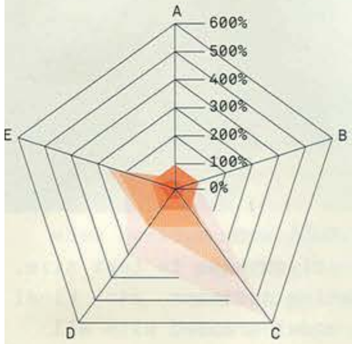


1.

CFRP (unidirectional)
GRP (unidirectional)
Titanium
Mild Steel
Aluminium
Oak (parallel to grain)

A DENSITY
B STIFFNESS
C TENSILE STRENGTH
D COMPRESSION STRENGTH
E FRACTURE TOUGHNESS

THE COMPOSITE HAS CHARACTERISTICS QUITE DIFFERENT FROM THOSE OF THE SEPARATE MATERIALS

By Bryan Harris

1. Comparison of structural materials, using mild steel as the base level for the different properties

Bryan Harris examines the structural use of fibre composites, which is illustrated with a case study on the carbon-fibre SNOFA overleaf.

Conventional materials are never as strong as we expect because they contain defects of various kinds which cannot be eliminated in practical manufacturing. The strength of bulk glass and other ceramics is determined not by their strong covalent bonds, but by the tiny pores or sharp cracks that exist on the surface or in the interior. The strength of any sample of a glass or ceramic is determined by the size of the largest defect or crack which it happens to contain, and the strength of the best bulk ceramic will rarely exceed about one thousandth of its theoretical strength. If flaw sizes can be reduced by control of the manufacturing process, the strength of the material will be raised and its variability reduced. One of the most effective ways of doing this is to produce the material as a fine fibre, and this has been achieved in the case of glass, carbon, and polymers. If these strong fibres are embedded in a matrix of some other material, such as a polymeric resin or cement paste, the resulting composite is a structural material with characteristics quite different from those of the separate components, and can be tailored to suit specific requirements.

The main reinforcing filaments currently used in structural composites are glass, carbon, and polymeric fibres, including aromatic polyamides like Kevlar and polyethylene. Most of these commercial fibres are obtainable in a variety of forms, including continuous tows, woven or braided tows, and chopped bundles.

These materials have profiles of properties quite different from those of other engineering materials. They can be made in forms that are highly anisotropic or they may be made isotropic and they must be used accordingly. The best (and most expensive) materials have high strengths and rigidities, but only in one direction. One of their most attractive features is that many composites exhibit very high levels of toughness. Some of the advantages of fibre-reinforced plastics are as follows:

- high strength/weight and stiffness/weight ratios compared with steel and concrete;
- rapid installation without heavy lifting equipment;
- resistance to harsh environments (hot, cold, wet, chemical);
- flame retardants can be added: fibre-reinforced plastics exhibit ablative properties in fire (like space-shuttle tiles) which increases the time available for evacuation of a burning structure;
- transparency to electromagnetic radiation;
- good impact and blast resistance;
- wide variety of surface appearances/finishes/colours (including optical transparency, if required);
- good-quality products normally require little maintenance (although they are not 'maintenance-free'); and
- excellent means of repairing/strengthening other materials by adhesive bonding.

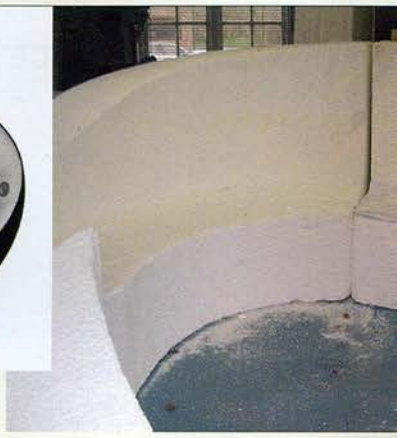
Bryan Harris is a professor emeritus of materials science at Bath University

CASE STUDY
CARBON-FIBRE SNOFA
Architect: Snell Associates

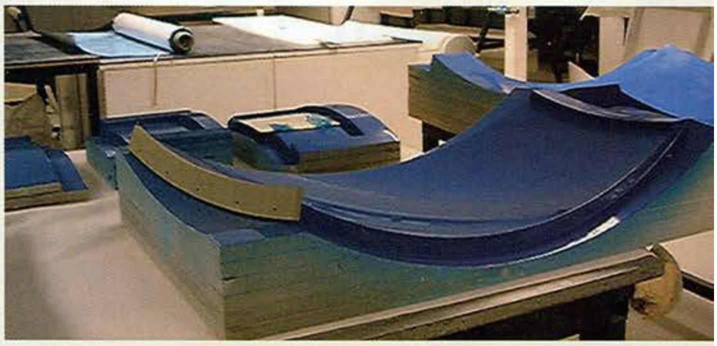
'We wanted to produce something truly comfortable, for several people to sit or recline on, with all the qualities of traditional comfort but made with the technology of today,' explains Robin Snell. 'It's very snug, but at nearly 3m in diameter it's rather more than a sofa, so we called it the SNOFA'. The SNOFA is an integral part of Snell Associates' reconfiguration of a penthouse apartment in London. The apartment has been stripped back to its original steel structure, reclad, reglazed, and fitted with a bespoke-designed interior for a client who was involved with every detail. The open-plan 'living' wing is divided by a purpose-made 'multi-function' unit, designed as a freestanding piece of furniture, 13m long and clad with black Macassar ebony. One side faces the kitchen and houses appliances; the other faces the living space with a dining recess, a media centre and a fireplace recess. The SNOFA is a polished black shell of carbon fibre (technically known as carbon-fibre-reinforced plastic, or CFRP). It encloses a curved seat large enough for a group of people to relax in upholstered leather comfort, either sitting or reclining, which is in front of the media centre. Raised armrests incorporate carbon-fibre tables. Inset into the back are recessed compartments for a telephone and a computer console – an AMX touch-screen-operated computer system which controls the environment, including opening the rooflights and the blinds and maintaining the Lutron lighting system, the air-conditioning, media, security and CCTV. The choice of carbon fibre – rather than the more obvious glass fibre – was dictated by the need to resist impact damage, especially at the tightly curved ends; in Snell's experience the major cost in both materials is that of the mould, and carbon fibre has the added advantage of strength. Visually it is also more attractive; the carbon-fibre material is a fabric weave impregnated with epoxy resin and in its completed state it is just possible to see the woven grain behind the polished surface.
By Susan Dawson

Furniture maker: Silver Lining Furniture
Mould making: The Cutting Room
Composite material engineer: Brookhouse Paxford
Leather upholstery: Farnham Upholstery
AMX system: D&T Electronics
Leather supplier: Moore & Giles Inc. USA

1. Concept and design developed by Snell Associates. Drawings and specification issued for pricing



2. Full-size mock-up made in polystyrene to test size, seating position, etc. Final 3D model created with all construction details agreed

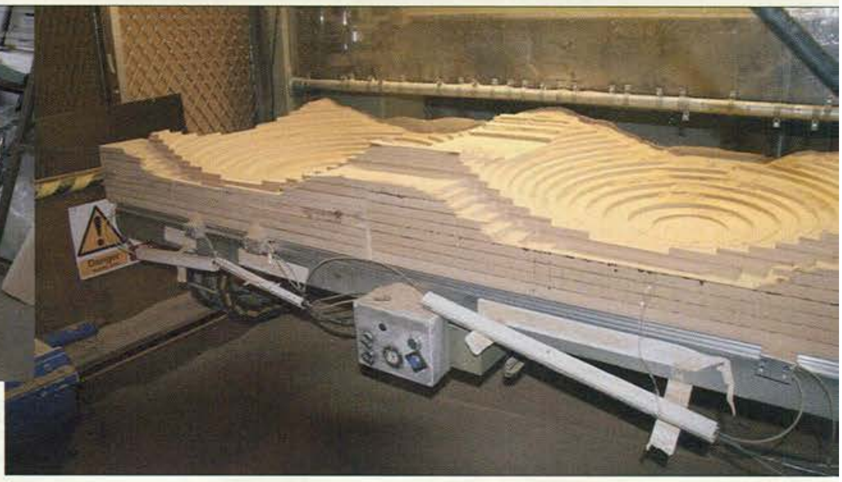


5. Two pre-impregnated carbon-fibre sheets plus a flexible foam core are formed around the moulds, using a process of vacuum forming and oven baking in an autoclave to create a 25mm-thick stressed-skin laminated composite panel of carbon, foam and carbon

8. Completed sections polished using polyurethane lacquer and cut back to a full gloss using fine cutting paste and lambs' wool bonnets on hand-held polishers

9. The upholstery is a traditional assembly of springs and wadding covered with stone-coloured leather hide

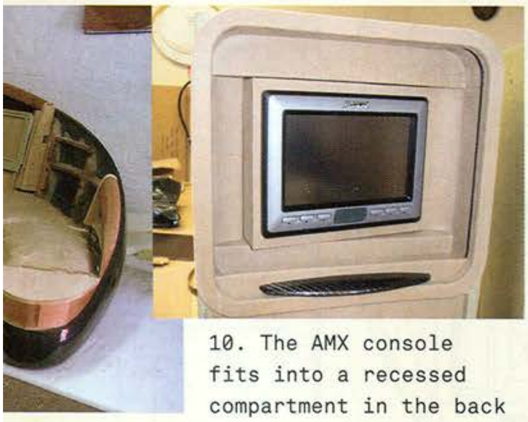
3. Part-section mock-up prepared in timber and fabric to test comfort/upholstery and technical aspects of construction, including detail of concealed AMX and telephone



4. Carbon-fibre moulds made from laminated MR MDF and shaped using a CNC router using information from 3D drawings. The moulds are surfaced with an epoxy coating and cut back to a smooth finish by hand

6. The panel is demoulded after curing; the release film and breather fabric have to be removed in a controlled and clean environment

7. Skeleton made from 18mm marine-grade ply components, cut with a CNC router. Finished panels bonded to frame with epoxy to produce rigid shell structure



10. The AMX console fits into a recessed compartment in the back

DENNIS GILBERT

11. The completed SNOFA is installed in the apartment

A SOFA WITH A CARBON-FIBRE SHELL

Due to its size – 3 x 2.8m – the SNOFA was prefabricated in six sections and made on site.

The curved carbon-fibre shell elements were bonded in the mould to 25mm rigid foam sheets, cut to accommodate the curved shapes. At the top edges the carbon fibre was wrapped over the foam so that the upholstered back seat could butt cleanly against it. The curved edge joints between adjoining carbon-fibre sections were radiused to take up the tolerance between the carbon fibre and the leather upholstery.

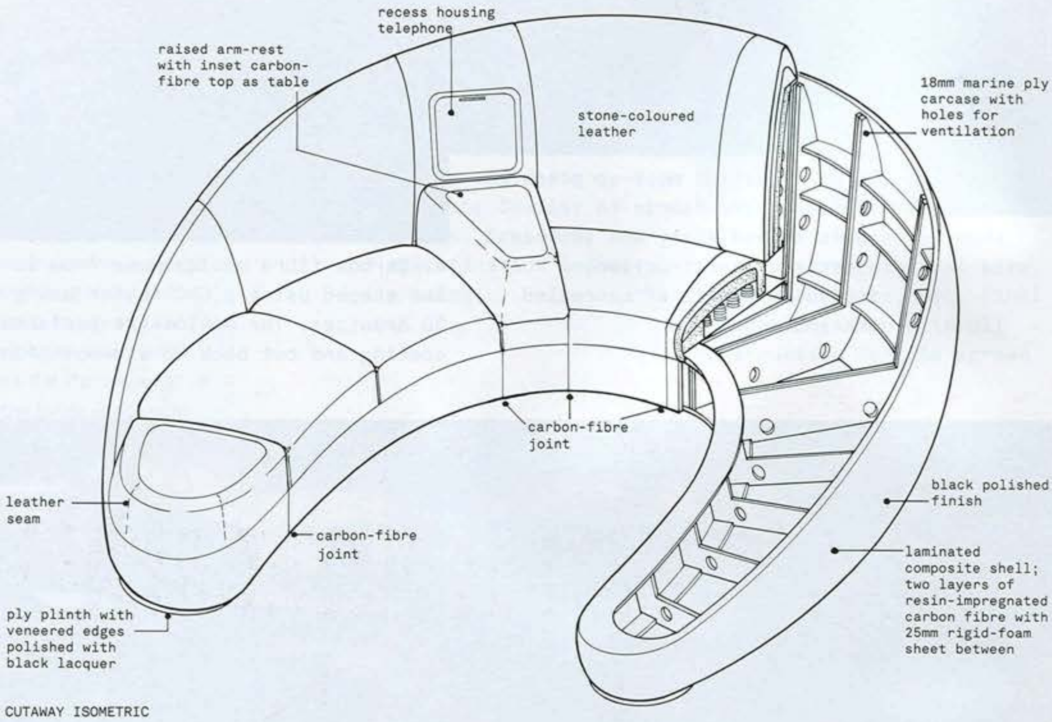
A skeleton frame of 18mm ply sheet was then fabricated and bonded to each shell section with epoxy; the frame has slotted holes to ventilate the AMX console and telephone. Ply seat frames and back frames were then fixed to the skeleton. The curve of the back frames came from laminating 1.8mm-thick ply sheets together.

An assembly of traditional upholstery seating – springs, wadding, calico – was finished with a surface of high-quality cowhide leather, much of it hand-sewn to achieve the tight curves.

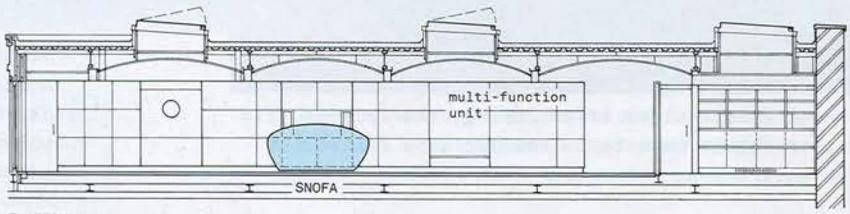
The AMX console and the telephone are housed in recessed compartments of ply, each fitted with a sliding door of curved aluminium clad with rolled and finished leather.

On site, the Snofa sections were bolted together through adjacent ply skeleton frames, and the seat-back upholstery panels were locked in place.

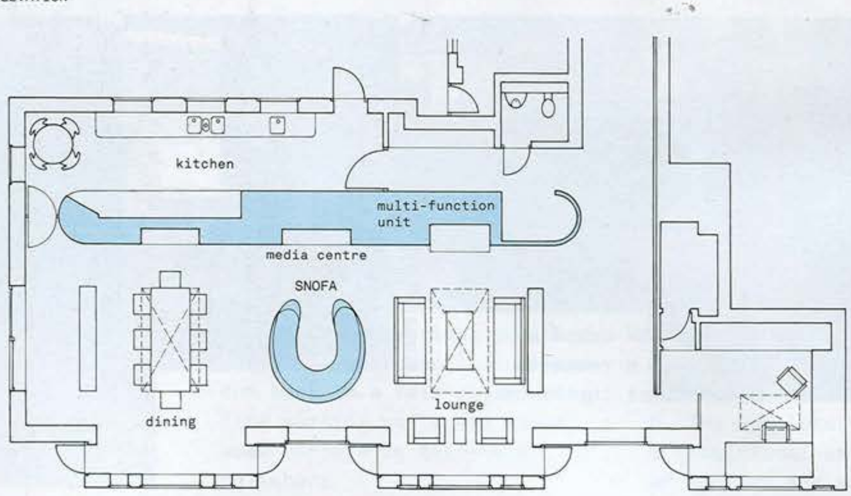
Susan Dawson



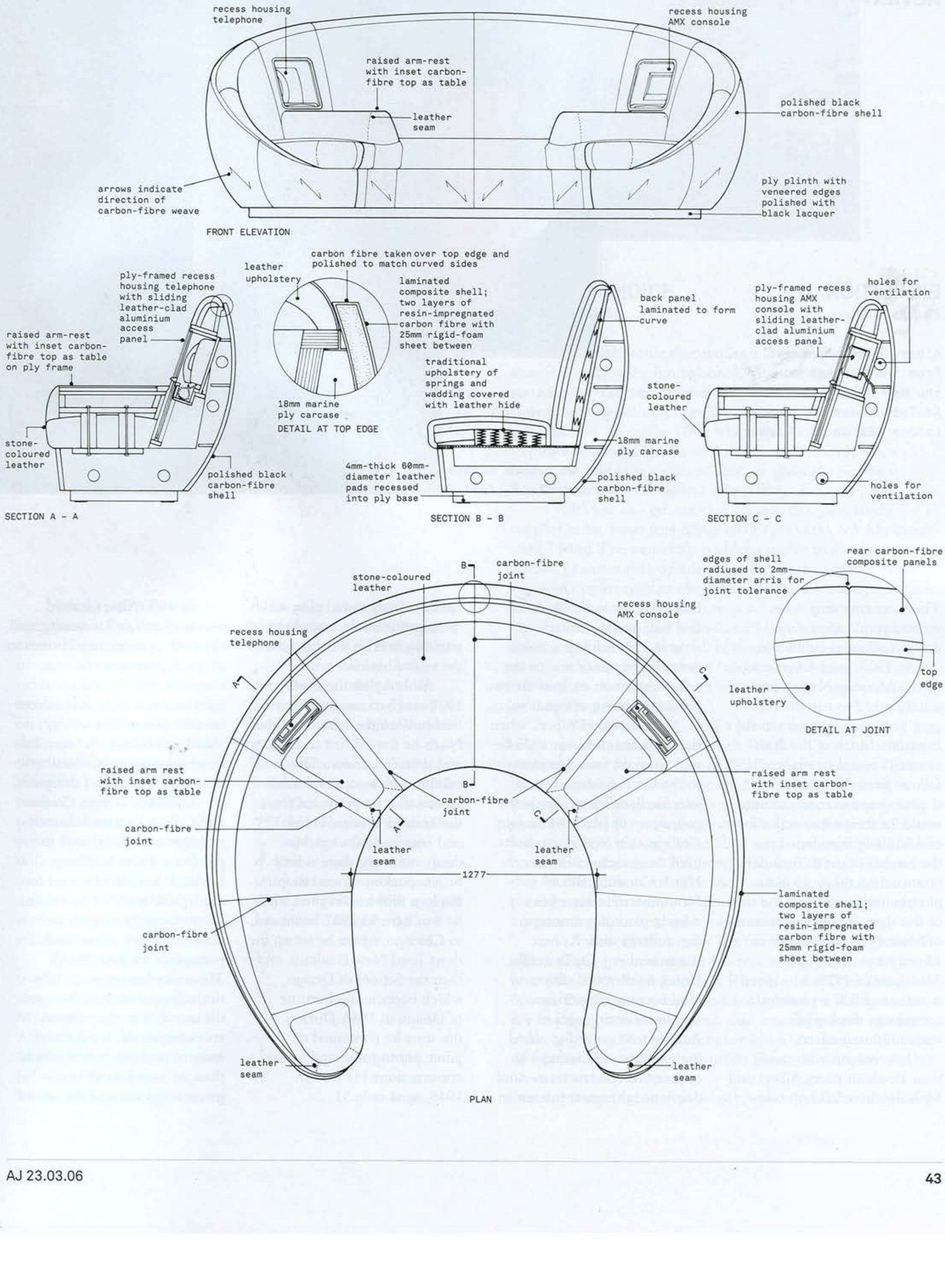
CUTAWAY ISOMETRIC



KEY SECTION/ELEVATION



KEY PLAN OF LIVING SPACE



recess housing telephone
recess housing AMX console
raised arm-rest with inset carbon-fibre top as table
leather seam
polished black carbon-fibre shell
arrows indicate direction of carbon-fibre weave
ply plinth with veneered edges polished with black lacquer
FRONT ELEVATION
ply-framed recess housing telephone with sliding leather-clad aluminium access panel
raised arm-rest with inset carbon-fibre top as table on ply frame
stone-coloured leather
polished black carbon-fibre shell
SECTION A - A
leather upholstery
carbon fibre taken over top edge and polished to match curved sides
laminated composite shell; two layers of resin-impregnated carbon fibre with 25mm rigid-foam sheet between
traditional upholstery of springs and wadding covered with leather hide
18mm marine ply carcase
DETAIL AT TOP EDGE
back panel laminated to form curve
stone-coloured leather
18mm marine ply carcase
4mm-thick 60mm-diameter leather pads recessed into ply base
polished black carbon-fibre shell
SECTION B - B
ply-framed recess housing AMX console with sliding leather-clad aluminium access panel
holes for ventilation
holes for ventilation
SECTION C - C
B
carbon-fibre joint
stone-coloured leather
recess housing telephone
edges of shell radiused to 2mm diameter arris for joint tolerance
rear carbon-fibre composite panels
recess housing AMX console
top edge
leather upholstery
DETAIL AT JOINT
A
raised arm rest with inset carbon-fibre top as table
B
carbon-fibre joint
C
raised arm rest with inset carbon-fibre top as table
carbon-fibre joint
A
leather seam
leather seam
1277
C
laminated composite shell; two layers of resin-impregnated carbon fibre with 25mm rigid-foam sheet between
carbon-fibre joint
leather seam
leather seam
PLAN