Paper issued for written discussion

THE ROLE OF EVAPORATION OF INGESTED SALTS IN HOT CORROSION MECHANISMS OF GAS TURBINES

Dr. C. G. McCreath*

The marinization of aero gas turbines involves many problems, not the least of which is hot corrosion. A complete understanding of the mechanism of such corrosion is a necessary precursor to solving the problem and this involves a knowledge of the history of the ingested salt throughout the engine.

This report develops a theoretical model for salt particle evaporation in high temperature environments (900–1100°C) and reinforces this model with experimental evidence. The model is then extended to cover the effect of increased pressure and predictions are made of particle size histories in the marinized Olympus B and Tyne RM1A combustion chambers at cruise condition.

INTRODUCTION

The problems, associated with the "marinization" of gas turbines developed for aircraft propulsion, have been known for many years[1]. One of the most prevalent of these problems is the lack of an intimate, quantifiable approach to the phenomena of hot corrosion.

It is known that sea salt is ingested through the engine air intake. It is also established that the fuel contains some sea water and a larger sulphur content than conventional aircraft fuel. In recent years, a fairly extensive knowledge has been obtained of how a variety of super alloys, typical of turbine blade materials, react to various corrosive environments. What is not so well known is what happens to the ingested sea salt between the point of ingestion and the surface of the turbine blade.

It has been ascertained[2] that the maximum sea salt concentration in air at sea level in bad weather is not more than 2 ppm and the particle size is less than 25 μm. Much of this salt content is removed by baffles and filters before entering the compressor. Some measurements suggest that up to 70 per cent of the salt content of the ingested air can be removed in this way. The particle size entering the compressor is dependent on the efficiency of the filtration media but could be as low as 5 μm. How much of the salt which enters the compressor survives to emerge and enter the combustion chamber is a question of some doubt. So too is the salt particle size at this point. The salt concentration gradient across the compressor cannot be small since large deposits of salt are formed on the compressor blades necessitating frequent cleaning. Suggestions have[3] been made that deposition of smaller salt particles (<1 μm) is favoured at this point.

The extent to which particles surviving the compressor will be evaporated in the combustion chamber depends on the route they take. Particles entering the primary zone have longer residence times in a high temperature environment than do those particles which enter with the dilution air. Further complications are introduced by the possibility of fragmentation of compressor deposits to form quite large particles at the compressor exit plane.

* University of Sheffield, Department of Chemical Engineering and Fuel Technology.

Only that material which survives the previous stages can be considered in the deposition processes at the turbine blade surface. Various indications have contributed to the belief that sodium sulphate is an undesirable constituent of any turbine blade deposit and previous work[4] at Sheffield has shown that the short residence times inherent in gas turbine combustion chambers preclude the gas phase sulphation of sodium chloride to sodium sulphate. The likelihood of salt deposition followed by sulphation would thus seem more feasible. It is likely that both particles and vapour exist at the combustion chamber exit plane, the proportion of each being dependent on the particle size distribution at the compressor exit plane, the temperature history of the particles during their transit of the combustion chamber and their residence time in the combustion chamber. The deposition of particles on the turbine blade will be dependent upon their size and inertia, the blade geometry and its position relative to the flow. The larger particles will be deposited by direct impaction and the smaller particles by eddy impaction and particle diffusion. The vapour deposition will be mass transfer controlled and will be dependent upon the difference in temperature between the blade surface and the gas phase and the boundary layer thickness. Very close to the blade surface the salt vapour is likely to encounter large temperature gradients which could result in vapour saturation followed by condensation to form small particles. The temperature gradient and boundary layer thickness are both likely to vary over the blade surface.

The work reported here provides some answers to questions about the history of the ingested salt between the compressor and the turbine of the engine.

THE THEORY OF SALT PARTICLE EVAPORATION

In calculating the rate at which particles evaporate it has first been assumed that the particles can be considered as stationary with respect to the gas, i.e. the particles are rapidly accelerated to the gas stream velocity, and secondly, that the rate determining factor in the evaporation mechanism is diffusion of the vapour away from the particle surface. Under these conditions the Nusselt number approaches the numerical value of 2 and the boundary layer thickness around the particle approaches half the diameter of the particle. The rate of evaporation is given by the equation (1).

$$N = \frac{2DM(p - p_o)}{d\,RT} \quad g/cm^2 \qquad (1)$$

Where N = rate of evaporation, g/cm^2
D = molecular diffusivity, cm^2
M = molecular weight of the vapour
p = vapour pressure at surface, $dynes/cm^2$
p_o = partial pressure of diffusing material at a remote point, $dynes/cm^2$
d = drop diameter, cm
R = gas constant, ergs/°C g.mole
T = absolute temperature, °K.

For a given set of conditions this may be written as

$$N = \frac{K}{d} \qquad (2)$$

Where $k = 2DM(p - p_o)/RT$ (3)

Then denoting the particle diameter by x, the rate of change of mass of the particle is

$$\frac{dw}{dt} = -\frac{k}{x}\pi x^2 = -\pi k x \qquad (4)$$

but

$$\frac{dw}{dt} = \sigma\frac{dy}{dt} = \frac{\sigma x^2 \pi}{2}\frac{dx}{dt} \qquad (5)$$

where y = particle volume
σ = particle density

Equating (4) and (5)

$$\frac{dx}{dt} = \frac{-2k}{\sigma x}$$

integration then yields

$$x_o^2 - x_1^2 = C^* \qquad (6)$$

x_0 = particle diameter at time $t = 0$
x_1 = particle diameter at time $t = t$
C is a constant of value $\frac{4k}{\sigma}$

Since k is a function of temperature, then the constant C will also vary with temperature. The time for complete evaporation of the particle is given by the condition $x_1 = 0$ and $t = \sigma d^2/4k$ (7)

The diffusion coefficient D in equation (3) was calculated from the Gilliland equation

$$D = \frac{0{\cdot}0043\,T^{1{\cdot}5}}{P(V_1^{0{\cdot}3} + V_2^{0{\cdot}3})^2}\sqrt{\frac{1}{M_1} + \frac{1}{M_2}}\ cm^2/sec \qquad (8)$$

Where M_1 and M_2 = molecular wts. of the two gases
P = total pressure atm.
V_1 and V_2 = molecular volumes

The vapour pressure P_0 was assumed to be negligible and for comparison purposes the vapour pressure at the surface was derived by a number of different equations. Zim and Meyer[5] suggest that the vapour pressure of NaCl can be derived from the equation (9) below the melting point.

$$\log_{10} p = 11{\cdot}093 - 12{\cdot}288\left(\frac{1000}{T}\right) + 2\log_{10}\left(\frac{1000}{T}\right) \qquad (9)$$

where p = vapour pressure in mm. Hg
T = absolute temperature.

Fiock and Rodebush[6] have measured vapour pressure data for NaCl above the melting point.

$$\log_{10} p = -9419/T + 8{\cdot}3297 \qquad (10)$$

The vapour pressure can also be determined from first principles by application of thermodynamic theory. For a solid or liquid vaporizing without decomposition the standard free energy change at absolute temperature T is given by the equation

$$\Delta F^\circ = -RT\log_e f \qquad (11)$$

where f is the fugacity or for an ideal gas, the vapour pressure.
For the reaction [7]

NaCl (liquid) → NaCl (gas)

$$\Delta F^\circ = 52{,}800 + 15{\cdot}9T\log_e T - 81{\cdot}89T \qquad (12)$$

The vapour pressure can then be calculated and corrections for pressure can be applied by means of the equation (13). This correction has been assumed to be negligible.

$$\frac{\Delta p}{P} = \frac{V}{RT}\Delta P \qquad (13)$$

In calculating the numerical value of the vapour pressure no account was taken of the effect of a curved surface. This is given by the Thomson-Gibbs equation (14).

$$\log_e\left(\frac{p}{p\infty}\right) = \frac{4\gamma M}{\sigma RT\,d}$$

where $p/p\infty$ = the ratio of vapour pressures over a curved surface and plane surface.
γ = surface tension of liquid.

For a 0·1 μm diameter particle at 1273°K the ratio of vapour pressures is 1·025. This effect is small, even for very small particles, and has been ignored.

EXPERIMENTAL APPARATUS AND TECHNIQUE

The experimental system is shown in Fig. 1. It consists of a three way electric furnace within which the salt particle was suspended on a fine silica thread, and an optical system to photograph the particle size as a function of time. The optical system consisted of a variable, low wattage, continuous light

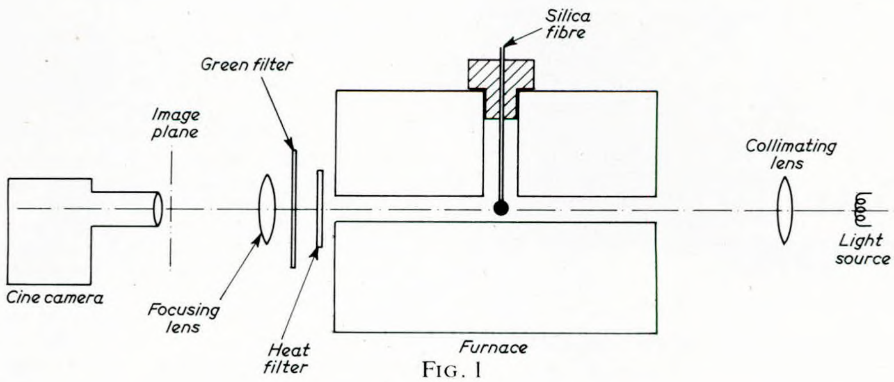

FIG. 1

source and a collimating lens to produce a parallel beam of light which illuminated the particle. The image of the particle was then focused by means of a conventional remote camera lens (f 2.8/150 mm) on to a plane approximately 1 cm in front of the cine camera lens. This arrangement produced an object on to which the cine camera was focused. The use of a small objective distance, together with the use of extension tubes and a 10 cm focal length cine camera lens, produced a greatly magnified real image in the camera film plane. This image was then recorded by a black and white panchromatic Mk IV Ilford film and developed for $2\frac{1}{2}$ min at 20°C in Patersons acutol "s" high acutance developer. The frames were projected individually by a Leitz IV B projector on to a screen to produce an overall magnification of about 100. A Wratten 61 green filter, (to increase contrast) and a heat filter (to protect the remote camera lens) were also used to facilitate photography. The system was calibrated before each run by photographing a 19·5 μm diameter wire suspended in the same plane as the salt particle. Furnace temperatures were controlled by means of a variac/timing device and monitored by a Pt/Pt/Rh thermocouple. Data extraction from the negatives was carried out using a semi-automated data logging system described in detail elsewhere[8].

Molten drops of salt suspended on a silica thread within the experimental furnace deviated from spherical symmetry. In order to find the diameter of the equivalent sphere the major and minor dimensions of the molten drop were measured and a correction applied by equating the volumes of the two droplet configurations[9]. The corrected particle diameter is then derived from the relationship.

$$D = (l_1 \, l_2^2)^{0 \cdot 3}$$

where D = diameter of equivalent sphere
l_1 = major dimension
l_2 = minor dimension

EXPERIMENTAL RESULTS AND DISCUSSION

Rates of evaporation of molton drops of both sodium chloride and sea salt were measured in the temperature range 900–1100°C. The measurements obtained for both the sodium chloride and sea salt systems at 900°C and 1100°C are illustrated in Figs 2, 3, 4 and 5. The gradients of the linear relationships between the square of the drop diameter and time were found to be dependent upon the fibre diameter/drop diameter ratio, the combination of larger fibre diameters and smaller drops creating the greatest errors. A factor based on the experimental results was applied to correct for this effect.

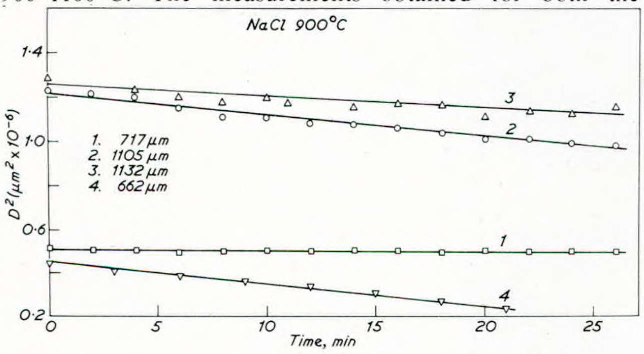

FIG. 2

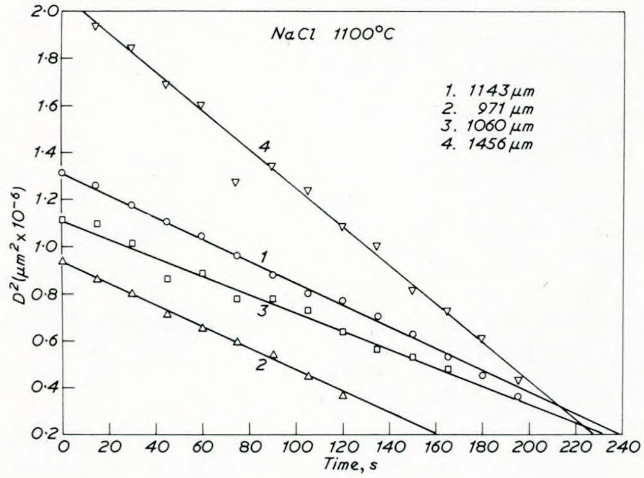

FIG. 3

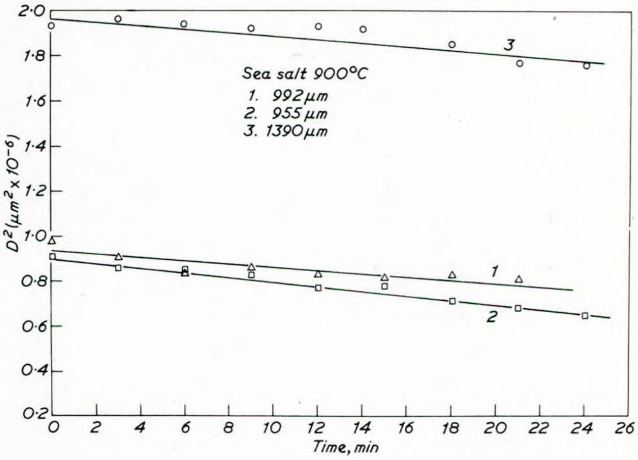

FIG. 4

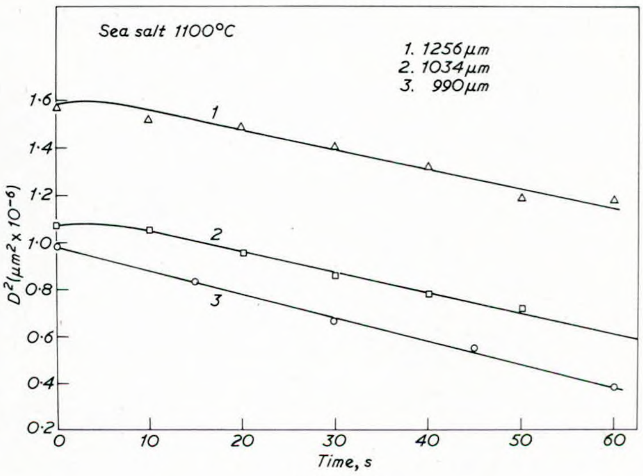

FIG. 5

The corrected gradients of the linear relationships between the square of the drop diameter and time, i.e. the value of C in equation (6), are plotted against temperature (see Fig. 6). It can be seen that sea salt and sodium chloride show similar evaporation characteristics and that for sodium chloride the experimental data compares favorably with the theoretical model. Input data in the case of the theoretical evaporation model for sea salt was not available in the literature. Both sea salt and sodium chloride show that the evaporation rate is strongly temperature dependent, particularly above 1000°C.

The theoretical computed conversion rates, i.e. percentage of original mass in the vapour state, after 5×10^{-3} s for a number of drop sizes at various temperatures and pressures are shown in Fig. 7. The nature of these curves emphasizes the significant role of increased pressure on the rates of evaporation of sodium chloride.

Figs. 8 and 9 show the theoretically derived particle size history of a variety of practical particle sizes for both the marinized Olympus B and the Tyne (RM1A) combustion chambers at cruise condition. In both cases it can be seen that all particle size reduction occurs in the primary zone of the combustion chamber.

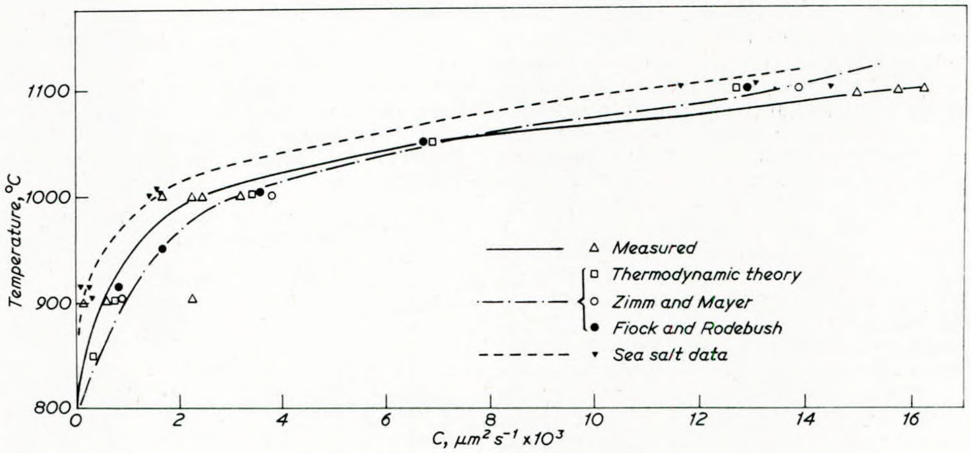

FIG. 6

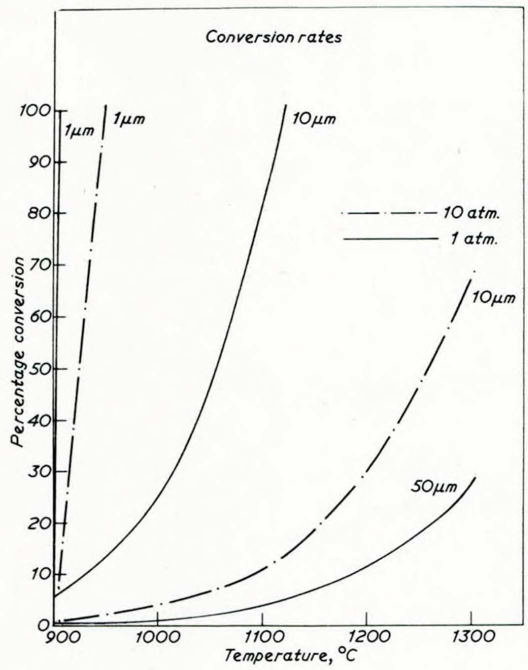

FIG. 7

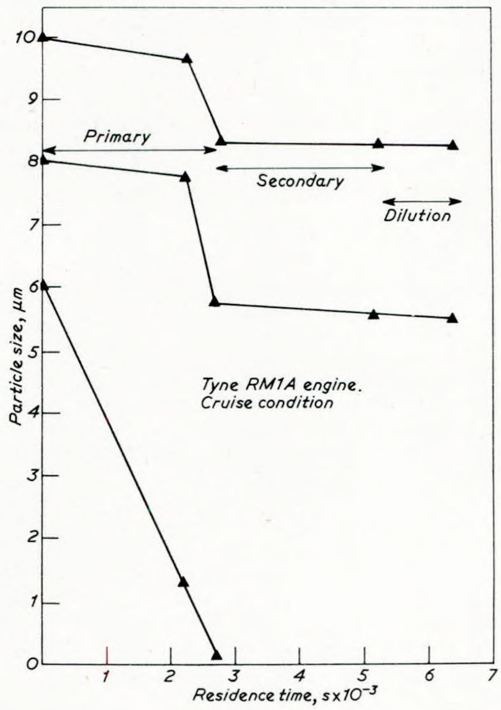

FIG. 9

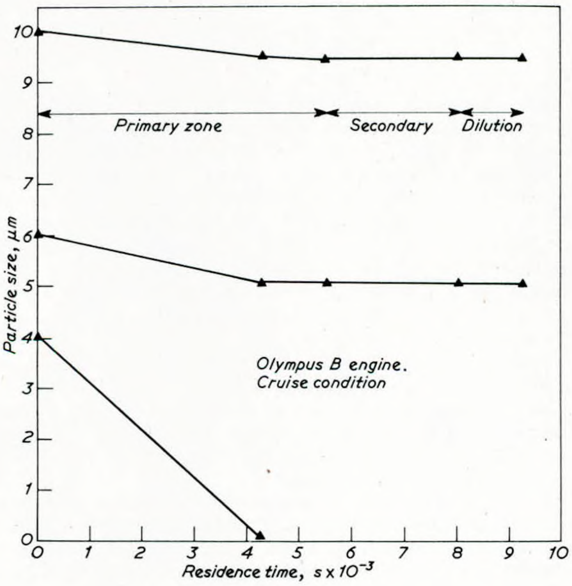

FIG. 8

CONCLUSIONS

The evaporation rates of both sodium chloride and sea salt particles are similar, both of these materials show strongly temperature dependent evaporation rates. The evaporation rates are also a function of pressure and for a particular temperature and pressure the square of the particle diameter is a linear function of time. The experimental data for sodium chloride particles compares favourably with data derived from a theoretical model of particle evaporation. Theoretical calculation of particle size histories for both the marinized Olympus B and Tyne RM1A shows that size reduction of sodium chloride particle occurs only in the primary zones of the combustion chambers.

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ANNUAL DINNER

The Seventy-third Annual Dinner of the Institute was held on Friday, 12 March 1976, at Grosvenor House, London, W.1., and was attended by 1500 members and guests.

The President, Mr. T. Kameen, was in the Chair.

The official guests included: His Excellency, Mr. Ole Jödahl, the Swedish Ambassador: His Excellency, Mr. Artur Starewicz, the Polish Ambassador: His Excellency, Senhor Dr. Albano Nogueira, the Portuguese Ambassador: His Excellency, Dr. The Hon. C. de Wet, the South African Ambassador: His Excellency, The Rt. Hon. H. Watt, the High Commissioner for New Zealand: Admiral Sir Anthony Griffin, G.C.B., Chairman of the Organizing Committee for British Shipbuilders: Señor Manuel Gomez-Acebo, Spanish Chargé D'Affaires: His Excellency, Dr. R. Totterman, K.C.V.O., O.B.E., The Finnish Ambassador: His Excellency, Mr. V. L. B. Mendis, the High Commissioner for the Republic of Shri Lanka: Rear-Admiral H. D. Kapadia, AVSM, Assistant High Commissioner in Glasgow, for India: Captain J. Chryssanthakopoulos: G. Victory, Esq., Deputy President: S. Clinton-Davies Esq., M.P.: Monsieur Michel Proust, Ingenieur en Chef de L'Armement, France: J. H. Kadijk, Esq., Minister-Counsellor (Economic), Belgium: Captain (N) J. W. Mason, C.D., Senior Naval Liaison Officer (Maritime), Canada: N. E. Leigh, Esq., C.V.O., The Clerk, Privy Council Office: Boris A. Titov, Esq., Scientific Attaché (2nd Secretary), U.S.S.R.: Commodore F. H. Bland, O.B.E., Head of the New Zealand Defence Liaison Staff: Commodore C. L. Sachdeva, Naval Adviser, Indian High Commission: Captain I. R. Jones, R.A.N., the Naval Adviser Technical, Australia: S. T. Kidd, Esq., the Commissioner for the Hong Kong Government: Dr. S. Archer, Past President: A. R. Belch, Esq., President, Shipbuilders and Repairers National Association: F. B. Bolton, Esq., President, General Council of British Shipping: The Reverend L. E. M. Claxton, M.C., M.A., A.R.C.M., Rector, St. Olaves, London: R. J. Clayton, Esq., C.B.E., President, The Institution of Electrical Engineers: Dr. Allan W. Davis, Past President: G. A. Dummett, Esq., Chairman, Council of Engineering Institutions: F. T. Durkin, Esq., Chairman, Merchant Navy and Airline Officers Association: B. T. Ford, Esq., M.P.: W. E. Garrett, Esq., M.P.: Dr. R. Hurst, C.B.E., G.M., Director of Research, The British Ship Research Association: R. A. Huskisson, Esq., Chairman, Lloyd's Register of Shipping: A. Kelly, Esq., F.R.S., Vice-Chancellor, University of Surrey: J. McNaught, Esq., Honorary Treasurer: R. Munton, Esq., C.B.E., B.Sc., Past President: G. D. Nussey, Esq., President, The Institution of Mining Engineers: B. N. Preston, Esq., Chairman, British Marine Equipment Council: Vice-Admiral Sir George Raper, K.C.B., Past President: D. E. Rooke, Esq., C.B.E., President, The Institution of Gas Engineers: Sir Norman Rowntree, D.Sc., B.Sc., President, The Institution of Civil Engineers: Captain J. L. Watson, The Master, The Honourable Company of Master Mariners.

The Loyal Toast having been duly honoured

THE PRESIDENT said: On behalf of the Institute, it is with much pleasure that I extend to all our guests a very warm welcome and thank you for joining us tonight on this, our seventy-third Annual Dinner. While I do not propose to specifically mention all our friends at this table, I should particularly like to welcome our Past President, Mr. Tim Bolton, President of the General Council of British Shipping, and the Presidents of kindred Institutions. I am also delighted that Mr. Dummett, Chairman of the Council of Engineering Institutions, has found time to join us.

As the recent Controller of the Royal Navy, our principal guest, Admiral Sir Anthony Griffin, needs little introduction to the shipbuilding industry. After a distinguished naval career, Sir Anthony has now taken up his appointment as Chairman of the Organizing Committee for British Shipbuilders. I am sure that all present this evening would like to assure you, Sir Anthony, of their fullest support in the most onerous task which lies ahead of you. It is with great pleasure that I invite you to propose the toast of the Institute. (*Applause*)

ADMIRAL SIR ANTHONY GRIFFIN, G.C.B. (Chairman of the Organizing Committee for British Shipbuilders) proposed the toast of "The Institute of Marine Engineers".

He said: Mr. Chairman, thank you for your kind welcome to what until a few seconds ago was a most delightful occasion! When it comes to Marine Engineering I was until recently in some doubt whether I was a virgin or a eunuch. However, my doubts have been allayed by recent proceedings in the House of Lords, from which I gather virgins can be far more productive than I could ever be. *(Laughter).* I must therefore be a eunuch. A eunuch is a person who while he himself cannot do it, is always ready to tell somebody else exactly how to do it. *(Laughter).*

I am therefore extremely sensitive, Mr. Chairman, of the very great honour you do me in inviting me as your guest and asking me to propose the health of the Institute. There could scarcely be a time, I suggest, when all those present would wish more fervently to drink to such a toast. 1889, the year of the foundation of the Institute and still very much within living memory, was a vintage year in many other ways, too. Brazil became a Republic. Jerome K. Jerome wrote "Three men in a boat". Gilbert and Sullivan produced "The Gondoliers", and it was also the year of the Technical Education Act which demanded a penny rate for technical and manual education.

Now in 1976, two hundred years after Watt and Bolton produced the first commercial steam engine, I cannot help reflecting on our present position in the shipbuilding and engineering leagues. In the case of shipbuilding, I have just got to the point where I understand that critical path analysis is not a cliff-hanging Greek shipowner. *(Laughter),* I have also begun to meet the trade unions and a newly found colleague was telling me of his recent experience in hospital. The Secretary of his Executive Committee had called on him to pass on the best wishes of the committee for a speedy recovery, adding that the motion had been carried by six votes to five with three abstentions. *(Laughter),* So you can see, Mr. Chairman, how my status as a eunuch is beginning to build up. However, long before I get to the stage of acquiring "articles" even I can that we in the shipbuilding and engineering worlds, especially of this country, are facing a critical situation.

Brazil has now become a major shipbuilding country able to build not only merchant ships, but also the most sophisticated warships, as a result of the wholehearted commitment of the Brazilian government and that country's financial establishments to the support of a single minded venture into shipbuilding. Here one would like to think that our government, the trade unions and management were all in the same boat. However, if the number of voices is any guide, there are many more than three men in the boat: the Department of Trade, the Department of Industry, the Department of the Environment, the Department of Employment, the Ministry of Defence, the Treasury and many others, are all there: senior management, middle management and foremen, not to mention the Organizing Committee for British Shipbuilders. They all have their things to say. Then of course there are the trade unions — some 19 connected with British shipbuilders. They, too, have something to say. There are 40 firms who between them run about 84 different plants and yards, some 95 000 people, not to mention something like three times that number engaged in supporting industries, especially engineering, who provide the majority of the total value of each ship. So Jerome K. Jerome's boat has now become the size of a fleet of VLCC. The situation would be Gilbertian if it were not so serious. Here "The Gondoliers" reminds me of Italy, where most of the heavy crankshafts come from for installation in the slow speed marine diesels built in this country, the remainder coming from Japan. That, of course, is bad enough. But, to make matters worse, three quarters of the slow speed marine diesels being built in this country are under licence from Swiss or Danish firms.

Furthermore, in many other fields, for example gearing, an increasing number of firms are obtaining what they need from abroad. All this of course may well make sound, commercial sense, and we cannot blame either manufacturers or British shipowners if they find that they can get what they need at a better price, better quality and better delivery from abroad. The stark tragedy is we have the ability but, in many areas, we seem to have lost the will. Too many people have become loss happy and, instead of reacting violently, are increasingly accepting the situation and holding out their hands. Here, may I suggest that all of us have a responsibility, first to bring home the seriousness of the situation and, secondly, to do something about it. There are of course many different ingredients which need urgently to be addressed. We for our part, on the Organizing Committee for British Shipbuilders, are giving equal priority first to helping firms to obtain more orders and secondly to motivation, motivation through participation and the necessary education to make that participation constructive and effective. Here the Technical Education Act of 1889 seems to be another pointer from the past. It addressed both technical and manual education. Now, 87 years later, I suggest we still have a dual task: namely, to educate both management and the rest of the work force to appreciate each other's problems, and we believe this can best be done, not separately, but together. We also believe we should exploit our expertise by going for ships at the high value added end of the range and bring about a much closer liaison between all parties concerned, especially between shipowners and shipbuilders. There is certainly no time to lose. Indeed, unless action is put in hand immediately, there is a real risk that, for lack of orders, the fate of British shipbuilders will be settled before vesting day. If that fate is in line with past trends, we must expect the effect on British shipbuilding to be passed on and amplified in its effect on British engineering.

So, Mr. Chairman, whoever else is in the VLCC — and I trust we will not be building any more for some time — all of us present here tonight certainly are in the same boat, and I believe your members would wish to know, assuming we get our hand on the tiller, the broad organization and structure we plan to adopt in order to achieve our aim of a flourishing industry. Our ideas are still necessarily somewhat tentative as we have not yet finished our discussions with as many people as possible within industry. However, we have to-date visited some 44 plants and yards all over the country. This week we completed our seventieth meeting. We have about fifty meetings to go. The consensus so far emerging from these discussions points clearly towards a federal type of organization with a small policy making headquarters and some 40 substantially autonomous firms. This means that individual firms will be largely independent profit-making centres, having the delegated authority to go about their own business, find their own customers, fulfil their contracts and deal with their day to day problems, as they arise.

They would have responsibility for trading successfully as measured against new and demanding objectives which had previously been agreed on a long term basis between us. The headquarters staff, which we trust can be kept to something well below a hundred people, will have responsibility for devising a strategy for the industry as a whole, dealing particularly with international and national issues. In addition, it would be up to headquarters, acting in close consultation with experts, both within the industry and elsewhere, to promote the raising of standards to those of the best which already exist. Unlike most other nationalized industries, we appreciate we have few if any captive customers. Consequently, our standards have to be better than those of our competitors abroad in timing, price and quality. None of us has any illusion about the size of the task.

However, we are by no means despondent. We can even now point to areas of the industry where, measured even against world standards, customers can obtain in certain classes the best merchant ships, the best warships, the best diesel engines and the best repairs. So we know we already have the people and the skills and the management at least in those areas. We are therefore setting about bringing as much as possible of the rest of the industry into line with those standards, if not better. Our main concern, as I have already mentioned, is the full motivation of everyone concerned, while in the case of top management we think this can probably best be achieved through decentralization, autonomy and judgement by results. For the rest of the work force, we believe that what is mainly required is full information, genuine participation and a wholehearted commitment to the success of the enterprise as a whole rather than to any sectional interest. Here we are already enjoying the co-operation and support of the trade union movement.

I sincerely trust, Mr. Chairman, that you and your members reckon the Organizing Committee has broadly set out on the right course and are prepared to join us on what is bound to be a pretty hair raising voyage. If I may say so, Mr. Chairman, we for our part could not wish for better shipmates.

Gentlemen, would you please rise and drink a toast to "The Institute of Marine Engineers". *(Prolonged applause).*

The President, in reply, said: Thank you, Sir Anthony, for the kindly way in which you have proposed the toast to the Institute. Like you, during my term of office I have attended many dinners such as this, and if I have realized one thing it is that brevity is the order of the day, appreciating that on such occasions when we have a large, captive audience, there are certain things which have to be said. On a recent occasion when I was privileged to hear you speaking, Sir Anthony, you referred to your new appointment, and you very properly expressed your belief that the British Shipbuilding and Marine Engineering Industry was technically equal to any in the world and that, provided the competition was fair, it was equally competitive. I fear that what is fair competition will never be agreed. What appears to be patently fair to a developing nation may not be considered to be so by the more developed countries. Such are the Facts of Life.

But I am sure, as must be everyone else in this room tonight, that the world does not owe us a living. It is there to be earned but not as of right. *(Applause).* This leads me to make a further personal observation regarding the industry of which we are proud to be part, and that is whether or not it is realistic to continue to believe that we as a nation can still compete in the manufacture of certain relatively unsophisticated hardware, such as many ships are.

Should we not accept the fact that there are some rather basic manufacturing industries in which we can no longer compete, and that our country's future lies in the export of more advanced technological products and know-how. No doubt our role lies somewhere in between, and our ability to design and produce the more sophisticated type of ship, and our pre-eminence in ocean engineering techniques, are prime examples of our capacity to take advantage of every opportunity. In a sense, much the same problems and possibilities lie before this Institute. Its ability to export know-how to developing nations has been known for a long time. Of recent years, because of all sorts of pressures — not least that of inflation — the opportunity presented in this direction has been grasped. I would not weary you with details but suffice to say that it is evident a very considerable service can be made available to such countries, and many of them, some through international agencies, are willing to pay for such a service. A recent visit to the Middle East by senior members of the staff has been most rewarding and indeed most stimulating.

I think it is the answer to some who have said that this country never moves quickly when something like this can be done in an environment which is reputedly and notoriously dusty — the professional engineering society — within the space of a few weeks. I think the combination of a professional society providing the platform and industry providing the actors is perhaps something to think about today.

Apart from immediate, pleasurable response, it has resulted in the formation of what I believe may be the first branch of a British engineering institution in the Middle East under the guise of the Arab Branch of the Institute. During the period 10–12 April this year, an inaugural conference has been organized which — and here I must express my gratitude to British industry — has been immediately and substantially supported by British industry in the preparation and delivery of technical papers. It is to be inaugurated by the Egyptian Minister of Maritime Transport.

I am sure that engineering institutions are going to change their shape. Fusion will take place: the type of service will change: and there will be a different form and different methods of conveying it, probably to different markets. I believe that the Institute is not only aware of this likelihood, but is trying to find ways and means of bringing it about in such a fashion that it is a controlled process.

I am sure that our organizations have not existed for, in many cases, a hundred years or more, only to find themselves lost for an answer to today's challenges. The ability of this country and its professional organizations to offer professional and technical services, and also to show leadership, probably has no limits. In this connexion I am not only talking of engineers or engineering. The entry into Europe by this country, for example, provided CEI with a challenge to see what it could do to help to achieve recognition for engineers under the terms of the Treaty of Rome. So far as I am able to judge, CEI can consider this one of its major successes. It has others to its credit, and I might be excused for mentioning the Engineers' Registration Board.

Unfortunately, recently there has been a good deal of ill-informed comment in the press which has not done the CEI or the profession any good. My only word on this subject tonight is that the Institute of Marine Engineers has been glad to do what it can to help solve the problems and it looks forward to helping in any way possible the successful future development of the Federation based on decisions taken during the latter half of last year. So far I have only spoken about matters which affect those presently on the stage: but we must not forget those who have retired and perhaps have found themselves incapable of coping with the difficulties of reducing money values, and possibly also ill health. The Institue, through its Guild of Benevolence, provides moderately for these people and their families who have spent their working lives in the environment of marine engineering. The Guild of Benevolence, unlike the Widow's Cruse, needs regular injection of funds and I am glad to take this opportunity tonight to ask those of you who are not members to consider becoming so, and those who are interested to remember the Guild and perhaps send it a donation. As we have so many chairmen from the Branches here tonight I particularly commend this thought.

Lastly I should like to take the opportunity of thanking all Branch officials for their untiring efforts, all voluntary, and on which the survival and strength of our Institute depends. It has been my privilege to be President of this Institute for the past eleven months. It has been my privilege to be in the Chair at this dinner tonight: I have enjoyed meeting many of you, old friends and new. May I express the hope that you have found the evening a happy one yourselves, and I thank you for joining us tonight. *(Prolonged applause).*