CONSTRUCTION OF A FIXED LINK BETWEEN FRANCE AND THE UNITED KINGDOM.

"THE CHANNEL TUNNEL"

A PRESENTATION TO THE 1990 CONFERENCE OF THE INTERNATIONAL MACHINERY INSURERS ASSOCIATION, TORONTO, SEPTEMBER 1990

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At the 1989 IMIA Conference reference was made to the Channel Tunnel and considerable interest was shown in the project itself and its insurances.

It was proposed that the 1990 Conference might include an informational presentation on the project for the construction of the fixed link between UK and France. This could include a brief history of the project, a description of the work being undertaken, an analysis of progress achieved at that time, and a review of the insurance aspects. Messrs.Bardon and Davies were in a unique position to make such a presentation as their companies are the joint leaders of the Project Insurance Policy and each has a personal management role in relation to that involvement.

The proposition was favourably received by the conference delegates and Messrs.Bardon and Davies have accordingly prepared a presentation which will be made to the 1990 Conference in Toronto.

This has not been undertaken as a 'Working Party Study' in the normal tradition of IMIA but is intended as an opportunity for delegates to acquire an enhanced knowledge of a project which, when complete, is likely to have a significant impact on the political and economic future of Europe. A project which has presented challenges to engineers, financiers, and of course, insurers - and which continues to arouse great public interest within Europe although more especially in the two countries most directly concerned.

These notes do not therefore comprise the report of a study group but are intended to complement the presentation, and, together with the other material made available to delegates at the conference should give an impression of the technical and insurance challenges presented by the concept of the historic joining of the British Isles with the Continent.

Some of the delegates to Conference are officials of insurance companies who have a participation in the project insurances. Those companies will have already in their possession a great deal of the information we will be referring to. Our aim during the course of the presentation will be to identify and discuss the main areas of interest and to bring the status of the project (and the insurances) as up-to-date as communication technology permits.

Others of the delegates may be considering the implications of this project and its insurance requirements for major infrastructure developments in their own markets. It is appropriate therefore to comment at this stage on the opportunity presented by adherence to IMIA for international co-operation and exchange of information on an informal basis. There is a particular example to cite here in the context of the Channel Tunnel.

A very early stage of consideration by Commercial Union and Union des Assurances de Paris of their joint tender for the project insurances of the Channel Tunnel coincided closely with the 1986 Tokyo Conference of IMIA. There was an awareness in general terms in Europe of the problems experienced during the construction of the Seikan tunnel in Japan but as this had not been insured (being a Government financed project) there was little hard fact to indicate to what extent the Japanese experience provided precedential evidence of what might be relevant for European tunnellers and their insurers. The opportunity of IMIA contact during that conference was taken to ask the Japanese delegation for information that might be more readily available to them.

This they were kind enough to organise and a considerable amount of data was provided to France and the UK as a result, which enabled the Japanese project and its problems to be clearly technically differentiated from the European one.

Facts and figures available on this project could fill a substantial volume. In addition to a great deal of published material which is freely available to the general public, the British and French leading underwriters on the project insurances amassed a considerable quantity of information as a pre-requisite to quotation and acceptance. Since then, this information has been amended and up-dated as many aspects of design and working methods have evolved. As with many projects in the 1980's there are 'fast-track' aspects to this project which means that detailed design had not been established before the start. New information on selected methods of approach to each major aspect of the work has to be assessed as it becomes available.

In these notes we will provide some relevant facts and figures to give an indication of the scale of the project.

HISTORIC DEVELOPMENT OF THE FIXED LINK CONCEPT.

There is a saying in English which aptly illustrates the paradoxical attitude of the inhabitants of the British Isles towards their mainland European brothers. "Fog in Channel - Continent isolated".

The people of France have always been more enthusiastic than the British to 'bridge' this gap.

The channel separating the South East corner of England from the North East of France may only be 21 miles at its narrowest point (34KM) but this has represented for centuries a far wider psychological barrier.

Mass travel opportunities presented by Ro-Ro ferries and (relatively) cheap air transport have partially lifted the physical barriers. Membership of the European Community has begun to break down the psychological ones. Completion of the Fixed Link in 1993 will accelerate the process.

The Fixed Link concept is not a product of this generation. A visionary in 1802, M.Matthieu is said to have first conceived the idea and proposed it to the French Emperor Napoleon, although it stayed an idea. A further scheme in the late 19th century led to tunnelling being started in 1880 when Colonel Frederick Beaumont and Captain Thomas English of the Royal Engineers devised a tunnelling machine and completed almost 2KM before fear of invasion caused its abandonment. Tunnelling from the French Coast was completed to the extent of some 1.7KM.

Wars intervened to prevent any serious reconsideration of the project until the 1920s when it was briefly revived only to fall out of favour again until the 1970s. A contract was signed in November 1973 for the first phase of the Channel Tunnel construction including 2KM of service tunnel with a driven diameter of 5.27M. An artist's impression of the projected system in a newspaper article of February 1973 shows a remarkable similarity to the current construction - twin rail running tunnels linked by a central service tunnel. The estimated contract value was £600M for the finished job.

In the early 1980's investigations began into the possibility of the construction of a Fixed Link financed by private capital. Discussions between the Governments in 1984 and 1985 led to an 'Invitation to Promoters' dated April 1985 to submit proposals within certain guidelines to develop finance construct and operate a Fixed Link across the Channel.

The ideas presented by serious engineers ranged from the conventional to the bizarre. Huge bridges descending on artificial islands to plunge into a central tunnel section were proposed.

The Government opted for the relatively proven conventional approach proposed by Channel Tunnel Group Ltd. and France Manche S.A. to construct and operate a twin bored rail tunnel linked by a central service tunnel. Mrs.Thatcher and President Mitterand announced their decision in Lille on 20th January 1986.

Economically the proposals appeared more viable than the alternatives and the proposed construction methods had been developed from tried and proven techniques. Valuable lessons had been learned from the aborted 1973 start.

The project cost as estimated in the construction contract issued on 30th June 1986 would be £2.55Bn based on 1985 prices although this figure was expected to increase during the construction period.

As this presentation is given the converging cutting heads of the British and French service tunnel machines are only some 3.5KM away from a truly historic moment of breakthrough to create the first dry land connection between England and France since prehistoric times.

BASIC DATA

THE PROJECT

The design procurement construction testing, commissioning and maintenance of the works for the Fixed Link between the United Kingdom and France.

Essentially the project concerns the creation of a transportation system by means of a rail link between Cheriton (in the South East corner of England near the port of Folkestone) and Frethun, near Calais in the North East of France.

The Fixed Link comprises twin bored rail tunnels for the greater part of its length totalling 49.2KM. Each tunnel with a finished lined diameter of 7.6M carries a single standard gauge railway track on which will run passenger, and vehicle carrying trains. These trains will be of two distinct types.

Firstly the purpose designed shuttle trains owned and operated by Eurotunnel and built to a much larger loading gauge than either British or French railway systems permit. These in turn will be of two distinct types - those used for the transportation of private cars and their passengers - vehicles being carried on two decks within enclosed wagons and the expectation that passengers will remain with their vehicles during the 35 minute transit. Secondly, a very different looking heavy goods vehicle carrier train comprising wagons capable of transporting 44 tonne articulated trucks. These latter will be of open lattice construction capable of speeds of 130 kph.

The other generic type of train to use the system will be through trains of the National systems of Britain and France which will feed into the closed loop shuttle circuit at either end permitting through services without interruption within the wider European network.

The running tunnels described are located either side of a central service tunnel, finished diameter 4.8m, and linked to it by cross passages at intervals of 375m. To counter the problem of pressure build-up ahead of trains in the running tunnels, piston relief ducts connecting the running tunnels directly are constructed at intervals of 250M.

The 49.2KM of route is apportioned 3.7KM under land in France, 36.5KM under sea (the longest undersea tunnel in the World) and 9.0KM under land in the UK. These distances include at the French terminal end a short distance of cutting and at the UK terminal end a cut and cover section between two hills, and a section constructed by the New Austrian Tunnelling Method through a hill immediately before the terminal area.

The geological formation of the sea bed of the Channel at the shortest crossing point between England and France has been the subject of various detailed surveys over the years.

As part of the preliminary research for the Project, a new study of all available geotechnical information was carried out, covering every area where work was proposed. Particular attention was given to those lengths of tunnels where an increased possibility of fissuring was indicated. Information came from earlier survey work on the geological conditions in the relevant areas, as well as from existing records.

The studies show that there are three principal strata along the chosen route of the Tunnel.

The Upper Middle Chalk comprises fractured chalk and it was anticipated that water would be encountered in fissures which are characteristically found in such strata. The Chalk Marl, which is part of the Lower Chalk, comprises a combination of clay and chalk and is a virtually impermeable stratum ideal for tunnelling. The Gault Clay, while also impermeable, is weaker.

The route and alignment of the tunnels were planned, so far as is consistent with operational requirements, to locate the maximum length of the tunnels within the most favourable medium and to minimise, wherever possible, construction in disturbed or unfavourable ground conditions. In the undersea section, it was planned to bore approximately 90% of the tunnels through the Chalk Marl. The depth below sea level varies.

The construction programme reflected the progress expected in the varying geological conditions. Chalk Marl provides an excellent tunnelling medium, as is demonstrated by the fact that, even though it is unlined, the tunnel commenced on the UK side in the 1880s has retained its structural integrity.

Despite the availability of the comprehensive geological data gleaned over the years, as a matter of prudence, Eurotunnel in conjunction with Transmache Link, made further detailed exploratory studies both on and off-shore. This was used to verify the existing information and confirm the exact location of the line of the tunnels.

To create operational flexibility and reduce interruption to services through track and tunnel maintenance there will be two undersea crossovers where trains can switch between running tunnels.

The UK crossover cavern has been excavated some 7.5KM from Dover and is a structure 163M long by 21M wide and 15M high. At this point the service tunnel diverts from its central position to a location at the side of and below the crossover. The corresponding structure on the French side at a point 12.5KM from shore has not yet commenced construction.

Tunnel Boring Machines.

French Side

Five tunnel boring machines are used, two for the pilot tunnel - one for land, one for seaward drive; and three for the rail tunnels - two for the seaward and one for the land drive. The closed faced machines are designed to withstand an external water pressure of 12 kilogrammes per square cubicmetre. The landward service and south running tunnel drives have been completed. The south running tunnel TBM has been turned round at the terminal end to carry out the return bore.

English Side

Six tunnel boring machines are used, two for each of the three tunnels, one of which will be used for the land drive and the other for the seaward drives. Because the ground conditions are better, these are open-faced machines, that is to say, there is a gap between the machine face and the last tunnel segment.

TBM values vary between £3M and £6M for the UK machines and up to £10M for the more complex French machines which are required to cope with more difficult ground conditions.

Access for tunnelling at the closest practicable position to the coast is by an improvement to the 1974 sloping adit system at Shakespeare Cliff Dover and by a newly constructed vertical access shaft 75M deep and 55M diameter at Sangatte.

Whilst the tunnels represent a major portion of the construction work for the Fixed Link they constitute only about 50% of the construction cost.

The remainder is taken up by the equipment, particularly the shuttle trains, signalling, track, control systems etc. and the construction of the terminals.

The Cheriton terminal is limited by the surrounding geography to some 150 hectares (in itself a substantial area) which is the minimum practicable area in which to locate a run-round loop for the shuttle trains which can be up to 775M in length and accommodate the platforms and administrative buildings. The Frethun terminal has some three times the area available which permits the maintenance workshops and other facilities to be accommodated.

Ancillary services and equipment are to be found on all major construction projects. The Channel Tunnel is different only in degree.

Standby electrical generating capacity is provided at both access points.

Construction camps accommodate thousands of workers.

Almost 900,000 precast concrete tunnel lining segments will have been made in two purpose built factories. These will form the major part of the tunnel lining supplemented by cast iron segments in specific areas.

7.6M cubic metres of spoil has to be disposed of. At Dover this has been used to create a vital working platform at the tunnel access site. Near Sangatte a valley has been dammed to make a dumping area.

Fresh water shortages in S.E.England necessitated desalination plants for the work sites.

SAFETY AND UNDERWRITING FEATURES.

Safety means many things on a construction project. It means above all the management of the project in a manner which is efficient and effective, where planning and attention to detail in choice of method, quality of equipment, and selection and training of personnel are given a high priority. If this happens, accidents are minimised, damage and delay are contained, and workers and the public are protected.

Space was more readily available for the French side elements of the work and this has permitted less congested working areas and more logical layout (e.g. the precast plant being located immediately adjacent to the tunnel access shaft rather than 70KM away as in UK). Space availability and lack of congestion make for more efficient and safer working practices.

For good reasons Eurotunnel and the contractors discourage public access to the tunnel faces or access shafts. However, there is continual pressure to satisfy requests from 'important' members of the public who have an interest in the project. These have to be fitted in to a congested and potentially hazardous environment and their activities strictly supervised.

Public access to surface sites is controlled and limited to the extent that it is practicable to secure them.

Exhibition centres have been created at Folkestone (with an observation platform overlooking the terminal area) and Sangatte complete with audio-visual presentations, high quality informative and educational displays, models, and refreshment facilities.

The centres have become established tourist attractions which present a totally different type of safety (and material damage) risk to insurers.

As a generalisation the activities of greatest potential hazard to the public are well secured from uncontrolled access. The risks of injury to the public are otherwise regarded as normal or even lower than would be expected for major building and civil engineering works.

Public attention has been sharply drawn to the injuries and fatalities which have occurred - mainly underground, to employees particularly on the English side. There are differences between the working methodology, and of the technology employed by Translink and Transmanche Construction which may partly explain this. As a generalisation the French tunnelling procedures are more automated than the English ones although the different technology is also partly explained by differing geology!

The risk factors affecting the safety of the works vary according to the sub-divisions of the project already listed. The variation is far wider than normally found in project construction.

The pre-cast plants are operational factories presenting standard fire, perils and all-risks exposures after their initial construction and commissioning. Underwriters regard them as such and carry out risk control surveys pertinent to a property risk.

The terminal sites can be categorised as large scale activities representing (relatively) low risk other than to the constructional plant.

The main features of concern to underwriters were the extent to fill, surcharge and ground stabilisation needed - sites were inspected before any work commenced to assess this risk - and the bridge works both internal to the site and particularly in the case of the UK terminal the road and rail bridges linking the terminal area proper to the public systems which necessitated bridging a busy motorway.

When considering safety features of a project which includes the longest undersea tunnel in the world, thought is inevitably given to the risk of water ingress. One of the principal safety concerns of underwriters, and the one which produces the main Maximum Probable Loss scenario, is that of a Tunnel Boring Machine striking an uncharted borehole which has remained open to the surface. The extent of water inflow, time taken to implement recovery procedures, and extent of damage and delay anticipated were calculated as accurately as possible.

The Channel bed between England and France is one of the most extensively researched and probed stretches of seabed in existence. Boreholes have been drilled over many years for a variety of reasons. Many of these were intended to prove the geology for previously planned Channel crossings. All of them should have been plugged and charted. The risk remains that some were not. Even if not plugged the probability of one remaining open is low.

The service Tunnel Boring Machines have probed in advance to confirm the geology and to detect (hopefully) any such rogue drill holes - none has yet been found.

Quality control procedures exercised by the contractor and by suppliers have to be strict. The quality requirement for example of the tunnel lining segments is such that the dimensional tolerance is 0.1MM (100% achievement claimed) and the strength achieved is up to 100N/mm2 (14500psi) 90 days. Rejection rate from Grain is 1/1000. Design life is 120 years.

At the initial underwriting stage little had been decided as to the design and construction of the shuttle rolling stock.

We now have much more information regarding power size dimensions etc. of the locomotives and an outline specification of the shuttle wagons. Of prime importance to would be passengers, the safety equipment specifications are still being agreed with the relevant safety authorities.

ORGANISATION OF PROJECT INSURANCES.

The organisation of the Eurotunnel project insurances as a joint UK, French policy, covering British and French Insureds including the respective governments and quasi-government agencies, written and subject to interpretation in two languages and subject to either of two legal jurisdictions is unique.

The Treaty between UK and France giving effect to the Fixed Link proposal allowed the formation of a joint Intergovernmental Commission but there is no government involvement in the project as such and no government financial support for it.

Eurotunnel, the owner/operator or more properly the concession holder, was formed from France Manche SA and The Channel Tunnel Group Ltd.

The Maitre d'Oeuvre for the project is a joint venture of W.S.Atkins, and S.E.T.E.C.

The contractor for the project is a consortium of two joint ventures.

Transmanche Construction comprises Bouygues, Dumez, S.A.E., S.G.E. and Spie Battignoles.

Translink comprises Balfour Beatty, Costain, Taylor Woodrow, Tarmac and Wimpey.

Transmanche Construction and Translink together form Transmanche Link - TML.

Eurotunnel's insurance needs are managed by its Group Insurance Manager.

Eurotunnel employed a consortium of brokers to obtain competitive quotations, market and put in place the Channel Fixed Link Project Construction Policy. Those brokers are Sedgwick In London and Faugere & Jutheau and Gras Savoye in Paris.

Selected shortlisted potential lead insurers were invited to tender for the lead of this policy with the brief that they must be able to work together as joint leaders, produce a policy to satisfy the requirements of the various insureds, government, and supervisory bodies and manage the covers during the period of insurance.

Having worked together on the previous Channel Tunnel project CU and UAP offered a ready-made joint lead. After negotiation of covers and prices, and the clear requirement that coinsurance and reinsurance support could be obtained - the lead was offered to CU/UAP.

The policy wording was subjected to scrutiny by many interested parties.

As there was no precedent for a UK/French policy the French supervisory authorities had to be convinced that it was acceptable. (UK supervisory authorities do not intervene in such matters).

Thus an Anglo/French policy was created and gained official acceptance before Freedom of Services within the European Community came into force.

The CU/UAP underwriting and management team remains in existence and meets regularly to service the insurances.

The Project Policy is in three sections.

Section 1 provides Third Party Liability cover in the sum of £25M or FF equivalent. An excess layer placed separately takes total liability protection up to £100M. The coverage is broad but not exceptionally so.

Employer's Liability risks are covered in France by the social security system. The recourse risk is covered by the Project policy.

The UK EL risk is separately insured in the name of Translink and does not form part of the Project policy. Activities as diverse as the operation of the exhibition centres open to the public and the running of the precast factories are fully covered by the policy.

Section 2 gives material damage cover in respect of the works, the temporary works, plant and equipment, site camps, employees tools and effects. The cover is wide and extends to indemnify unintended damage resulting from defective design materials and workmanship.

Breakdown of construction plant is excluded but a tailor made wording brings back into coverage fire and external impact if resulting from, breakdown.

Tunnelling exclusions apply - dewatering, overbreak, loss in advance of the tunnel face. Limited sea/air transit cover is given within Europe.

A 72 hour clause is in place to interpret the deductible application.

Up to 24 months visits and defects maintenance is given but does not apply to the manufacturers risk for the procurement items (notably rolling stock).

Section 3 Delay in start-up. This cover was arranged to insure the Principal and finance providers only for a limited element of debt service in the event of significant delay caused by a peril insured by Section 2. It equates to approximately £1M per day and a maximum of approximately £250M. It is intended as a catastrophe cover excluding delays due to individual physical loss/damage events which take less than 14 days to repair or reinstate. Delays from losses requiring a longer period to repair or reinstate are subject to a deduction of 14 days and any excess contributes to a 90 day aggregate deductible. This complex formula was necessitated to provide the maximum catastrophe coverage within an available budget.

The policy period runs (construction phase) from 1.12.87 to 15.5.93 with an extension option of up to 12 months.

The premium for Sections 1 and 2 is adjustable on final contract price. CU/UAP's involvement did not start with the 1.12.87 inception date. Work had already started long before that date and a limited cover was required which was shared 50/50 between CU and UAP.

Further back in time CU provided (with help from the international market an unusual political risks policy which would have indemnified the promoters CTG Ltd. and France Manche SA for part of the costs incurred should the project not proceed because the enabling legislation (The Treaty between UK and France permitting the project to go ahead) not be ratified by the respective governments before 31.12.87.

Insurers often state with good reason that they are instrumental in providing a vital part of the financial structure which permits a project to proceed. In the case of the Channel Tunnel it was a clearly stated pre-requisite of the finance providers and the Governments that the prescribed insurances should be in place. The international insurance and reinsurance market responded by providing the necessary cover and capacity.

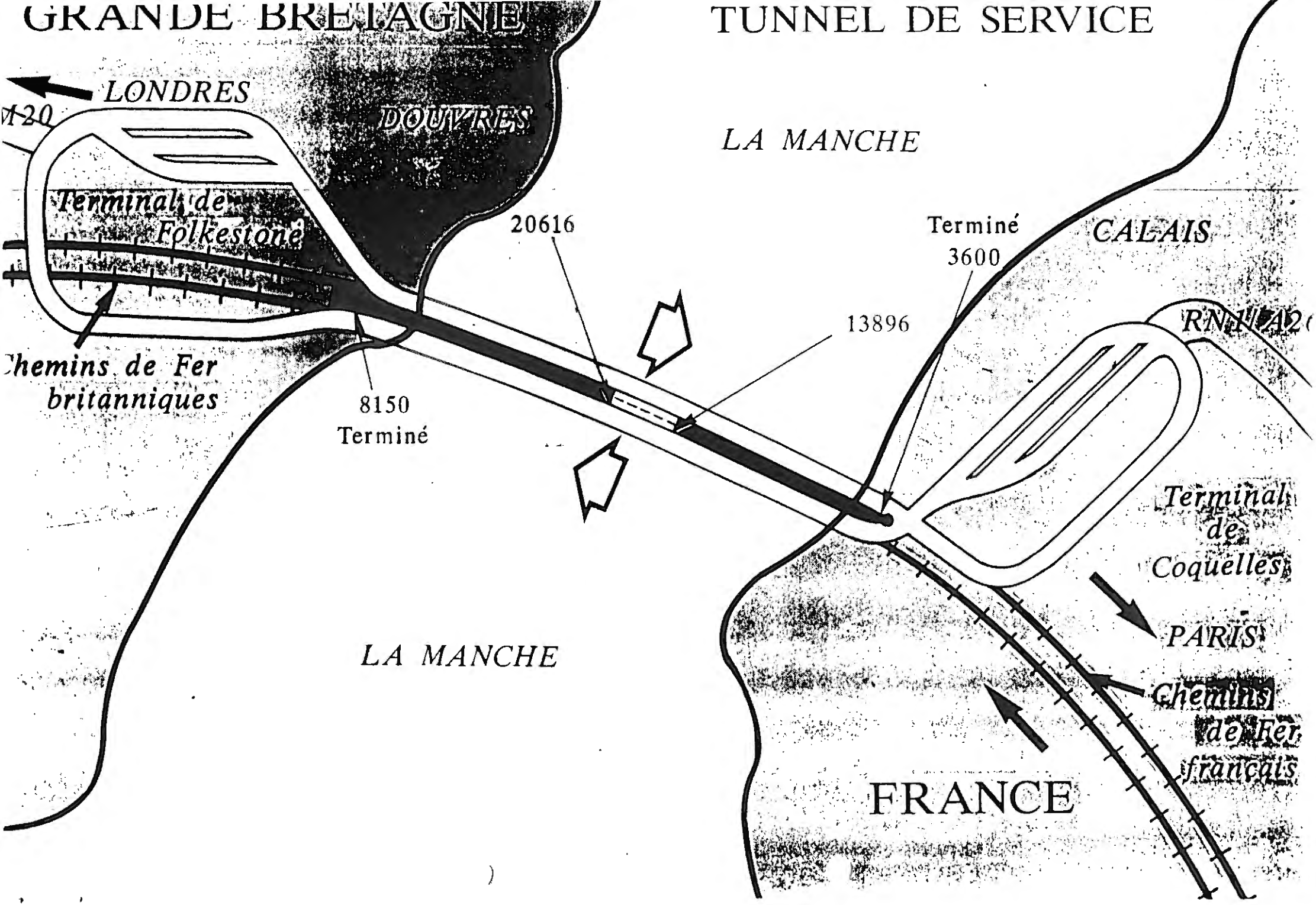
To protect Insurers' interests in respect of Section 3 of the policy a Progress Monitoring Consultancy Contract has been let to a joint Anglo-French team.

Their brief is to produce quarterly a report on project progress identifying the incidents which may lead to an eventual claim for delay in start-up and/or additional cost of working. At the same time to identify deviations from programme from uninsured causes which may postpone the commencement of commercial operations even in the absence of insured causes of delay.

PROJECT PROGRESS.

The presentation includes an update of tunnelling and general progress illustrated by slides and video material. Some 60% of total tunnel has been bored and lined. Excavation of one of the two crossover caverns is almost complete. Work is well advanced on the two terminal sites. Eurotunnel is predicting that the Fixed Link will open on the revised scheduled date of 15th June 1993.

Inevitably a number of problems have arisen during the tunnelling work which have required mechanical modification to the TBMs. Ground conditions have varied from those predicted but not significantly.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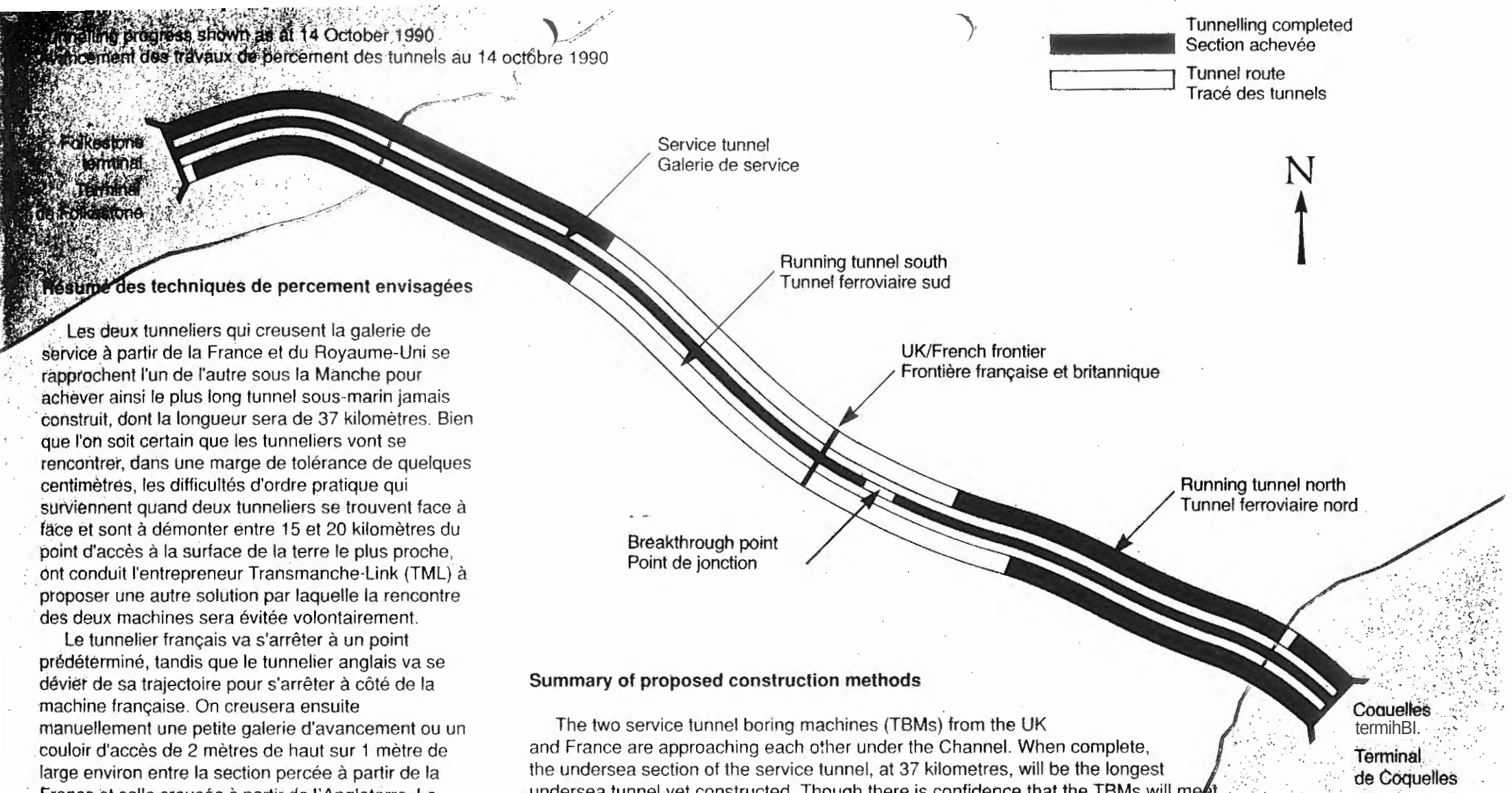

Résumé des techniques de percement envisagées

Les deux tunneliers qui creusent la galerie de service à partir de la France et du Royaume-Uni se rapprochent l'un de l'autre sous la Manche pour achever ainsi le plus long tunnel sous-marin jamais construit, dont la longueur sera de 37 kilomètres. Bien que l'on soit certain que les tunneliers vont se rencontrer, dans une marge de tolérance de quelques centimètres, les difficultés d'ordre pratique qui surviennent quand deux tunneliers se trouvent face à face et sont à démonter entre 15 et 20 kilomètres du point d'accès à la surface de la terre le plus proche, ont conduit l'entrepreneur Transmanche-Link (TML) à proposer une autre solution par laquelle la rencontre des deux machines sera évitée volontairement.

Le tunnelier français va s'arrêter à un point prédéterminé, tandis que le tunnelier anglais va se dévier de sa trajectoire pour s'arrêter à côté de la machine française. On creusera ensuite manuellement une petite galerie d'avancement ou un couloir d'accès de 2 mètres de haut sur 1 mètre de large environ entre la section percée à partir de la France et celle creusée à partir de l'Angleterre. La tête de coupe du tunnelier anglais sera murée pour toujours dans une masse de béton, et le tunnelier français sera démonté et ramené vers Sangatte. Du côté anglais, en suivant la nouvelle technique de percement autrichienne, on creusera alors la dernière section de raccordement à l'aide d'une machine d'attaque ponctuelle. On posera ensuite un revêtement constitué de voussoirs en fonte. Les derniers mètres seront creusés à proximité du point où va s'arrêter la machine française.

Summary of proposed construction methods

The two service tunnel boring machines (TBMs) from the UK and France are approaching each other under the Channel. When complete, the undersea section of the service tunnel, at 37 kilometres, will be the longest undersea tunnel yet constructed. Though there is confidence that the TBMs will meet within a tolerance of a few centimetres, there are practical difficulties if two tunnel boring machines meet head on and have to be dismantled 15 to 20 kilometres from the nearest surface access point. This means that tunnel contractor Transmanche-Link (TML) has had to come up with an alternative solution involving the two TBMs deliberately 'missing' each other.

The French TBM will stop at a predetermined location and the UK TBM will turn off to one side to end up beside the French one. A small heading or hand dug access about two metres high and one metre wide will be constructed between the two tunnels. The UK TBM cutting head will be left in place and concreted up, while the French TBM will be dismantled and removed to Sangatte. The final connection tunnel will then be completed working from the UK side, using the New Austrian Tunnelling Method with excavation carried out by a roadheader machine before cast iron linings are installed. The last 'wall' of the tunnel will be excavated near where the French TBM stopped.