:

. . . there would be some excitation from the generators but . . . I am not sure what (the subsequent stress) would be (and I am not sure) whether or not that stress would propagate the crack.

The principles of the Paris law were not in dispute. It was Dr Palmer who introduced the Paris law into the case. As was put to Dr Palmer in cross-examination, any calculation based on the Paris law would be a somewhat speculative exercise. In these circumstances the plaintiffs submitted that the quantitative conclusions contained in the defendants' submissions were not justified.

I find that the position was fairly and accurately stated by Dr Ward when he said that if the possibility of a faulty fuel injection was excluded there would be some excitation from the generators but he was not sure what the subsequent stress would be and whether or not that stress would propagate a crack. The exciting force and the damping properties of the final element of the piping were unknown factors. There would be stresses set up in the pipe due to the excitation of the generators but Dr Ward did not know what value they would have and hence whether there would be any crack propagation. There would be a noticeable increase in vibration from the engine with a faulty fuel injector.

(b) Faulty generator operation

The defendants submitted that even in the extremely unlikely event of a misfiring generator, it is still highly unlikely that there would have been sufficient vibration in the pipe to cause failure.

The plaintiffs referred to the statement in Dr Ward's third report that a faulty fuel injector would excite resonant vibration in the DOST pipe in its first mode. The plaintiffs accepted that there was no direct evidence of a faulty generator but referred to the problems that had been encountered with the generators from time to time. Thus, submitted the plaintiffs, rough running of a generator was a possible cause of resonant vibration of the pipework and it could have been sufficient to cause the crack to propagate to failure.

In their letter dated Oct 15, 1992 MAN B & W Diesel AG stated:

Sudden malfunction of one or more fuel valves will cause misfiring of the respective cylinders. An unbalance of rotational forces (leads), consequently, to more or less severe vibrations of the complete plant.

Mr Corlett agreed with the general propositions set out in Man's letter.

I find that the position was fairly and accurately stated by Dr Ward when he said that there would be a noticeable increase in vibration from the engine with a faulty fuel injector. There is no evidence of a faulty fuel injector before the grounding. There is evidence that problems had been encountered with the generators from time to time. The chief engineer is recorded as saying in the first interview:

No problems with purifiers on voyage. No problems with generators on voyage. Some regular problems with generator fuel injectors because dirty.

The chief engineer is recorded as saying in the second (joint) interview:

Experienced usual problems with blocked injectors on diesel generators. Fuel dirty, two to three times each trip. Cleaned all injectors after leaving Hamburg.

Although the chief engineer did not notice anything wrong with the way the generators were operating as he said his mind was on other matters --

I got very scared when I was manoeuvring astern, so much so that I had to force myself to see it through and not stop the engine and abandon engine room myself . . . there was so much vibration that I myself nearly abandoned the engine room and left.

It is clear from oiler Tsakaridis' account as recorded in the interviews that his visit to the engine room was brief.

(c) Pounding

The defendants submitted that this theory, even on the plaintiffs' case, remained an interesting speculation the probability of which could not be measured. The defendants referred to the fact that Dr Ward did not suggest there would be any source of vibration other than the generators which would be sufficient to finish off the crack.

In their response to the outline of the defendants' case on the cause of the fire the plaintiffs had stated:

The Plaintiffs do not suggest that vibration caused by the rolling and pounding of the vessel would have been likely to be responsible for the original initiation and propagation of the fracture but they could have been sufficient to cause the ultimate failure.

Mr Fyans' evidence as to pounding was not foreshadowed in any of his reports. The defendants submitted that the evidence showed that the rolling and pounding of the vessel had substantially died away by the time the fire broke out. The defendants further submitted that the evidence of Mr Corlett that pounding due to roll was exceptionally unlikely and that pounding due to heave was very unlikely, should be preferred to the evidence of Mr Fyans.

The plaintiffs confirmed that they did not rely upon the evidence of Dr Ward in this context. Pounding was not relied upon by the plaintiffs to provide a continued source of vibration of the pipework but they submitted that a single load application was sufficient to break the valve which had been partly cracked as a result of the earlier engine manoeuvres. The plaintiffs accepted that Mr Fyans did not make a quantitative assessment but the facts were not available to enable him to do so. The plaintiffs referred to the evidence of Mr Corlett that if there was pounding of a sufficient severity to cause significant impact on the bottom of the ship, the impact could readily be transmitted up a vertical pillar, along the longitudinal which supported the cantilevers which in turn supported the DOST. Such a shock would impart a vertical force on the tank which would be transmitted through to the valve.

I refer to the summary of Mr Fyans' and Mr Corlett's evidence as to pounding at D above and also to my findings as to pounding set out above. I do not accept the defendants' submission that the pounding of the vessel had substantially died away by the time the fire broke out. It was unsatisfactory that Mr Fyans' oral evidence as to pounding on Day 59 was not foreshadowed in any of his reports. As Mr Corlett commented in the course of one of his answers pounding is a very difficult phenomenon to analyse in detail. As the tide rises the risk of pounding increases. Although Mr Fyans' evidence was only of limited assistance as to pounding, I felt that Mr Corlett was inclined to understate the likelihood and significance of pounding.

My overall findings and conclusions as to Steps 4 and 5 are as follows. It is possible that faulty generator operation or pounding might have caused a crack to propagate to failure. There was no direct evidence of the former but problems had been encountered

with the generators from time to time and only minimum work was being carried out on Apr 12. There was significant pounding but this is a very difficult phenomenon to analyse in detail. It is to be noted that Mr Tsakiridis is recorded as saying "Hear cracks as vessel moved" (emphasis added) when he was in the engine room (see the first interview).

Step 6: Oil escaping from the fractured valve must within 15 minutes or so find its way to a point of ignition.

Step 7: Burning oil must fill from the point of ignition into the saveall or bilge under the aft inboard generator.

It is convenient to consider Steps 6 and 7 together.

(a) Points of ignition and the probability of ignition

The defendants referred to Dr Taylor's evidence that it was a "pretty neat shot" if the oil landed on one of the six small "hot spots" of exposed exhaust piping and his acceptance that such a flow of oil was "conceivable". The defendants submitted that the highest that one could assess the probability of this neat shot having occurred was "highly unlikely".

The plaintiffs relied on Mr Cook's evidence that it was almost inevitable that any significant amount of diesel leaking onto the generator would find an ignition source on the exhaust system. This was because the temperature of the exhaust system would be very considerably in excess of the auto-ignition temperature of diesel. Mr Cook said that exhaust systems were a very common source of ignition where diesel oil leaked from a generator or a fuel supply system. With that combination, it was almost impossible not to get ignition. Mr Cook added that if there was a fracture in way of the valve, the prospects of diesel oil getting onto the exhaust manifold were quite high.

I prefer the evidence of Mr Cook to the evidence of Mr Taylor. It is significant that Mr Taylor said that he (and Dr Bound) had any number of experiences of this sort of ignition taking place on generators.

(b) The physical evidence

The defendants submitted that there was no physical evidence to support the plaintiffs' theory of ignition. The absence of any traces of oil burning on the generators made this theory substantially less likely. The defendants further submitted that an even more substantial objection was the complete absence of any signs of a major outflow of oil from the broken valve. The defendants also submitted that there was no trace of any fire in the vicinity of the fractured valve.

The plaintiffs submitted that if diesel ignited on the generator it would fall into the saveall and cause a fire there. In so far as there was diesel in the saveall from the valve, it would have ignited. Thus it was submitted that once oil ignited on the generator the fire could readily be accounted for. The plaintiffs further submitted that there would not be a fire, let alone a sustained fire on the top of the generator, as for example in way of the rocker boxes. Burning oil would simply fall into the saveall. The answer to the question "where did the oil go?" was that part of the oil went into the saveall and part into the main engine bilge. The plaintiffs further submitted that if all the oil came from the rep, it was striking how little damage there was in the vicinity of the generator (see I above). The plaintiffs accepted that neither Dr Bound nor Mr Cook formed the view that fire damage could be seen at the valve. However the plaintiffs submitted that the inspection of the valve was not very thorough since it was a preliminary inspection and that by the time it was made the fire experts had jumped to the conclusion that the cause of the fire was the open tap. The plaintiffs further submitted that Dr Taylor's initial assessment of the situation was based on a misapprehension of the true position. In his

first report he said that if oil had been leaking from the outset the valve would have been one of the very first areas to be involved in the fire. He plainly envisaged an "early fire". Mr Cook pointed out in his supplementary report that that view ignored the fundamental fact that the diesel oil would be well below the fire or flash point. Dr Taylor had now accepted that. The plaintiffs further submitted that Dr Taylor ultimately accepted that the photographs of the tank were not inconsistent with flame impingement. It followed that Dr Taylor's evidence did not lead to the conclusion that there could not have been a fracture before the fire. If there had been a fracture before the fire, the plaintiffs submitted that it was quite likely that there would have been no fire in the vicinity of the fractured valve because all the oil apart from a film would have escaped, or if there was a fire it would not have caused significant damage and if it did any damage was masked by debris and later sooting.

Mr Cook was cross-examined at length on this subject. In the course of his evidence he gave a number of answers which call for careful analysis. Three matters must be borne in mind when considering Mr Cook's evidence. First, that he did not give due consideration at the time of his inspection to the possibility of the fracture of the valve being the initiating event. Thus when asked about the fatigue/vibration mechanism (a possibility which he did not consider let alone investigate) he was, I felt, inclined to make statements that reflected his dilemma ("if this was a realistic possibility why didn't you investigate it") rather than saying "I regret that I did not investigate this possibility". Second, Mr Cook was at times, in company with other experts, inclined to weigh probabilities beyond his area of expertise. Third, it is important to have regard to his evidence when read as a whole.

On day 40 Mr Cook said:

There (are) a number of complicated steps (in the fatigue/vibration mechanism) . . . and they have to operate within a particular time scale. To that extent, the mechanism is less rather than more likely, unless it can be shown . . . that . . . the valve could not have broken during the fire or as a result of it, -- then I would regard (the fatigue/vibration mechanism) . . . although very unlikely as being the most probable . . . I have examined (the physical evidence) in some considerable detail, and I do not find the physical evidence inconsistent, in terms of the fire structure, with that mechanism. The mechanism nonetheless remains very unlikely.

On Day 42 Mr Cook said:

I would certainly consider that (the patterns of damage) are more consistent (with the tap having been the source of fuel for the fire). I do not consider that the burning patterns are inconsistent with the (fatigue/ vibration mechanism) . . . I think it is more likely (that the fire fuelled by the tap than from the broken valve) . . . I do not think that the fire evidence is inconsistent, however, with the other mechanism . . . (at the time of my inspection) I did not give due consideration . . . to the possibility of the fracture at the valve being the initiating event.

On Day 42 Mr Cook also said:

It is likely that there would have been some further signs of damage than there are (if the fatigue/vibration mechanism is correct).

On day 44 Mr Cook gave the answer quoted in the summary of his evidence at D above which includes the statement:

. . . the order of probability would change if there was no satisfactory mechanism by means of which the broken valve at the tank could be accounted for.

In re-examination on Day 44 Mr Cook said that there was nothing that he saw in the vicinity of the tank, the valve or the saveall which was inconsistent with the fatigue/vibration mechanism. He was asked:

. . . in your opinion is there anything in the damage that you have seen which is inconsistent with such a mechanism?

His answer was as follows:-

No. I expressed the view during cross-examination that if there had been a very large amount burning on the engine, I would have expected to have seen more localized damage. But I do not find the damage to this engine inconsistent with the mechanism that I have suggested . . . for two reasons. Firstly, the parts of the engine that we are concerned with . . . are subjected, as a matter of norm, to very high temperatures. It would only be a persistent fire in that area for quite a few minutes that is likely to have caused damage to the lower melting point material such as the rocker valve covers and possibly the temperature gauges. But under these sort of circumstances I think the fire is likely to have been rather more transient than that and I would not necessarily expect to find evidence of a sustained fire on the generator itself. Secondly . . . it is quite frequently the case, that the after effects of a subsequent . . . or major fire, may well disguise or mask any minor effects that may have been evident.

I have carefully considered whether I should rule out the fatigue/vibration mechanism in the light of Mr Cook's and Dr Taylor's analysis of the physical evidence. I find, however that the physical evidence is not inconsistent with the fatigue/vibration mechanism for the following reasons:

1. I refer to my findings set out at F above as to the nature of the inspection carried out by Mr Cook and Dr Bound. Once the open tap had been discovered the further investigation was to see whether the other physical evidence could be accounted for in terms of fire spread from that area. A rigorous scrutiny of the broken valve and the area surrounding it was not carried out. Mr Cook did not give due consideration at the time of the inspection to the possibility of the fracture of the valve being the initiating event. He did not at the time of the inspection consider the possibility of diesel oil escaping from the valve and finding its way to hot areas of the exhaust system of the aft inboard generator and becoming ignited in that way. Thus the fire experts did not carry out any inspection on the ship with a view to establishing whether or not the physical evidence was consistent with the fatigue/vibration mechanism. An examination of photographs many years later is no substitute for a thorough on site inspection. Further Mr Cook when giving evidence was in the difficult position that he had not considered this mechanism at the time of the inspection.

2. As Mr Cook pointed out shipboard fires, particularly engine room fires, often progress unchecked and disguise the earlier events that have occurred. It is sometimes difficult to interpret all of the evidence in a badly damaged engine room. Mr Cook also referred to the difficulties caused by considerable heating, accumulation of debris, obscuration as a result of smoke deposition or more severe damage and masking by subsequent effects of fire. As Mr Cook put it --

. . . the sort of damage which occurs subsequently during a fire can well mask the sort of effects that we have been looking for.

3. If a deliberate fire was started as alleged by the defendants it is difficult to account for the limited nature and extent of the damage to the tap and to the generator flat (see I above).

4. In Dr Taylor's first (joint) report only two matters were relied upon in support of the

contention that --

. . . it is extremely unlikely that the valve fractured before the fire.

In evidence Dr Taylor accepted that the second was a neutral factor. He also accepted that the first:

. . . soot generally on the front face of the DOST in places adhering to paint which is itself still adhering to the tank

may have been premised on a rather larger fire in the saveall than was now being envisaged. Because of debris it was not possible to tell by looking at the area of the saveall whether there had been a fire. Thus the reasoning put forward in the first report in support of the contention that it is extremely unlikely that the valve fractured before the fire was confined to the tank wall. Dr Taylor subsequently put forward additional reasons in support of his contention that it is extremely unlikely that the valve fractured before the fire. If these were compelling reasons it is surprising that they were not included in the first report.

5. As to the area immediately surrounding the valve there is a considerable amount of debris shown in the photographs. Because of debris it is not possible to tell by looking at the area of the saveall whether there had been a fire. Thus Dr Taylor confined his reasoning to the tank wall. There was a discontinuity in the saveall at about the valve so that much of the oil from the broke valve would flow down the hole under the valve. It is a matter of speculation what if any oil would remain in the vicinity of the valve. There would only be significant damage to the side of the DOST if a significant pool of oil developed and caught fire in this vicinity. Dr Taylor agreed that photograph L was not inconsistent with the possibility of some flame impingement in the area of the tank wall. He could not say that there was not a little flame impingement looking at photograph C. If there were only thin films of oil then there would only be small flames in that area. Mr Cook's answer in cross-examination that it is very much more likely that some damage caused by burning oil would have been found in the area of the broken valve, if the fire had been caused by the fatigue/vibration mechanism, must be read in the light of his other evidence on this subject. Mr Cook said that he could not expect to find a substantial amount of fuel collecting in the tank saveall which was discontinuous immediately underneath the valve. Liquid will find its own level. Any liquid escaping from the tank at a temperature below the fire point would not necessarily burn. It was in Mr Cook's view marginal whether the tank contents could have been heated sufficiently, certainly in the first half an hour after the fire, to have attained the flash point. The cooling effect of cool oil being added from the purifier had to be taken into account. By the same token there would be some heated oil returned to the tank. Any oil flowing from the valve would disappear very quickly. Only residual oil would be affected by the fierce fire beneath. Thin films of oil would be raised to their fire point and quite probably to the auto-ignition temperature but thin films of oil would not support very large flames. Mr Cook said he would not expect to see burning of that type around the valve. Further for completeness it should be noted that the aluminium handle of the drain tap to the aft of the valve had melted.

6. As to the staircase shown in Mr Cook's photographs 46 and 50 Dr Taylor agreed that there was a certain amount of burning near the support at the side of the ladder/staircase and that there were very distinctive individual streaks at the bottom of the staircase which suggested that something had run down vertically in a liquid form. Mr Cook said that if there had been evidence of fire burning on the ladder at an early stage, that could well have been masked by the subsequent effects of the fire.

7. As to the generator Dr Taylor said that he could not be sure without an inspection on site, whether there had been any fire between the rocker covers. Dr Taylor agreed with

Mr Cook that it would be difficult in the conditions in which the fire experts were working on the ship with torches in darkness given the damage and debris etc, to follow such a route of diesel if it existed. Dr Taylor said there was no evidence in the photographs of liquid having run down the generator but he could not say categorically that it didn't. The photographic evidence did not provide any direct support for this mechanism but "I wouldn't have said it was one way or the other really". I have referred to Mr Cook's evidence as to this above. He said that the parts of the engine are subject to very high temperatures. Only persistent fire would cause damage to the lower melting point material such as the rocker valve covers and possibly the temperature gauges. Under the circumstances contemplated by this mechanism Mr Cook thought the fire on the generator is likely to have been transient and he would not necessarily expect to find evidence of a sustained fire on the generator itself. In any event the after effects of a subsequent fire frequently disguise or mask any minor effects that may have been evident.

8. Mr Cook's photograph 46 shows the floor plates in way of the aft inboard generator. There is a great deal of debris on the floor plates shown in photograph 46 which had been walked over by many feet and Dr Taylor agreed that one could not tell whether there was any oil under that debris. On the left hand side of the photograph signs of burning can be seen and Dr Taylor accepted that this could have been diesel burning. He agreed that he could not really tell anything one way or the other from photograph 46. Mr Cook said that the most probable explanation of the damage in photograph 46 was that it was oil that had spilled from the saveall but if oil from above had fallen in that area that might well have been masked. The most likely explanation was that the fire damage to that area was consistent with the general damage that had been caused along that area on the bottom platform. Despite this evidence from Mr Cook I consider that the appropriate conclusion is that photograph 46 is neutral (as accepted by Dr Taylor).

9. I do not consider it would be safe to draw any conclusions from the time scale of the spread of the fire.

Finally I reiterate that Dr Bound was not called as a witness; nor have I seen the notes he made at the time of the joint inspection.

Step 8: The burning oil must create a fire in the saveall fuelled either by oil pouring into the saveall from above, or by oil or other materials already in the saveall.

I accept the plaintiffs' submission that the vessel's movements would determine how much of the oil went into the main engine bilge and how much into the saveall. Dr Taylor pointed out that the oil would have to fall down from the area where it was burning without losing its heat and without being quenched and arrive down in the saveall still flaming. He agreed that you would not need very much oil "and this we know from history, it has happened". There have been a large number of fires which have started as a result of oil of one kind or another coming into contact with hot spots on generators.

Step 9: The fire in the saveall must damage the packing of the tap in such a way as to destroy its resistance to rotation, and allow it to vibrate open under the influence of the generators.

This is considered at H above.

Conclusion

My conclusion as to the fatigue vibration/mechanism is set out at P below.

O. THE CIGARETTE MECHANISM AND THE RAG MECHANISM

The cigarette mechanism involves the following steps.

Step 1: Mr Tsakiridis (per the plaintiffs: a 60/80-a-day man) must have been smoking a cigarette in the engineroom.

Step 2: (Per the plaintiffs: Mr Tsakiridis, who went to have a general look around the engineroom as well as to start the DO purifiers (which are at bottom level), must drop his cigarette through the grilles or the generator platform into the saveall beneath the generator.) (Per the defendants: Mr Tsakiridis, who went into the engineroom to start the DO purifiers (which are at bottom level) must throw his cigarette through the grilles of the generator platform, into the saveall beneath the generators. This involves an accurate throw either on coming down the ladder or when passing the steps which lead from the walkway to the grille above the saveall.)

Step 3: The cigarette must land (per the defendants directly) on a piece of discarded rag or cotton waste (also in the saveall).

Step 4: There must also be a pool of oil in the saveall.

Steps 5 and 6 (per the plaintiffs: The cotton rag must not be completely soaked in oil and lying in the pool of oil). (Per the defendants: the cotton rag must not be completely soaked in oil. The part on which the cigarette lands must be sufficiently dry to smoulder and burst into flames when in contact with a burning cigarette end. Another part of the rag must be soaked in oil, and lying in the pool of oil).

Step 7: (per the plaintiffs: The (dry) part of the rag on which the cigarette lands must smoulder and then inflame (after Mr Tsakiridis has left the engineroom or, alternatively is in the early stages of ignition when Mr Tsakiridis hurriedly leaves the engineroom)). (Per the defendants: The cigarette must cause the dry part of the rag to smoulder and burst into flames (after Mr Tsakiridis has left the engineroom)).

Step 8: The burning part of the rag must ignite the oil-soaked part of the rag, which (per the plaintiffs: would then draw diesel from the surrounding pool) (per the defendants: could then draw diesel from the surrounding pool, so as to burn long enough to heat the surrounding oil). After some time the (per the defendants immediately) surrounding diesel will burst into flame, and fire will develop progressively throughout the remainder of the pool creating a fire in the saveall.

Steps 9 to 11: (per the plaintiffs: The fire in the saveall must damage the paaa of the tap in such a way as to destroy the tap's resistance to rotation and allow it to vibrate open under the influence of the generators). (Per the defendants: The fire in the saveall must not be so intense so as to completely envelop the tap (or else the aluminium handle will melt), but must damage the packing of the tap in such a way as to allow it to vibrate open. The fire must destroy the resistance to rotation of the tap. The tap must vibrate 80 per cent open under the influence of forced generator vibration).

As to the rag mechanism Mr Cook said in his supplementary report dated Sept 28, 1992:

If rags or cotton waste had been left on the valve covers on top of the number two generator they could have become dislodged during the grounding and attempted refloating of the vessel and could have fallen onto the engine exhaust manifold. Although not an inevitable consequence, eventual ignition of that material would be possible, and if ignition did occur, burning material would almost certainly fall into the generator bilge. For this to result in the sort of fire that had clearly taken place on the Ikarian Reefer then, just as in the case of carelessly discarded smoking materials, there would have to have been a substantial amount of oil already present in the generator saveall. It is

possible that oil could have accumulated in the generator bilge over a period of time as a result of leaks and spillages. One potential source of such a leak would be the spill return lines which incorporated sections of flexible tubing held in place with jubilee clips and twisted wire.

The rag mechanism involves steps 9-11 of the cigarette mechanism so as to account for the open tap. This is considered at H above.

Both the cigarette and the rag mechanisms provide possible innocent explanations for the fire if the valve fractured in the course of the fire.

As to the cigarette mechanism the plaintiffs submitted that it was not a tenable objection to rely on Mr Tsakaridis's evidence that he was not smoking unless his evidence that he did not open the tap is also accepted.

Mr Cook said that he had investigated a very large number of shipboard fires, including a number for which cigarette ignition of cotton waste had been demonstrably a most probable cause. Once the open tap could be accounted for he described the cigarette mechanism as a viable, plausible explanation for ignition. Once the first step was achieved he regarded each of the remaining steps as being quite possible. Mr Cook said that in his view the finding of the cotton waste was consistent with the cigarette mechanism and not inconsistent with the rag mechanism.

Dr Taylor said that leaving the tap on one side subject to the necessary steps, the cigarette and rag mechanisms could produce a fire.

As to the rag mechanism the second engineer referred to a fire which broke out on the No 1 generator during a passage from Cuba to East Germany. A rag or piece of waste ignited from sparks from the exhaust escaping from an exhaust indicator cock which had vibrated open. See also the evidence of the Chief Engineer as to this at VI H above).

Mr Cook said that he did not think it at all unlikely that rags might have been left on or near to the generator. He regarded this mechanism as being entirely plausible. Dr Taylor said that he did not disagree with Mr Cook's description of the mechanism but because of the number of steps required he regarded this as possible but very unlikely.

I accept Mr Cook's technical analysis of these two mechanisms.

P. THE FIRE CONCLUSION

I find that the underwriters have not proved to the relevant standard that Ikarian Reefer was deliberately set on fire. No Judge likes to decide cases or particular issues in cases on the burden of proof if he can legitimately avoid having to do so. There are, however, cases in which, owing to the unsatisfactory state of the evidence or otherwise, the only just course for the trial judge to take is to decide the matter or a particular issue on the burden of proof. The underwriters have not satisfied me, according to the high standard of proof required, that the Ikarian Reefer was deliberately set on fire. My reasons are as follows:

1. I refer to my finding that the grounding of Ikarian Reefer was not deliberate, but was due to negligent navigation by the master (see VI above).

2. The inspection of Ikarian Reefer, and in particular of the valve and the area immediately surrounding the valve, was materially inadequate. Given that the diesel passed first through the valve and given that the valve had fractured, the fracture of the valve cried out for careful investigation. Many of the difficulties and uncertainties that gave rise to protracted conflicting expert evidence would have been avoided if the valve

and the area surrounding it had been fully and carefully inspected. It is elementary that however compelling one piece of evidence may seem, fire experts should carry out a full and careful examination of other possible causes. In relation to the valve and the area immediately surrounding it, there was a failure to do this (see F above). In the result the Court was faced with numerous uncertainties referred to above.

3. I refer to my assessment of the evidence of the members of the crew as set out at VI H above. I was particularly impressed by Mr Tsakaridis as a witness. He did not strike me as someone who would be prepared to accept instructions to fire a vessel.

4. There was a scavenge fire during the 16 00-20 00 watch and a problem with a hot bearing during the last watch (see VI J above). Ikarian Reefer was not an efficiently run vessel and on Apr 12 only minimum work was being carried out by the crew, the Greek Good Friday being a day normally regarded as a holiday.

5. I refer to my findings and conclusions as to the open tap (see H above). It is possible that the tap could have vibrated open under the influence of the generators. Given exactly the same evidence (but with the cap closed) Dr Taylor would have found the evidence conflicting and returned an open verdict.

6. If a deliberate fire was started in the manner alleged by the defendants it is difficult to account for the limited nature and extent of the damage to the tap and to the generator flat (see I above).

7. Given that the diesel passed first through the valve and given that the valve had fractured, the defendants' experts at different times put forward mechanisms in attempts to explain the fracture of the valve. The heating the pipe mechanism can be disregarded both alone and in combination as a cause of the fracture of the valve (see J above). The fracture of the valve was not caused by the heating the valve mechanism (see K above). The movement of the floor plates mechanism is subject to a fundamental objection. The fracture of the valve probably started on the aft side and then propagated forward (as shown in Mr Deegani's Figure 3). In order for a fracture to start on the aft side and go forward the valve had to be displaced relative to the tank in a forward direction, whereas the only evidence indicated that the floor plates moved (if at all) forward to aft (ie in the wrong direction) (see L above). No other mechanism (or combination of mechanisms) put forward by the defendants' expert witnesses explains the fractured valve.

8. I have mentioned above my concerns as to the evidence of certain of the defendants' experts and as to the changes of position that took place. It is revealing to look back at the earlier reports of the defendants' experts to see how much of the reasoning (particularly in support of the defendants' mechanisms) has been shown to be unfounded. But for the remarkable contribution of Dr Walker I could easily have been misled. I do not impugn the honesty of any of the defendants' experts but I am left with a sense of unease about much of the defendants' expert evidence as to the fire. (Further the defendants did not call Dr Bound, the fire expert who had actually inspected the vessel on their behalf).

9. The fatigue/vibration mechanism involves a number of detailed steps. These are analysed at N above. I am certainly not prepared on the material before me to rule out this mechanism. Although there are difficulties and uncertainties with the fatigue/vibration mechanism (see N above) the defendants' experts were in my view inclined to overstate these in relation to several of the steps. My findings as to the valve (see 7 above) provide considerable support for this mechanism but in the light of my analysis at N above and the matters referred to in paragraph 2 above, the only fair conclusion is that I am left in doubt as to the cause of the fire.

10. The cigarette and rag mechanisms (see O above) provide possible alternative innocent explanations for the fire, if contrary to 7 above the valve did fracture in the course of or as a result of the fire. On the material before me I am not prepared to rule out these alternative explanations.

11. I do not consider that the technical evidence is such as to justify my rejecting Mr Tsakiridis' evidence and the other crew evidence.

12. Both sides referred to lists of circumstances in support of their respective contentions. For the reasons set out above this is not a case where circumstances exist in their cumulative effect establishing to the relevant standard that the vessel was deliberately set on fire.

VIII. MOTIVE AND CONNIVANCE

Motive itself is insufficient to afford proof of crime. It would be plainly wrong and improper to infer that because a ship owner has a motive to cast his vessel away he is likely to have done so. Where the facts proved against the owner are sufficiently unambiguous it is not incumbent on the insurers to prove a motive. But matters relating to motive did occupy much time at the hearing and were the subject of considerable evidence and accordingly I state my conclusions as to motive below.

Background

At the end of 1984, the shipping interests of the Comninos Brothers ("Comninos" or "the Group") consisted of 26 vessels, with a combined tonnage of 852,000 dead weight. In addition, the group had one bulker under construction and two yachts. As at Dec 31, 1985, the Group had 19 vessels (excluding Ikarian Reefer), with a total tonnage of 646,000 dead weight. The net decrease of seven vessels resulted from the sale of eight vessels, the loss of Ikarian Reefer and the acceptance into the fleet of the bulker that had been under construction at the beginning of the year.

Movement in shareholders'funds

In the years 1983 to 1985 the shareholders injected $5.7 m. The balance on advances to shareholders changed from a loan to shareholders (ie receivable) of $7.5 m on Jan 1, 1983 to a financing by shareholders (ie able) of $4.7 m on Dec 31, 1985.

Cash flow 1983 to 1985

Of the total net cash inflow in 1985 from operating activities of $5.9 m, $3.5 m was derived from a decrease in debtors, stocks and voyages in progress, and an increase in creditors. The net funds inflow from shipping operations (which excludes the effect of changes in working capital) was $2.4 m in 1985. This net funds inflow was insufficient to cover net interest costs in both 1984 and 1985. A combination of the sale of vessels and the rescheduling of loans translated into a net cash inflow to the group (or saving on cash outflow) of approximately $7 m during 1985. Net liquid funds (cash at bank and held by agents less overdrafts) fell from $4.3 m to $734,000 during 1985.

Movements on loan accounts in 1985

Chase Manhattan were mortgagees of Ikarian Reefer pursuant to a $21.7 m facility. By an assignment of insurance dated Dec 5, 1983 the plaintiffs assigned to Chase Manhattan the benefits of any insurance in respect of Ikarian Reefer. In 1985 Comninos enjoyed loans from Chase Manhattan, Midland, Hill Samuel & BSFE, Hill Samuel & Midland, Hill Samuel, Paribas and Continental Illinois. The movements in 1985 on the various loan accounnne set out below.

(a) Chase Manhattan

Joint Loan -- $21.7 m facility

At the beginning of 1985 the total balance on the loan was $21.3 m, of which $2.325 m was due in 1985. All payments due in the year were made. If the insurance proceeds in respect of Ikarian Reefer had been received during the year, this would have had an effect on the amounts repayable or repaid. However, as no proceeds were received, there was no change to the original schedule.

Two vessels, Anastasios C and Anna C, were sold in the year. For the internal purposes of the Comninos fleet only, part of the total loan had been shown in the accounts as attributable to these vessels, although the companies that owned these vessels were not parties to the loan agreement. The sale of these vessels therefore had no effect on the repayments either due or made in the year.

Harris loan -- $2.55 m.

This loan was both drawn down and fully repaid during the year.

Esperansa loan -- $11.28 m.

This loan was drawn down during the year, but no repayments were either due or made during the year.

(b) Midland

Joint Loan -- $11.2 m facility

At the beginning of 1985 the total balance on the loan was $10.734 m, of which $1.864 m was due in the current year in four equal instalments of $466,000. Two of the instalments were paid. In February, 1985 a prepayment of $1.5 m was made. According to the original agreement, this amount should have been applied pro-rata across all the remaining instalments (cl 5.04). It appears that, instead, the hank agreed to use part of the prepayment to satisfy the other two instalments due during the year, and to use the balance, being $568,000, to reduce the final balloon payment. During the year, insurance proceeds of $2.4 m were received for ice damage suffered in 1984 to Evangelia C, one of the parties to the loan. The cost of repairs was $891,000, giving a net receipt of £1.5 m. This appears to have been used to make the prepayment referred to above. Later in the same year, the Evangelia C was sold for scrap for $1.2 m and Saronic Reefer, also a party to the loan, for $340,000. Neither of these sales affected the repayments made in the year, so the bank did not receive any of the proceeds from the sales.

Recife loan -- $4.5 m.

The balance of the loan at the beginning of the year was $3.44 m, of which $640,000 was due, and was paid, in the year.

Esmeralda loan -- $11.28 m.

This loan had been drawn down in 1984. No repayments were either due or made in 1985.

(c) Hill Samuel & BSFE

Joint Loan

The balance of the loan at the beginning of the year was $720,000, all of which was due in the year. $370,000 was actually paid in the year. The outstanding balance of $350,000 was paid in February 1986 from the proceeds of sale of the Aegean Reefer.

(d) Hill Samuel & Midland

Join loan -- $8.3 m facility

The balance of the loan at the beginning of the year was $7.5 m, of which $1.1 m was due in the current year. Repayments were to be made in two equal instalments of $550,000 in April and July. In March, these banks agreed to reschedule the repayments and the company was required to and made two payments of $200,000. The balance in respect of the year, $700,000, was deemed to be repayable on demand by the banks.

Join loan $4.4 m facility

The balance of the loan at the beginning of the year was $3.6 m, of which $1.425 m was due in the current year. The payment schedule was made up of three payments of $375,000 in January, April and June, and a payment of $300,000 in October. In March, these banks agreed to reschedule the repayments, and two payments of $400,000 in April and July were both due and paid. Additional security was also obtained in respect of this loan, as the revised agreement incorporated an excess earnings clause.

(e) Hill Samuel

Amazon loan -- $1.5 in.

The balance of the loan at the beginning of the year was $1.36 m, of which $280,000 was due in the current year. The vessel was sold during the year for $2.15 m, and the loan repaid in full.

Sao Paulo loan -- $2.65 m.

The balance of the loan at the beginning of the year was $2.65 m, of which $400,000 was due in the year, in equal instalments of $100,000 in February, May, August and October. The first three repayments were made, totalling $300,000, but the final instalment was not paid.

(f) Paribas

Join loan -- $11.5 m facility

The balance of the loan at the beginning of the year was $3.775 m, none of which was due in 1985 per the accounts. It appears that there must have been a rescheduling before the preparation of the 1984 accounts. A payment of $1 m was made during the year, being the proceeds of disposal of Emmanuel Comninos, one of the two parties to the loan agreement.

(g) Continental Illinois

Repair loans

At the beginning of the year there were repair loans outstanding of $387,500, of which $275,000 was due in 1985. Total payments were made during the year of $325,000, of which $50,000 was the prepayment of an amount due in January 1986.

Chase Manhattan's perception of Comninos

Chase Manhattan's perception of Comninos can be seen from documents on their London files. A Senior Offlcer Approval Memorandum ("SOAM") dated June 1983 referred to Comninos as one of the six large Piraeus based operators and the largest independent Greek operator of reefer tonnage. It added:

. . . the principals Costas and Antonios Comninos have an excellent reputation in the market place for being conservative owners who have come up the hard way and are not about to lose everything. Costas Comninos is the President of the Group and Second Vice-President of the Union of Greek Ship Owners.

An internal Chase Manhattan memorandum dated September, 1983 referred to disposals and stated that:

. . . depending on market development they planned to dispose of another 3-4 vessels by June 1984. (Most probably the Ikarian Reefer built 1968) and 2-3 of their older bulk carriers.

On Dec 11, 1984 Chase Manhattan wrote to Comninos:

Recent audits have indicated a discrepancy in the minimum asset protection clause of your Loan Agreement because of declining vessels' values and have asked the Bank to respond accordingly. Although the Bank's intention is not to ask for any action on your part at this stage, however, we would like to bring this to your attention for future discussion and consideration.

A SOAM dated January, 1985 showed that Chase Manhattan's risk rating of Comninos was downgraded from 4 to 6. The Group was referred to as a capable management team of the highest integrity. The memorandum stated that the depression in the shipping markets continued in 1983 and 1984 affecting adversely the operating profitability and cash flow of Comninos. The situation was further exacerbated by the recent collapse of Salen which had thrown the reefer sector into disarray. Salen's collapse had brought about a substantial decline in reefer vessel values and a price cutting war in the major reefer routes. As a result Group leverage had increased, given the decline in the asset values (especially on the reefer vessels). The Group had implemented a programme to shift away from the older bulk carriers and reefers in its fleet, employed on a spot basis, to tankers, with confirmed employment to improve Group cash flow. The accompanying annual review stated that industry sources believed that the 1986 season would see the beginning of an upturn in the reefer market. This was based on the comparatively low order book for reefer vessels in 1986 and the continuing high rate of demolition of older reefer tonnage. The Ikarian Reefer was listed among four reefers (together with 4 M/Vs) that would "go for scrap this year".

A SOAM dated Mar 6, 1985 showed that there had been a further downgrade of risk rating from 4 to 8 (self criticized). The memorandum concluded that projections based on the rates currently earned by the Comninos fleet indicated that the Group would be able to meet 1985 debt service requirements, mainly through the disposal of vessels. However, if the market stayed at the then current low levels, the Group would not be able to service all of its 1986 debt requirements. Despite the current market driven problems faced by Comninos, the bank still believed in the management of the Group, their integrity and their ability to weather the recession.

A criticized loan report dated Mar 13, 1985 set out Chase Manhattan's appraisal of the situation. The management of the Group was considered to be of high quality and integrity. slight improvement in the market would be sufficient to get the Group out of

their present difficulties. If the market stayed at present levels throughout 1986 a restructuring of Chase Manhattan's facilities would be required for that year. It is unclear on the material available to me where the figure of $8.4 m estimated for net operating profit in 1984 came from.

A SOAM dated Mar 29, 1985 sought approval for two facilities, first up to $2.6 million to acquire tanker tonnage (Harris) for scrapping in the Far East, second $3.75 m refinancing in respect of two vessels OBO Sao Paolo and MT Bellem. The first facility was granted in early April, 1985. The second was refused in early May, 1985.

Ikarian Reefer ran aground on Apr 12, 1985 (and subsequently a fire broke out).

On Dec 4, 1985 Chase Manhattan offered Comninos a moratorium on principal instalments for twelve months beginning Jan 1, 1986. This offer was accepted by the Group on Feb 14, 1986.

Mr Alexiou

Mr Alexandros Alexiou joined Chase Manhattan Piraeus in 1983 and succeeded in obtaining the Comninos account. He got to know the brothers and particularly Anthony so well during that period that when he got married in 1984 Anthony Comninos was the best man at his wedding. Mr Alexiou was an impressive witness. Despite his close connection with the Comninos brothers I have no hesitation in accepting his account of the dealings between Chase Manhattan and the Group.

Mr Alexiou said that in contrast to the other owners within his portfolio, one of the striking features of the bank's relationship with Comninos was the extent of the flow of information provided by, in particular, Mr Poulman on behalf of the Group. The bank regarded Comninos as very informative. Unlike many other owners, Comninos provided the bank with audited accounts. In addition, Mr Poulman would provide the bank with reasonably regular fleet statements. Although there was an expectation that the recession would end in 1985, it continued and worsened in 1986. By the beginning of 1985 the risk rating on almost all the owners in Mr Alexiou's portfolio had increased gradually and a number of owners had become subject to Criticized Loan Reports. At that time it was the policy of the bank to reschedule loans rather than pursue a confrontational approach. This was particularly the case with Mr Costas Comninos who was the second vice-president of the Union of Greek Ship Owners and had a high profile and good reputation in the Greek shipping community worldwide. Accordingly Comninos would have received more than sympathetic treatment if they had approached the bank for refinancing at any stage in 1985. There was no doubt whatsoever that the bank would have granted Comninos a loan rescheduling irrespective of the fate of the Ikarian Reefer. Mr Alexiou was asked about a statement in a bank memorandum of about August or September, 1985 that the two Comninos Brothers had sold their private yachts and had injected the proceeds in the Group. Mr Alexiou said that he never thought that the yachts would be sold because they were used as vehicles in order to provide business. He did not think Mr Costas Comninos would have sold his yacht and disposed of his interest altogether. The memorandum was intended to indicate that the bank had got out of the yachts what they could. The bank always intended to reschedule the Comninos account if necessary. The bank had done that with a number of customers. Mr Alexiou did not think that the bank ever said anything to Mr Comninos before April 1985 which might have led him to think that the bank would not reschedule. (It was not until some years later that Chase Manhattan changed its policy and sought to reduce their exposure in the shipping finance sector.) Mr Alexiou said that although the Ikarinan Reefer was certainly a candidate for scrapping the bank was told from time to time that a number of ships would be scrapped. The Group would change its mind because they found employment for a particular ship. The bank left such decisions to the Group.

In an affidavit sworn in the Hyundai proceedings on Feb 22, 1985 Mr Alexiou had said:

The Comninos Group and those they represent are in satisfactory financial condition. The group meets all its obligations to the Bank and operates profitably. The difficulties which they face are created by the current market conditions which are the same for everyone. The Comninos group are coping better than most. I would be quite prepared to recommend a further loan to the group, on reasonable terms, if such a request was made.

Mr Alexiou said that although the bank had a discretion as to how to apply the insurance proceeds when received, it would have applied them in inverse order of maturity (ie against the balloon payment). There was a note (probably signed by Mr Ward) on a SOAM dated Nov 4, 1985 "Insurance proceeds are applied to maturities in inverse order". Even if the insurance proceeds had been received the effect on the Comninos position vis-a-vis the bank would have been very marginal. There would still have been a cash flow problem and there would still have been a quite acute problem with the minimum value clause. Mr Alexiou did not think that the insurance claim played an important part in the negotiations for the rescheduling for 1986.

Charter market evidence

Charter market evidence was provided by Mr Siemers of Ernst Russ GBMH & Co for the plaintiffs and Mr Tim Rayment for the defendants. In addition both sides referred to extracts from trade publications.

The plaintiffs' case is that Ikarian Reefer would have made two more voyages generating a profit of $72,000. But for the casualty Ikarian Reefer would have been redelivered by Chargeurs Reunis at the beginning of May, 1985. Relying on Mr Siemers (whose active involvement in the reefer market extended over years) the plaintiffs submitted that the Ikarian Reefer could have performed further voyages given that (i) the vessel would have been redelivered in the Western Mediterranean and therefore well placed for employment on the citrus trade from Morocco (ii) the reefer market was still active. In addition the plaintiffs submitted that there would have been other available employment for the vessel following completion of the citrus fixture, most notably a banana voyage or on a meat/poultry trade. The plaintiffs submitted that this analysis was consistent with the evidence that the 1985 season lasted longer than 1984 (Ikarian Reefer had been employed on charter until about July 11, 1984).

I see no reason to reject Mr Siemers' evidence based as it is on considerable experience in the relevant market. In his first report he said that 25 years of age was not an unrealistic life expectancy for a strongly built reefer vessel, provided the ship is properly maintained and operated. The Ikarian Reefer was built in about 1968.

Scrap value of the Ikarian Reefer

The scrap value of the Ikarian Reefer was agreed at US$455,000.

View of Mr Philip Birch

In a memorandum dated June 26, 1985 Mr Philip Birch, the defendants' marine claims manager set out his view of the matter as follows:

We have led the Insurance of the Comninos fleet for many years and in my experience the operation of the vessels has been highly efficient and there has been no reason to suspect any malpractice, however, the present claim is very unsatisfactory. The circumstances of the grounding are suspicious and there is a serious problem concerning

the cause of the fire . . . It is possible that the Owners were in financial difficulties as they have been investing heavily in ships recently.

Whilst as the Brokers point out, it must be questionable whether a total loss settlement in respect of this comparatively low valued vessel would assist them and it is tempting to give these Owners the benefit of the doubt, all the evidence points to a deliberate fire and untrue statements from certain of the crew members.

The plaintiffs' solicitors' letter dated Aug 15, 1991

In a letter dated Aug 15, 1991 the plaintiffs' solicitors listed some of the principal non-shipping assets of the Comninos brothers. The defendants submitted that by this letter the plaintiffs attempted to suggest that the brothers were at the relevant time so rich that it was inconceivable that they would have procured the loss of Ikarian Reefer and that after extensive investigation at trial the letter had been totally discredited. The principal non-shipping interests listed in the letter consisted of a share in land in Virginia USA, deposits with various Swiss Banks in Geneva, a villa in Florida, an apartment in Piraeus (all said to be jointly owned by Mr Costas and Mr Anthony Comninos) a villa in Florida, the motor yacht Alpega and a historic house in Athens (owned by Mr Costas Comninos) and a villa in Florida, a villa in Athens and the motor yacht Bila (owned by Mr Anthony Comninos). I will take by way of example the 70 per cent share in land in Virginia which was said in the letter to have an approximate value in 1985 in excess of US$20 m. The competing valuations as at Jan 1, 1985 are per the plaintiffs $22 m (Comninos 70 per cent interest $15.4 m) and per the defendants $9.7 m. (Comninos 70 per cent interest $6.8 m). The plaintiffs submitted that the Washington Land was perceived by the Comninos Group to have substantial value in excess of the purchase price ($7.2 m) and a conditional offer made in 1984 ($21.6 m). The expert evidence supported the conclusion that the land had considerable value even with its 1985 zoning. The land was an asset available for the Group. The fact that it was described as a "Family" asset did not mean that it could not have been used for the benefit of the Group given that the family business was shipping. Although there were unsatisfactory aspects of the letter dated Aug 15, 1991 (eg the value ascribed to the Alpega) I do not consider that a further analysis of the letter is helpful in relation to the issues that I have to decide.

Mr Poulman

Mr Alexander Poulman, an Oxford graduate who became a Director of Comninos in 1981 and was responsible for the management of the finances of the Group, gave evidence. No allegation of complicity and scuttling was made by the defendants against Mr Poulman. Following a separation of the shipping interests of the two brothers Mr Poulman now works with Mr Anthony Comninos. Mr Poulman seemed to me to be competent, responsible and reliable. A substantial part of Mr Poulman's work in the Group was to liaise continuously with the banks. Mr Poulman said:

The discussions with (Chase Manhattan) during 1985 did not give me an indication that the bank would be unco-operative.

Mr Poulman's position was such that he undoubtedly had a clear appreciation of the Group's relationship with Chase Manhattan. I am confident that Mr Poulman would not have been party to casting a vessel away.

Mr Costas Comninos and Mr Anthony Comninos

Both Mr Costas and Mr Anthony Comninos gave evidence. They were both cross-examined at length as to credit and in particular as to their conduct in relation to financial institutions, particularly banks. A great deal of this cross examination related to

events after the casualty.

Mr Anthony Comninos agreed that Chase Manhattan had been told in about August or September, 1985 that the two brothers had sold their private yachts and injected the proceeds into the Group. Although Mr Anthony Comninos said this was untrue in the case of his brother's yacht the Alpega and that this amounted to a sort of a "lie" it should be remembered that Mr Alexiou said that he knew the true position. Although the accounts showed that Ionian Reefer had been sold in the course of 1985 Mr Anthony Comninos said that part of the beneficial ownership had been retained. Ionian Reefer had been trading since 1985 for the benefit of Mr Costas Comninos. The banks however had been told that the ship had been sold. Further Aegean Reefer was sold in 1986 to a company in which the two brothers had a beneficial interest. Mr Anthony Comninos said that if a bank asks about personal assets he would give --

. . . an almost honest answer because you have to keep something for yourself after thirty years of hard work.

A Chase Manhattan letter dated Nov 24, 1987 consent to the sale of the Esperansa subject to a number of conditions including an "arms-length (sale) to a third party buyer". Mr Costas Comninos agreed that a bank memorandum dated Dec 3, 1987 could he read as indicating that he had told the bank that Esperansa had been sold at arms-length to a third party. He maintained, however, that the bank wanted $10.4 m and that the sale price achieved was the best that could be obtained at that time.

Mr Costas Comninos was also cross-examined about the negotiations leading up to an agreement dated December, 1988 whereby he and certain of his companies agreed to pay US$2.67 m in full and final settlement of Chase Manhattan's claims. Mr Costas Comninos said that he was never asked for a statement of personal assets. He added that if the Bank had asked for such a statement he would not have given a full list of his assets. He also said:

. . . I would never have sacrificed this company . . . in order to save or safe-keep a personal asset.

Although some of Mr Anthony and Mr Costas Comninos' answers reveal an unsatisfactory approach to their dealings with banks, I should point out in fairness that they were cross-examined by reference to Chase Manhattan's London records and that the only witness who gave evidence who had been employed by Chase Manhattan, Mr Alexiou, indicated that he knew the true position in relation to some of the earlier transactions. There may well be a distinction between what Chase Manhattan Piraeus knew and what Chase Manhattan London and New York knew. But even if dishonesty had been clearly established in one respect, such dishonesty would not necessarily involve dishonesty in another and different respect. As Lord Sterndale MR said in The Elias Issaias sup at p 187

It is a long step from deceiving a bank to scuttling a ship [see further The Michael sup per Lord Justice Roskill at p 21].

Mr Anthony and Mr Costas Comninos emphatically denied giving any instructions to anybody to cast away Ikarian Reefer. Both men (particularly Mr Costas Comninos) were proud of their standing in the Greek shipping community. Both would do their utmost to retain their shipping interests but having seen and heard them give evidence over a number of days annavng watched their demeanour in the witness box, I accept their evidence that they did not give instructions to cast away Ikarian Reefer.

The delay in prosecuting the claim is most regrettable. It is however to be noted that before October, 1989 the benefits of the insurance were assigned.

Motive and connivance generally

The following matters are in my view important when considering motive and connivance (and the case generally).

(1) The size of the Comninos Group, the extent of its operation and its relationship with its bankers, including in particular Chase Manhattan.

(2) Any insurance proceeds would not have benefitted the Group generally but were assigned to Chase Manhattan and would probably (had they been received) have been applied by Chase Manhattan to maturities in inverse order (ie the balloon payment).

(3) The Chase Manhattan London files provide the best available independent evidence of the nature of the relationship between Chase Manhattan and Comninos in the months immediately prior to the casualty. The Group's not inconsiderable problems in early 1985 were common to the industry as a whole. It is clear from Chase Manhattan's documents that the management of the Group was considered to be of high quality and integrity as well as totally committed to the survival of the business.

(4) Shortly before the casualty Chase Manhattan approved the Harris Loan (up to $2.6 m) albeit subject to strict conditions including the assignment of a time deposit of $1 m. This was not the action of a bank about to withdraw facilities and the evidence indicates that the relationship with Chase Manhattan was such that the Group could have expected in April, 1985 to obtain a restructuring if this proved necessary.

(5) No one decides to scuttle a ship lightly; are are too many risks of failure or blackmail or both. If the general financial position in this case were in itself to be treated as a sufficient motive for scuttling, few tramps would have survived the depressed market conditions of recent years [per Mr Justice Kerr in The Michael [1979] 1 Lloyd's Rep 55 at p 73].

It would have been an extremely high risk strategy for owners of a Group of this size (dependent on the support of banks, insurers and others) to give instructions to cast a vessel away so that one particular bank received the insurance proceeds. If the truth emerged via a member of the crew in crew interviews or otherwise, the Group could not expect to enjoy continued support from any reputable bank or financial institution. The defendants accept that Comninos were fully cooperative in allowing access to the crew in the form of crew interviews by Mr Arditti after the casualty.

(6) As Mr Philip Birch recognized in June, 1985 --

. . . As the Brokers point out, it must be questionable whether a total loss settlement in respect of this comparatively low valued vessel would assist (the Group).

(7) A decision to cast the Ikarian Reefer away would have involved the following further disadvantages -- the loss of good will of a major European charterer, loss of hire, payment to the charterers for the bunkers remaining on board, increased hull and machinery and P & I premiums for the whole fleet in future years and considerable wasted time and costs in Sierra Leone and elsewhere (even if the claim had eventually been settled in full).

Conclusion

If, contrary to my conclusion in VII above, Ikarian Reefer was deliberately set on fire by a member of the crew, I find that the defendants have not proved that the owners in any way consented, or were privy, to that action. If the burden of disproving privity lay on

the owners, I would hold that they had discharged it. If, contrary to my conclusion, the vessel was deliberately set on fire I consider that Mr Cook's original explanation is the most likely. About five members of the crew had been ordered to remain on board -- a fire started by one crew member who did not want to stay on board would have forced those ordered to remain to abandon the vessel.

IX. OPPORTUNITIES FOR COMMUNICATIONS BETWEEN THE OWNERS AND THE MASTER

The defendants submitted that underwriters can never be expected to have any direct evidence of the plot, the conspiracy, who was party to it and when the arrangements were made. I have referred above to the fact that Judges have long recognized the special difficulties facing marine underwriters and have defined the task of the Courts accordingly and I have given due weight to this. The defendants at one point submitted that --

. . . it may be no more than standing instructions . . . most Greek ship masters . . . would know full well that if they had an accident their owner would far rather they had a total loss than a partial loss.

I find that there were no such standing instructions in the present case. I also find that the master tried to save the vessel. Captain Tamvakis was reappointed master of Ikarian Reefer in October, 1984 at Piraeus on completion of her special survey. The Chronology set out above shows the vessel's movements between Apr 3, 1985 and the casualty. Between November, 1984 and Apr 3, 1985 the vessel had sailed to Yugoslavia, Cuba, Panama, Cuba, Hamburg, Cuba and Rostock. There is a schedule from Athens Radio of communications to and from the vessel through the Greek Coastal Stations between Apr 1 and 13. There is no indication that the Comninos brothers spoke to the master via Athens Radio between those dates. It is perhaps unlikely that instructions to cast a vessel away would have been communicated otherwise than face to face but there is no evidence of any meeting between the owners and the master at any time between November, 1984 and the casualty.

CONCLUSIONS

The grounding of Ikarian Reefer was not deliberate but was due to negligent navigation by the master. The underwriters have not proved to the relevant standard that Ikarian Reefer was deliberately set on fire. If, contrary to my conclusion, the vessel was deliberately set on fire by a member of the crew, the defendants have not proved that the owners in any way consented, or were privy, to that action. If the burden of disproving privity lay on the owners, I would hold that they had discharged it. If, contrary to my conclusion, the vessel was deliberately set on fire I consider that Mr Cook's original explanation is the most likely. About five members of the crew had been ordered to remain on board -- a fire started by one crew member who did not want to stay on board would have forced those ordered to remain to abandon the vessel.

It follows that there must be judgment for the owners for the appropriate sum.

In conclusion I would like to acknowledge with gratitude the great help I have received throughout this case from the legal teams on both sides. The solicitors performed their duties with conspicuous care and attention. Both leading counsel conducted the case at all times with very great skill and propriety. Junior counsel were of considerable assistance. I would also like to thank the shorthand writers and Mr Robert Diamond for his remarkable help as interpreter.

DISPOSITION:
Judgment accordingly.

SOLICITORS:
Clifford Chance; Ince & Co