Large Gas Turbines - the Insurance Aspects (Update)

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Introduction

In the course of the last decade gas turbines have emerged as a core component of modern power plants. Key for this development has been the structural change of important power markets along with the rapid progress in technology, i.e. the fields of aerodynamics, cooling, combustion and materials. In a combination with improved thermodynamic cycles, standardisation and optimised production processes, manufacturers succeeded in strongly upgrading efficiency, power output plus environmental compatibility on the one hand and, on the other hand, in drastically reducing installation costs. These trends have been followed by growing need for insurance of gas turbine power plants.

The following paper, which is based on an earlier IMIA-publication /14/ tries to give a run-down of these developments, large industrial gas turbines serving as examples. Most reflections concentrate on 50 Hz models. Statistics and loss examples help to analyse the impact of the latest developments on typical loss mechanisms, their frequency and costs involved. On this basis some proposals on loss prevention, underwriting considerations and also a depiction of future prospects are given.

Content

Market Situation

Gas Turbine Power Plants

Over the last decade the world-wide power plant markets have been characterised by the trend towards the opening and privatisation of important electricity markets. An increasing number of power plants are being ordered and operated by Independent Power Producers (IPP's) or as merchant plants. Influenced by strong competition, capital spending decisions are mainly governed by cost criteria, e.g. lowest investment costs or short amortisation periods as well as minimal operation and maintenance costs. As a consequence of this phenomenon and the progress in technology as well as the growing availability of natural gas, more and more power plants use gas turbines for electricity and heat generation.

As can be seen from Figure 1, the gas turbine capacity yearly sold rose from less than 10 GW/p.a. in the middle of the eighties to more than 70 GW/p.a. in 1999. These figures correspond to a share of gas turbines in the total capacity, which climbed from 20 % to more than 50 % in this period of time. When speaking of gas turbine power plants, both single cycle and combined cycle applications are meant.

Since the begin of the nineties, continuous strong competition and overcapacities dropped the prices down by approx. 50 % to less than US$ 400/KW for a turnkey combined cycle plant. In the meantime due to a gas turbine order boom from U.S.A. this fall in prices has stopped and prices have stabilised. In parallel to this development, manufacturers were more and more forced to grant very comprehensive guarantees regarding efficiency, output, emissions and availability.

As a consequence of the economic environment, manufacturers reacted by continuously improving the technology of their range of products. The introduction of ever larger and more efficient units, the implementation of low-cost standard solutions and a logically consistent pursuit of homogeneous product families demonstrate this trend.

A further reaction of the manufacturers is the permanent optimisation of their business processes. This includes outsourcing development activities and the production of essential plant components as well as a constant adaptation of personnel to order situation. Contrary to the development process for aircraft engines, with large industrial gas turbines for cost and time reasons time-consuming prototype tests before release for series production were reduced or even rationalised away. Completely new machines or components are frequently installed and tested for the first time with selected customers. In parallel, series production starts up, identical machines are manufactured, shipped and erected. This procedure, however, requires both overcoming expected starting problems with the prototype plant and the timely implementation of necessary corrective actions in all other machines of the fleet.

During the last two years there has been a massive reorganisation of the big players. Siemens took over Westinghouse, an immediate competitor. Mitsubishi, partner of Westinghouse so far, successfully proceeded in supplying gas turbines for the 50 and 60 Hz market. ABB sold its power generation segment, gas turbines included, to Alstom and thereby disappeared from this market segment. Simultaneously Alstom's former activities in large gas turbines were transferred to their original license holder GE. By taking over several of its former license holders or packagers like Alstom, EGT, Nuovo Pignone or S&S, over the last years GE has increased its turnover in this field of business over proportionally.

So far, GE and their license holders have reached an average of approx. 40-50 % of the newly installed gas turbines per year, whereas the remaining producers share the rest. The next years will show, rather interestingly, the influence of the current restructuring processes on the market position of the manufacturers.

Altogether, the technical and commercial advantages of gas turbines, their flexibility and development potential will lead to a big share of the new power plant business in the near future relying on this technology.

Insurance

The insurance market had to follow the changing requirements of the insured's needs, resulting - for example - from the delivery contract. Some trends within the insurance market have basically been driven by following forces

- Principal's controlled polices instead contractor’s owned policies
- Advanced Loss of Profits has more often become delivery contract requirement
- Growing influence of the lenders seeking for wider covers
- Changing local legislation, opening of markets
- Availability if possible of one comprehensive cover for various lines on business

These trends have led some insurers to develop new products such as the BOT Policy (Build-Operate-Transfer), BOO Policy (Build-Own-Operate) or Comprehensive Project Insurance Policy and respective Comprehensive Machinery Insurance Policies. These policies provide multiline cover through the different marine/erection/testing and operational phases considering the interests of all project parties involved.

Development in Technology

Since the end of the eighties, gas turbine technology has taken a tremendous step forward in development. This section will describe some of the important technical progress regarding performance figures, development strategies and model development, the large 50 Hz industrial gas turbines being used as an example.

Principally and according to the well-known basic rules of thermodynamics, the performance or efficiency of gas turbines is increased by raising the average turbine inlet temperature (TIT) and simultaneously optimising the pressure ratio. Since 1990, the hot gas temperature measured at the inlet of vane 1 has been raised from 1200 °C to almost 1500 °C. In parallel, the pressure ratio has gone up from approx. 12 bars to up to 30 bars with the present industrial gas turbines.

This improvement of the gas turbine cycle parameters during the nineties was achieved on the one hand by the introduction of completely new gas turbine models and on the other hand by a continuous development of the existing series (see fig. 2). For instance, the presently largest gas turbines models, the so-called F class (i.e. GT26, V94.3A, PG9531FA, 701F), have undergone substantial upgradings nearly every second year. The technical achievements from prototype engines were also used to modernise the proven E-class models (i.e. GT13E, V94.2, PG9171E, 701D). Even though this procedure offers undeniable advantages, questions came up regarding the risk involved and the logistic efforts required by this high speed of model development. The logistic efforts for new models have been increased already by the fact that in order to resolve teething troubles, some components had to be touched up again and again. Sometimes it might even appear as if every machine is unique whilst having the same designation.

Nowadays the majority of modern gas turbines are offered as part of a standard power plant configuration whereas hitherto the basic components of a power station have been optimised individually and tailored to the client's requirements. The standardisation of the whole power plant allows, in addition to cost saving, a better comparison of experience and as a consequence, at least theoretically, a minimisation of risks. Nevertheless, the benefits of modern high-tech gas turbines in some cases contribute towards an application into individual plant concepts e.g. in integrated gasification combined power plants (IGCC) or pressurised fluidised boilers (PFBC) and are also suitable for operation with alternative fuels such as naphtha or medium caloric gases. The risks involved in such applications have to be analysed carefully.

Compressor and Turbine Design

The use of new computing tools (CFD, CAD, CAM) has supported technical and organisational progress with aerodynamics and design of gas turbine components. For example, the development of improved compressor blade profiles made it possible to simultaneously increase air inlet flow, compressor efficiency and pressure ratio. Thus the new machines reach much higher pressure ratios, whereas the number of stages and main dimensions of the compressor remain practically unchanged. In conjunction with similar improvements to turbine aerodynamics, the realisation of minimised blade clearances and the use of more efficient sealing elements have contributed towards a significant increase of the gas turbine's efficiency.
These computing tools also allow a widely computerised design of gas turbine components. This means that time-consuming and expensive tests and thus development times could be reduced clearly over the last decade.

So far, the admissible gas temperature at the turbine inlet is limited by the thermal load capacity of the hot gas components and particularly the technology of the first turbine stage. By introducing a whole package of measures it has been possible to raise this temperature drastically. For instance, the permissible operating temperature of the blade materials could be raised by 50 to 100 K by changing over from polycrystalline casting material to directionally solidified (DS) blades or single crystal (SC) blades with anticorrosive coatings /1/. Simultaneously, thanks to the insulation effect, the application of thermal barrier coatings (TBC) on the surface of the blades made it possible to further increase the hot gas temperature by approx. 50 K, the temperature of the basis material remaining unchanged. A similar increase of the hot gas temperature could be reached by introducing modern cooling technologies derived from aircraft engine technology. Topics are "Shower Head", "Full Coverage Film", "Serpentine Cooling" and "Diffusor-shaped cooling holes" (see figure 3).

Modern turbine blades are rather complex systems and are made in a series of complicated manufacturing processes. The price of individual guide vanes and blades may easily reach the price of a middle class car. If, for reason of design optimisations, the casting form has to be changed, processing times of 2 years are common. As very strong development tools are available with the modern three dimensional computer simulations, the knowledge about the stresses of blades in design conditions is excellent. Based on this, safety margins on new turbines could be reduced to a minimum. Currently the sensitivity of such turbine blades and vanes greatly requires an exact control of all operating parameters. Even small deviations, for example of flow conditions, cooling parameters or hot gas temperature, may lead – contrary to earlier systems – to severe problems or even failure of the component. Moreover, issues such as lifetime or repair methods with directionally solidified or single crystal blades have not yet been completely resolved.

Combustion Systems

During the last decade significant improvements have been made in the field of burner systems. The NO_x-emissions formed in the combustion chamber have meanwhile decreased from several 100 ppm to less than 10 ppm without additional water or steam injection. The breakthrough was achieved by the end of the eighties, when instead of the standard diffusion type of burners, lean premix burners have been introduced. In principle these burners consist of a mixing zone, where the combustion air and the fuel are homogeneously premixed and a separate reaction zone where the flame is stabilised. The combustion process is controlled on such a way that so-called "cold" flames of approx. 1500°C are generated and thereby nearly no thermal NO_x is built up.
Since the turbine inlet temperature of stationary gas turbines is tending more and more towards 1500°C, which, in terms of emissions, is the preferable flame temperature, the requirements for the combustion chamber design have become significantly higher. It is nowadays necessary to have an almost airtight combustion chamber and to pass nearly all the combustor air to the burners to reach such low flame temperatures. Big silo combustors traditionally used by European manufacturers have been replaced by compact annular combustion chambers in order to minimise the cooling surface area and to smooth the temperature profile at the turbine inlet simultaneously. The design and cooling concepts of the combustor liners currently vary strongly between the manufacturers. ALSTOM and GE use convectively cooled combustion chambers made of metal sheets while Siemens-KWU use ceramic, nearly uncooled heat shields. Mitsubishi and Siemens-Westinghouse, in turn, test closed steam cooling systems for their transition pieces (see figure 4).

With the modern lean premix combustion systems the stabilisation of the flames in the whole load range and during fast load variations, the prevention of flashback into the premix zone and the reduction of thermoaccoustic oscillations proved to be rather complicated and problematic /4/. Since the available theoretical models are not yet capable of calculating these complex processes and the lowest emissions are reached close to the lower stability limit of the burner, the burner systems turned out to be adjusted and optimised empirically in risky and long-lasting tests in the field. The manufacturers are experimenting with systematic variations of fuel distribution, flow conditions as well as passive and active damping systems. In most cases the operational safety of the burner systems has to be monitored by means of additional instrumentation. Due to the increase of the turbine inlet temperature and through the permanent tightening of legal emission regulations, the technical success reached with combustion systems has in most cases been compensated immediately over the last decade. A good deal of additional attention is required if liquid fuels or synthetic gases are burnt instead of natural gas.

New Cycle Concepts

Since the outlet temperature of combustion chambers has almost reached 1500 °C with the newest models, the traditional, classic method of improving the efficiency by increasing the turbine inlet temperature seems to have reached its limits by reason of the emission problems. To overcome this dilemma, manufacturers are currently focusing their development efforts on improved gas turbine cycle concepts.

The future gas turbine models of GE, Mitsubishi and Siemens-Westinghouse provide a partial substitution of the air cooling by closed steam cooling systems. GE for example will cool both stator and rotating blades of the H-models by steam. Whereas the advantages of steam-cooled transition pieces, which are used in the current G-models of MHI and Siemens-Westinghouse, primarily focus on keeping the emissions low, the application of steam-cooled components in the turbine will at the same time make it possible to increase the gas turbine and the combined cycle efficiency. Provided a constant combustion chamber exhaust temperature, the firing temperature and thereby the efficiency rises, the more the turbine cooling air is saved or replaced by steam. Figure 5 outlines this principle with the example of a steam-cooled turbine vane 1. In this case the firing temperature increases for 111°C, the combustor exhaust temperature remaining at a constant level. The steam for cooling is usually taken from the heat recovery steam generator, led into the gas turbine casing or rotor and after being heated up in the elements to be cooled, fed back into the steam cycle. The steam cooling concept leads to highly integrated cycle systems, which only make sense in a combined cycle power plant.

The introduction of steam-cooled gas turbines might be even more complicated than was, and still continues to be, the case with the present large-size gas turbines of the F-class. When designing and constructing steam-cooled gas turbines, special attention has be paid to:

- New sealing elements in stationary or rotating components
- Choice of appropriate materials and coatings
- Provision of adequate heat transfers, e.g. at sharp edges of turbine blades
- Prevention of steep temperature gradients
- Definition of the required steam quality and the provision thereof
- Control of steam parameters and mass flow rates under operation.

Alstom has developed a meanwhile successfully tested reheat cycle concept on the GT24/26 know as sequential combustion (see figure 6) /5/. Through the application of a second combustion chamber after the high-pressure turbine, an optimisation of the thermodynamic cycle becomes feasible. The standard formula, according to which an increase in efficiency in the presence of comparable component technology can only be reached by higher turbine inlet temperatures, can thus be avoided. The greatest challenge of this conception is in the development of the second combustion chamber, running at an essentially higher inlet temperature and a lower oxygen content than is normal, comparable to the conditions of an after burner in military engines. Due to this additional combustion chamber the complexity of the gas turbine rises, which is, however, compensated by increased efficiency and optimal partial load operation performance.

Loss Experience and Loss Mechanisms

Data Base

The following analyses revealing typical loss experience and loss mechanisms is based on Allianz risk records with gas turbine projects. The data base providing the statistics mentioned hereafter supplies information on

- Project-specific information (plant, client, policy type)
- Technical information (plant type, gas turbine model, operation parameters)
- Loss information (loss extent, component causing the loss)
- Proximate cause (design failure, quality problem, operational failure)
- Repair or replacement costs (property loss), business interruption

The evaluation obtained on gas turbine claims is based on 393 major losses equalling a loss amount of US$ 535m, representing only property losses and neglecting BI losses. All losses occurred between 1990 and 1999. We only evaluate the real repair costs and not the indemnifiable costs. In case the loss data are incomplete, the missing information was replaced to the best of our knowledge and belief. Only major losses, where the repair costs exceed the sum of US$ 125.000, are taken into account.

The gas turbine in this evaluation comprises the thermal block, the air inlet and the exhaust gas system. Electric systems, the generator, the waste-heat boiler or buildings are not considered.

Loss Records

Figure 7 is a graph showing the loss expenses between 1990 and 1999. This study distinguishes between the losses which occurred during erection plus test phase and losses during the operation period. Since 1994 an unexpectedly high increase of losses can be noticed. As of 1995 losses remain at a high level of more than US$ 50m p.a. This substantial increase in costs can be mainly attributed to losses occurring during erection and the test phase of new power plants. During commercial operation, i.e. after hand-over from manufacturer to operator, the total loss amounts have risen less dramatically in the course of the years, in spite of usual fluctuations. Our further loss evaluations therefore only take into account the erection and the test phase of large industrial turbines.

When comparing the chronological development of gas turbine losses with the sales figures in figure 1 and assuming that statistical data are based on a roughly constant market share, loss amounts should have had a relatively continuous progression. Assuming that the price collapse for new plants during this period would also apply to spare parts prices and repair costs, decreasing loss repair costs should be expected. However, since this obviously does not prove to be the case, either loss frequency or loss repair costs or even both have risen disproportionately as of 1994. Both the chronological congruence of increasing losses and the overall supply of the market with new large industrial turbines are conspicuous. To explain this observation, figure 8 shows the loss figures during erection and test phases, broken down by technology or firing class as outlined in figure 2 (E- and F-class). As can be clearly gathered from the diagram, the strong increase of loss expenses after 1994 can indeed be widely attributed to the large new gas turbines of the F-class. Whereas loss frequency and relevant claims amounts of older proven models almost remained constant, these parameters significantly increase for the new models since their introduction to the market and, in 1998 the expenses for loss repair of these models reached a new peak of US$ 38m. As already mentioned, this development can partly be attributed to the growing market presence of these models. But nevertheless some critical review seems to be legitimate considering that both the market introduction and teething troubles should be over by now and the new models normally should be regarded as proven technology.

Figure 9 shows the development of the average repair expenses per event for both performance classes. As expected these expenses are significantly higher for new models than for proven ones. The average repair costs for the E-class models reach approx. US$ 1.2m per event. Due to the more sophisticated technology - especially with the turbine blades - the average expenses for the new large gas turbines are US$ 1.7m per event. These high total loss amounts during erection and testing can rather be attributed to middle-size frequency losses than to individual major loss events.

Loss Analysis: Causative Components; Loss Examples

When analysing losses, one possible focus will be pointing out the loss initiating components. Figure 10 shows the percentage of loss repair costs due to the main components whose failure gave rise to the damage. In addition some typical loss events are described to illustrate the diagram.

Proven Models

The older proven models supply the expected scenario: In 50 % of the losses suffered the reason can be found in a failure of the turbine. The majority of losses are due to manufacturing and erection failures, so-called foreign object damage (FOD), but the reason can also be faulty design or operating conditions that differ from the intended layout. More than 30 % of all damage can be attributed to losses caused by the combustion chamber. Flashback of the flame into the burners, local overheating of combustion chamber parts and cracks are among the typical failures. Often combustion chamber damage whose costs are manageable lead to immense secondary losses at the turbine blades. In most combustion chamber losses there is a close relationship with complications when introducing lean premix burners due to high combustor pulsations or faulty operation. Only 12 % of the losses have their origin in the compressor. Here, damage caused by foreign objects resulting from poor assembly and erection quality represent the majority. Auxiliary systems and rotor construction only produce a minority of the major losses.

New Large Models

The current large gas turbines make a significantly different showing. In simplified terms, losses are mainly caused by compressors, combustion systems and turbine, each accounting for 30 %. The remaining 10 % is equally distributed among failures with auxiliary systems and the rotor structure.

A large part of the compressor damage results from design faults, insufficient clearances, erroneously calculated relative expansion during operation or insufficient safety margins with regard to natural frequencies. Since in most cases the effects of such failures do not become obvious during the first test runs, often many machines of the same design have been delivered and put into operation before these problems have been recognised. And, prior to the availability of relevant analysis and solutions, serial losses will happen. Figure 11 illustrates another type of loss mechanism, the effects of foreign object damage to the compressor. In this special case, a bolt of the air inlet duct, which wasn't properly tightened during erection, caused the damage.

The reasons of losses originating in the combustion system can be compared with those above-mentioned losses relating to proven models. In this case safe operational margins of lean premix burners play a crucial role. Again the secondary costs of the turbine damage exceed those of the burners or combustion chambers clearly. The fact that the highly stressed turbines are very sensitive to problems that result from the combustion chamber has frequently entailed total losses of the turbine. Figure 12 shows a turbine loss originating in the combustion chamber. In this case the personnel adjusting the operation concept of the burner made a fatal programming error. Due to a typing error, a fuel valve opened completely for a short period of time and led to a massive overheating of the turbine. While burners and combustion chambers were nearly unaffected, the turbine blades had to be replaced.

We are glad to say that the turbine itself contributes only slightly to the losses with new models. This might be due to the particular care the manufacturers and plant operators take with these elements. By frequent and regular inspections the blade condition is surveyed very well and intolerable variations such as local overheating, vanishing coatings or cracks are recognised in time before the whole component fails. Therefore manufacturers, plant operators and insurers are in most cases confronted with additional costs regarding the reduced turbine life and additional replacements. Figure 13 shows turbine blades whose coating already flaked after short operation.

To give an example of rotor damage, figure 14 shows a turbine disk from which small particles have broken off. This damage was caused by transient conditions during start-up which were not considered in the design. This type of problem occurred several times in different engines before a proper solution of the design was introduced into the fleet. Besides the very high costs for the necessary replacement activities major incidents could be avoided in all cases by the use of sufficient online monitoring systems.

The failure of an apparently simple component, i.e. the expansion joint, is shown in figure 15. In this case a faulty installation produced intolerable tensions in the component and finally led to its breakdown. Since meanwhile such simple defects have occurred frequently, it is quite obvious that many of the notified losses cannot be attributed to the complexity of the new technologies but were caused by inadequate erection quality.

Loss Analysis: Causative Processes

As mentioned in the beginning all gas turbine losses are assigned to typical categories of causes. In the following section we distinguish between 3 different loss categories:

- Design
- Quality
- Operation

The aim of this distinction is to provide some proposals for efficient loss prevention. Often the assignment to the different categories is not quite clear and in isolated cases manufacturers and operators may have divergent views or assessments. However, due to the multitude of incidents, occasional uncertainties should not influence the overall impression.

The 1st category comprises all design faults discovered with the first prototypes of a new model or a new component. So far, 34 % of all loss repair costs for large gas turbines can be attributed to this group (see figure 16). To reduce these problems manufacturers are requested to further improve their development processes. In most cases, however, the new technologies do not give rise to major problems but the increased incidence of design errors that, at the first glance, seem to be relatively simple. Therefore we suggest carrying out more component and prototype tests, wide case and parameter studies and the provision of a wider range of safety margins in design. Even though this could involve higher costs for development projects, we maintain that higher investments for reasons of cost and image already pay the manufacturers in the medium term.

The second category comprises damage that could have been avoided by better management during the project execution phase. Here apparent quality failures are meant. To remedy this kind of failure it is necessary to qualify and motivate the staff more and, at the same time, to implement and apply those quality and process regulations that are widely available. An ISO 9000 Certificate only helps to improve the situation if all staff involved pursue the idea of quality as a central goal of the company. Realistic time and personnel management constitute an important prerequisite to reach this.
Damage arising from design errors one year after they first appeared in plants of the same type also belong to this 2nd category. Such serial losses could be avoided through a longer testing phase of the prototypes ahead of series production. Of course, optimum feedback of experience and implementation of improvement measures could be significant milestones. The number-one requirement is that there must be a professional product team collecting all information on current problems, defining and solving these problems and suggesting suitable strategies for the implementation of the "lessons learned" into the fleet. On the other hand, only realised implementation plans will yield favourable results. Thus, this means a challenge for suppliers, clients, operators and insurers. An improved project organisation, more transparency and frankness or a more realistic assessment of risks originating in new technologies could have helped to avoid quite a number of recent losses. As regards serial losses, non-availability of spare parts, e.g. of turbine blades or of rotor components, frequently led to unnecessarily long repair periods or even to an increased risk when continuing to operate slightly affected equipment. As a consequence, we recommend maintaining a sufficiently large stock of spare parts when introducing a new gas turbine type. In this context, increased product stability or a lower introduction rate of measures to boost the output would have a positive influence both on clarity and costs of spare parts stocks. Since 50 % of all loss expenses known to us can be attributed to the 2nd category, this offers, quite obviously, the biggest potential for improvements.

The 3rd category comprises operational losses, i.e. losses caused by faulty operation, natural disasters, fire or early wear. Approx. 16 % of all damage during the erection and testing of a new plant can be attributed to this category. A more sophisticated plant design, e.g. one that provides adequate redundancies and a fully automatic diagnosis programme routine, could contribute towards long-term improvements. Sometimes it is even sufficient to operate fire extinguishing systems already before the testing phase.

Conclusion and Outlook

Technology

From loss experience with the latest models of gas turbine plants we may conclude :

- The introduction of new technologies in gas turbines has not led to insoluble problems during the past years and we do not expect this in the future. Nevertheless the loss statistics made it very clear, that the "technology race" during the last decade was followed by a raising number of large insurance cases.
- The majority of design errors occurred in less critical components. This, however, needs to be improved. The extremely expensive loss series caused by failures of these components should give rise to increased care and attention to all elements and aspects of a gas turbine during their development and manufacture.
- It is indispensable to reach a significant reduction of so-called quality and serial losses. All persons involved should proceed a little more conservatively. In most cases, the belief that a new model makes all desirable technical progress possible, that the costs of production, development, erection and testing can be minimised simultaneously and in addition, high availability can be reached immediately after market introduction, turned out to be mistaken. In future, manufacturers are requested to clearly define priorities and targets for their new products and to provide sufficient resources for the development and to overcome teething problems. At the same time plant operators can also positively influence these problems i.e. by training their staff already during the erection and testing phases.
- We expect and hope that the loss frequency of the current top models of the 250-270 MW class (50 Hz) will decrease successively for all of the manufacturers. Even though there is still enough potential for improvement, most of the basic problems now seem to be solved. Major new problems coming along with future upgrades of current models can be reduced as long as manufacturers and operators take into account the lessons learned.
- With respect to the F-class models, in future the focus has to be on the lifetime extension of hot gas components and the development of improved repair and reconditioning procedures to achieve the predicted operation costs. Improved efforts to reach greater operational safety of the components, i.e. burners, must be made.
- With the current order boom for gas turbines the future availability of sufficient spare parts and repair capacities could lead to severe problems with business interruption of such power plants.
- During the next years another considerable challenge regarding gas turbines can be predicted when large steam-cooled combined cycle power plants are introduced. Their performance will reveal whether the manufacturers have learnt from the experience they have gained recently. The information available up to now gives rise to such hopes. The question of quality has been given more attention, components have been tested for years with prototypes. Some of the manufacturers even plan to run a prototype plant under commercial conditions over a long period before starting serial production

In view of these developments, insurers will also continue to play a decisive role by accepting new power plant risks and they will have to offer increased technical service in such projects.

Underwriting Considerations

The following underwriting considerations and conclusions may be considered as a supplement to IMIA papers 16-59 (93)E /15/ and IMIA 16-70 (98)E /14/. Since then, as outlined above, the market developments (including pricing of power plants) and their product developments have led to a stronger impact on power plant risk exposures, which in day to day underwriting should have been reflected within the underwriting terms and conditions. While the gas turbine technology has further improved its advanced technology was not always transferred and considered within the underwriting philosophy.

- This was due to the down cycle within the industrial business which has also affected the power plant business. Furthermore, the scope of cover has widened and deductibles have decreased. Today the underwriting considerations and recommendations of IMIA papers 16-59 (93)E and IMIA 16-70 (98)E have become a even more meaningful guideline than ever.

- Under the above mentioned circumstances it seems difficult now a days to achieve overall positive underwriting results, unless the market changes into a harder market. This would allow reasonable testing and maintenance deductibles, especially for prototype gas turbine-sets driven by new technology, for example using steam cooled engines.

- Regular uprate and upgrade developments of gas turbines have made it more difficult to define and distinguish prototype engines from proven machines. In this context reference is made to the prototype definition of IMIA paper 16-70 (98)E.

- Active and passive risk management, monitoring and services will considerably contribute to a common understanding of critical features and therefore allow new technology to be regarded as an insurable risk.

- In a summary, neither the competitive situation nor underwriting approaches have changed, however for engineering insurers and re-insurers it has become vital to keep pace with the technical developments. Only a sufficient pricing will determine in the near future if insurers can afford to continue to cover new turbine technology.

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Figures

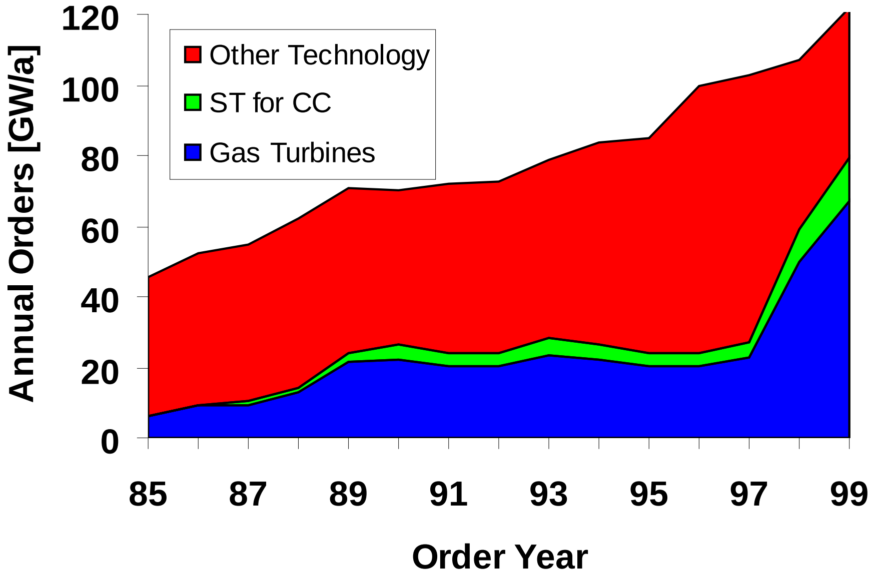

Figure 1: Development of the annual orders for power plants (source: Alstom)

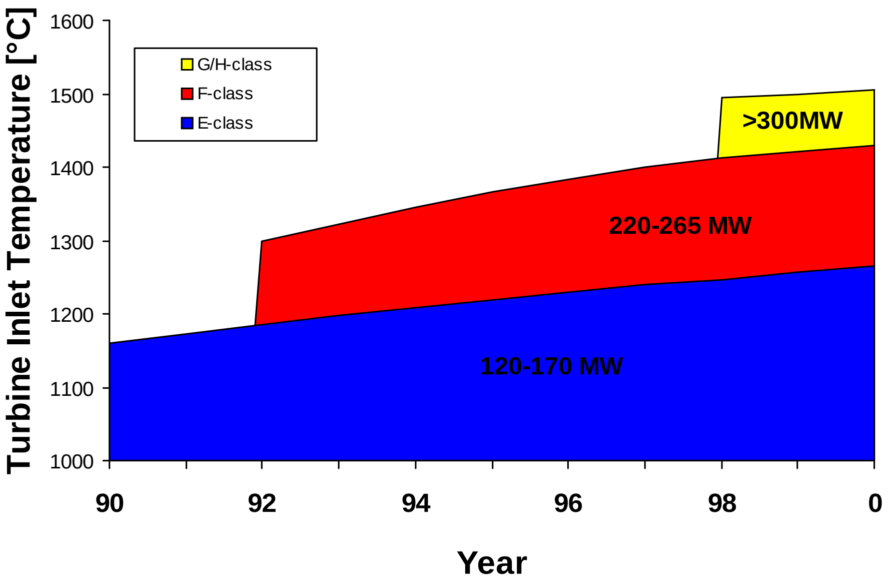

Figure 2: Development of the gas turbine inlet temperature, measured upstream of vane 1

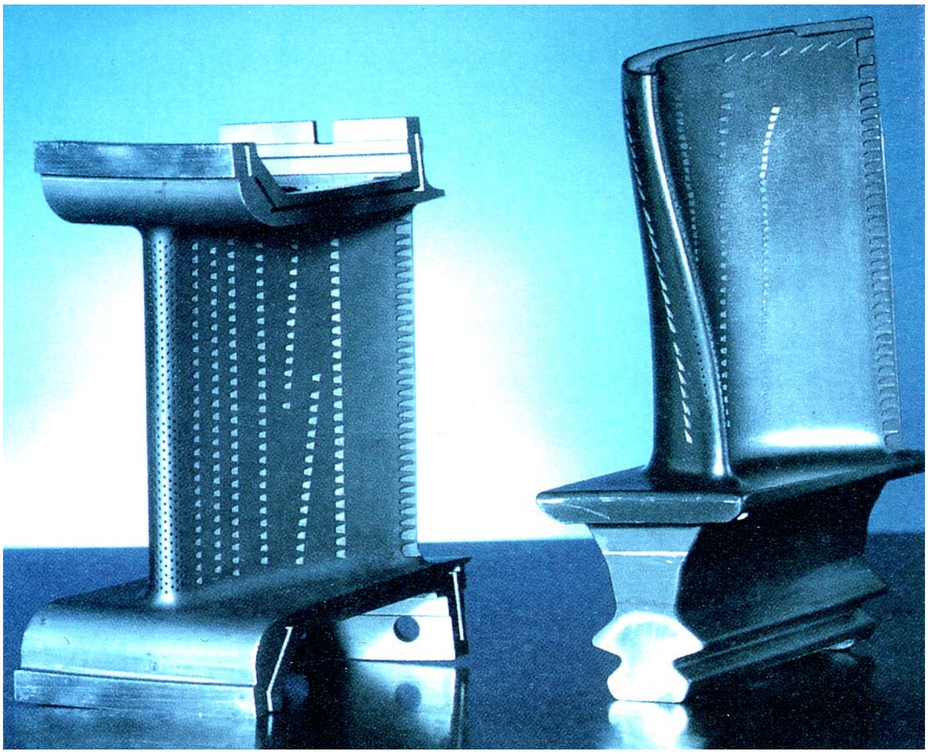

Figure 3: Example of a modern gas turbine vane and blade (source: Siemens)

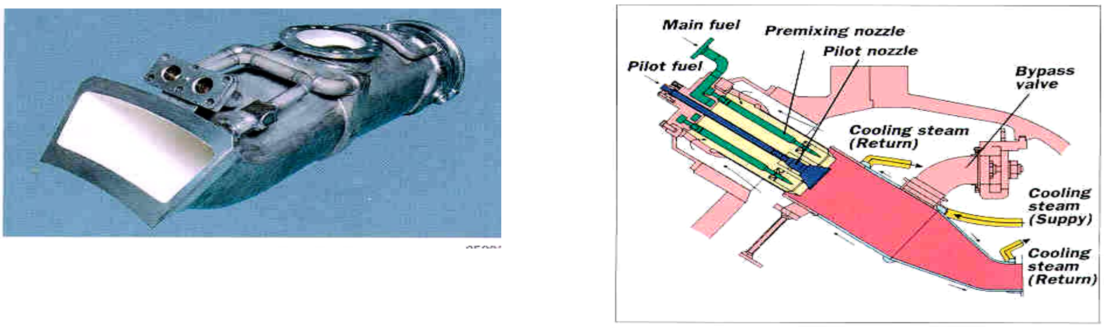

Figure 4: Lean premix burner with steam-cooled combustion chamber (source: MHI)

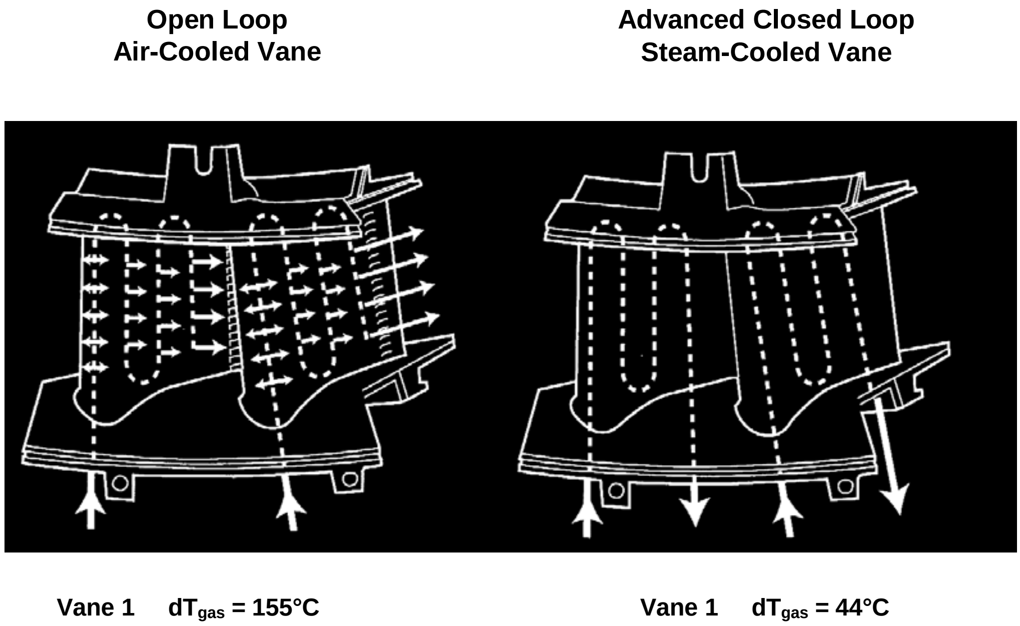

Figure 5: Principle of a steam-cooled gas turbine vane 1 (source: GE)

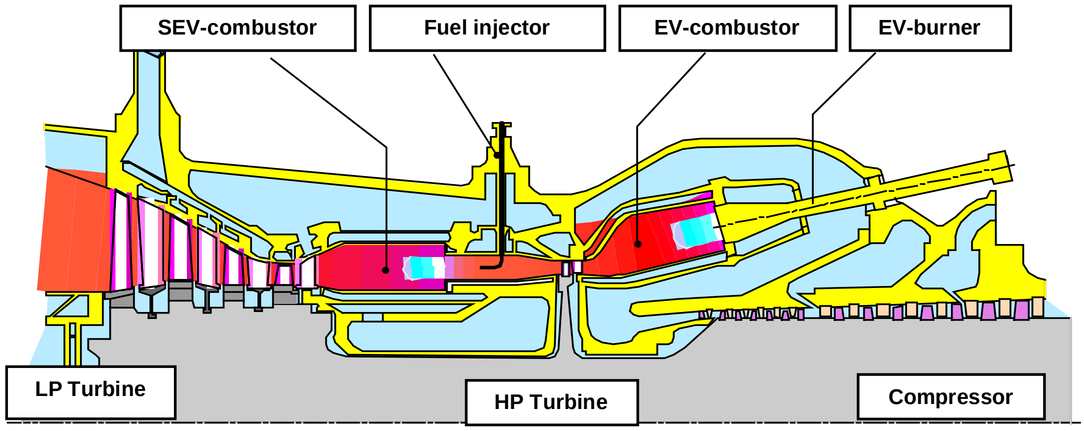

Figure 6: Basic drawing of Alstom GT24/26 (source: Alstom)

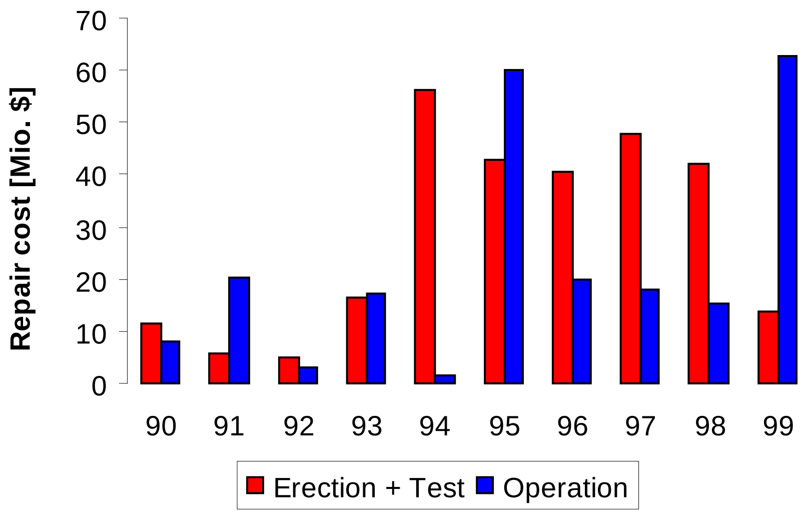

Figure 7: Development of repair costs for gas turbine losses

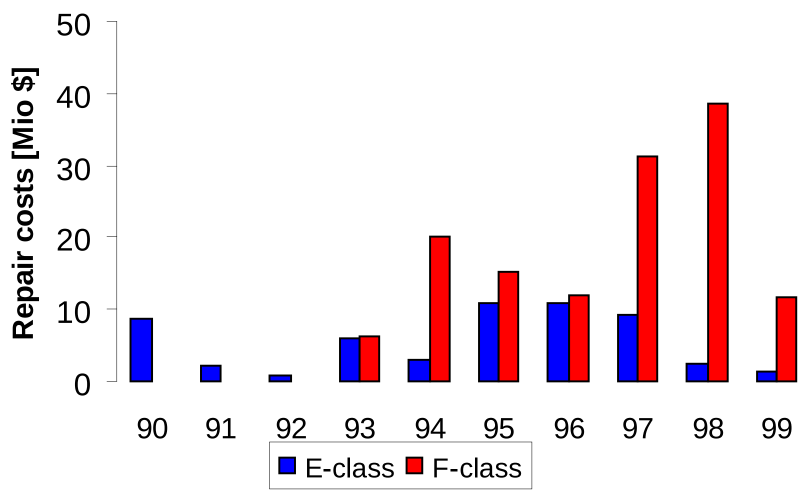

Figure 8: Development of repair costs during erection and testing of large industrial gas turbines

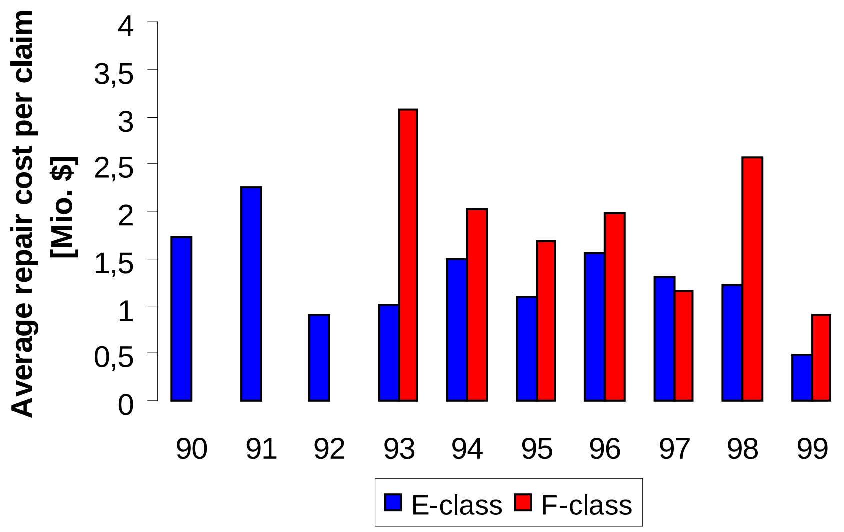

Figure 9: Average repair expenses per event for large industrial gas turbines

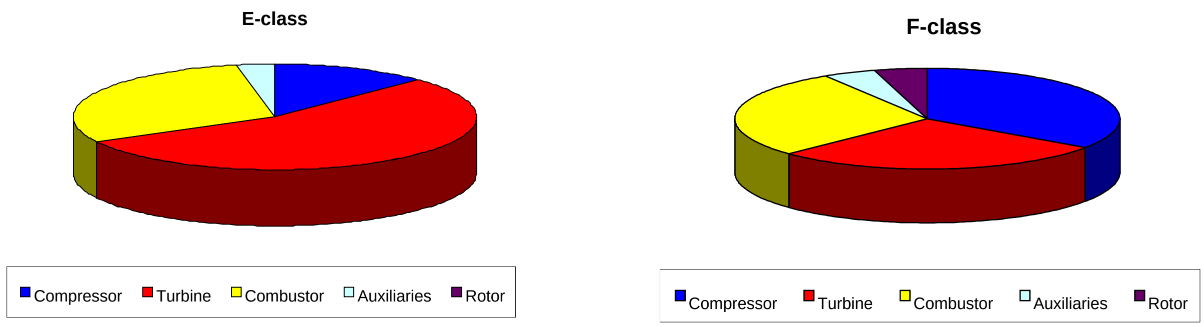

Figure 10: Percentage of losses caused by various components for large industrial gas turbines

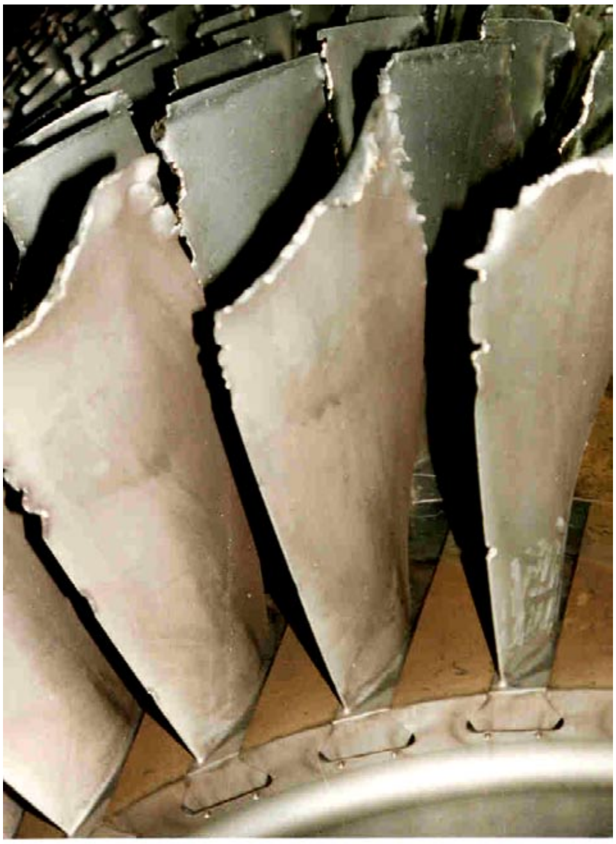

Figure 11: Compressor damage caused by foreign object

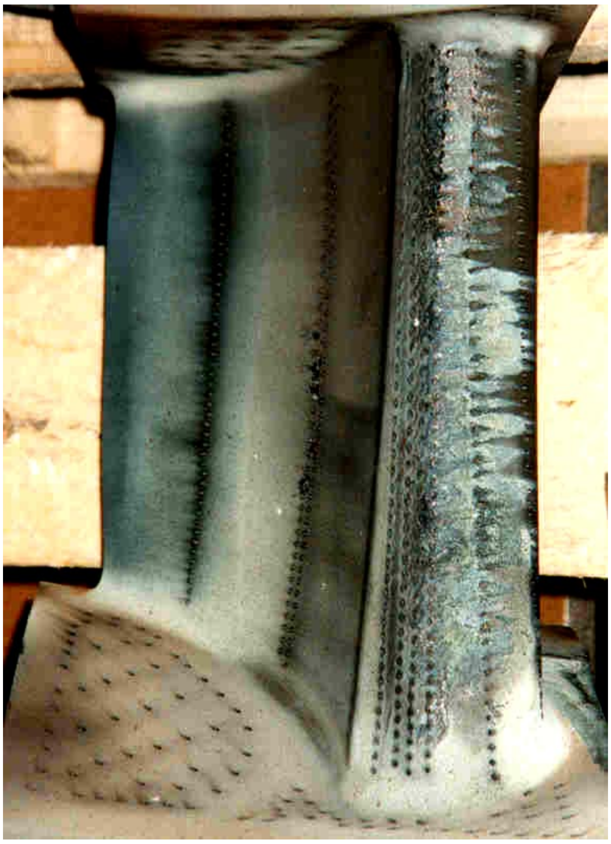

Figure 12: Turbine blades overheated by faulty burner adjustment

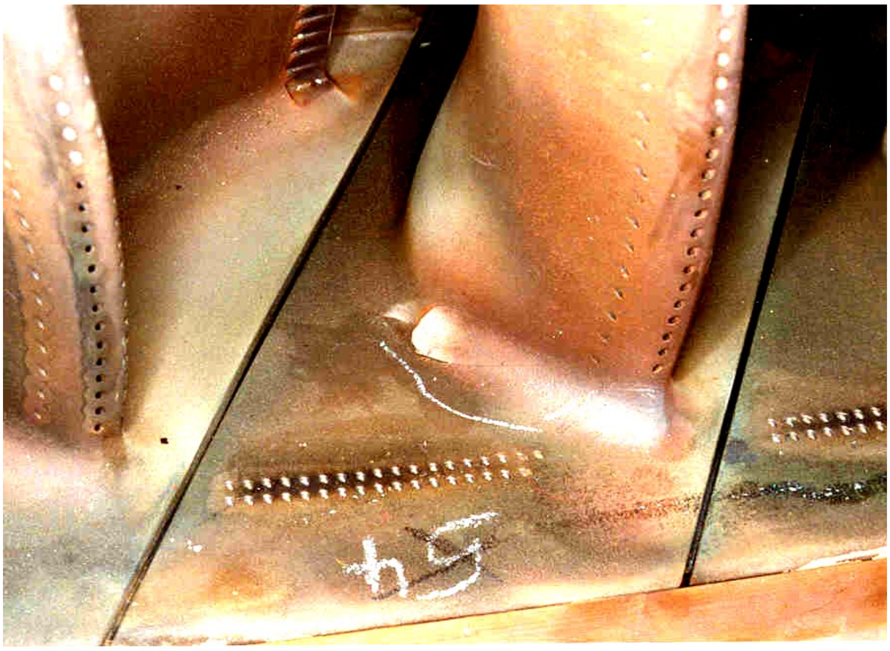

Figure 13: Flaking of coatings from turbine blades

Figure 14: Damaged turbine disk

Figure 15: Cracked compensator of gas turbine exhaust

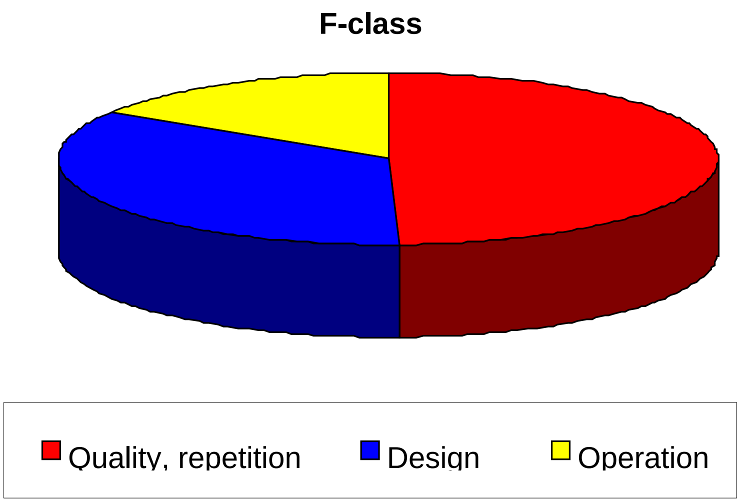

Figure 16: Typical categories of losses of large industrial gas turbines