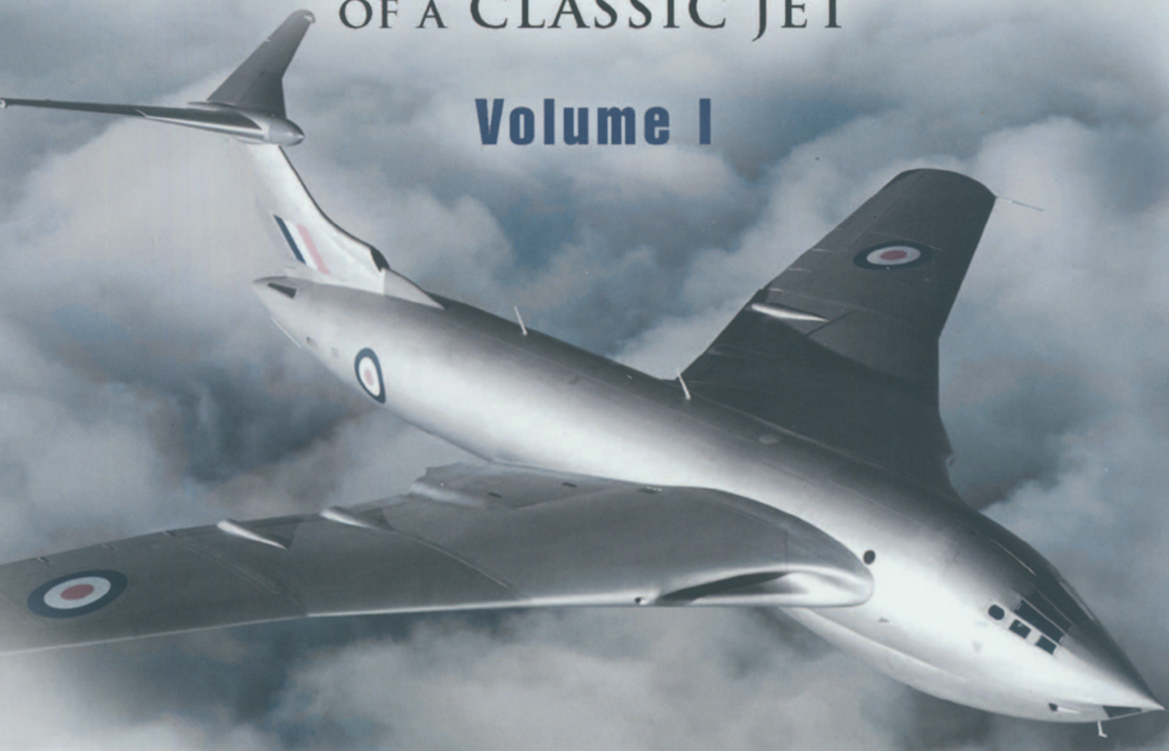
THE HANDLEY PAGE VICTOR

THE HISTORY & DEVELOPMENT OF A CLASSIC JET

Volume I



The HP80 Prototype & The Mark I

ROGER R. BROOKS

ARAeS

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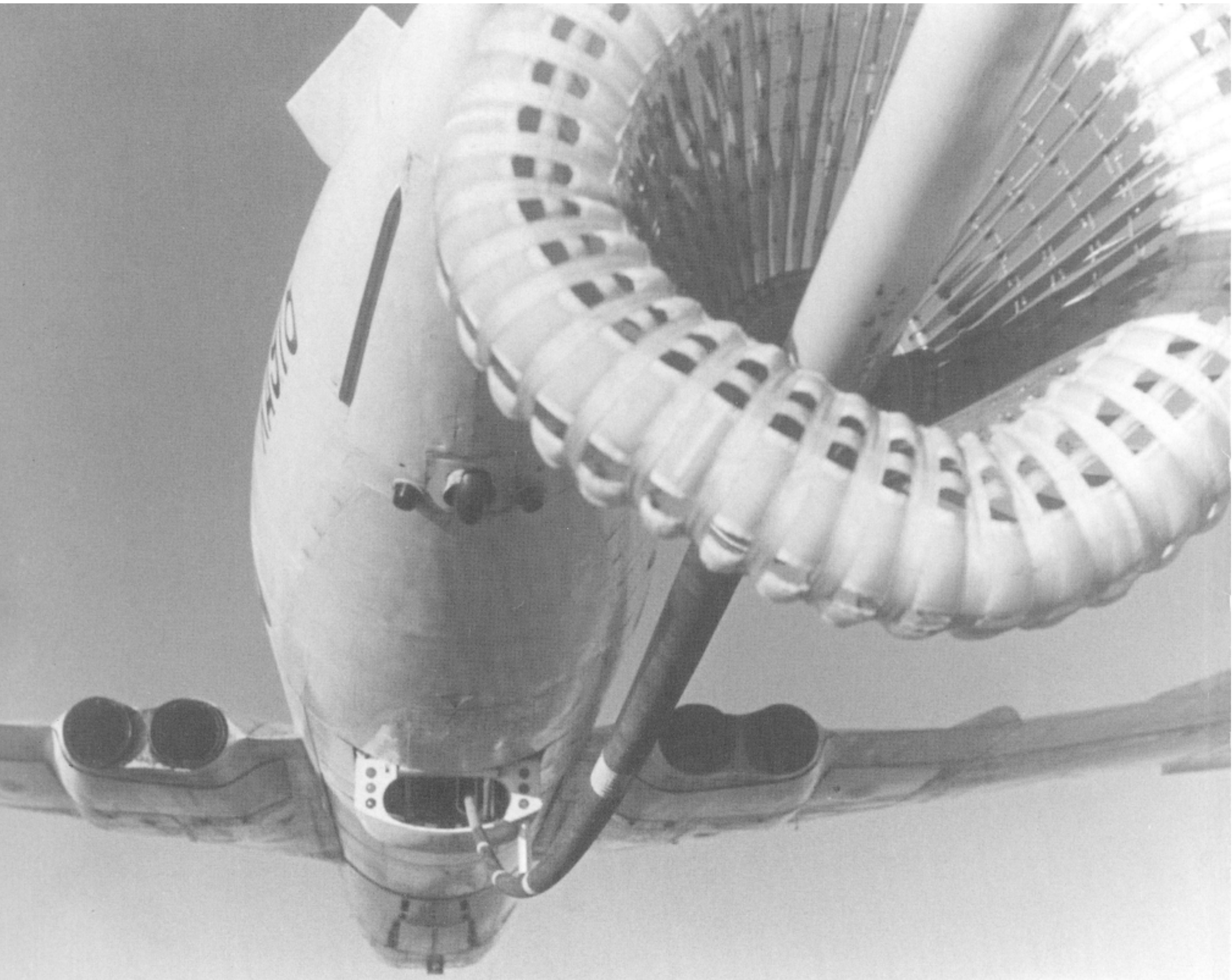
VOLUME ONE



Victor BK1 XA 918 refuelling on trials duty with the A&AEE during 1964. Author's collection

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THE HP 80 PROTYPE AND THE MARK 1 SERIES

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Pen & Sword

AVIATION

Dedication

To my wife Heather, also known as 'Heater' for support and encouragement over the many years this book has been in development and compilation.

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FOREWORD

I am honoured and delighted to have been asked to introduce this book, which is an in-depth study of an aircraft whose design and development, occupied on and off nearly half my working life from 1951. I have great affection for it, not least because it brought me into close working contact with so many highly competent people, one of the foremost being the Author. In fact, I did not meet him until long after the parent company Handley Page, went out of business, since I was an aerodynamicist by trade and (unfortunately) had little contact with the RAF people at the 'sharp end' operating and maintaining the aircraft.

Roger Brooks has some 40 years of experience of working at the 'sharp end' with the Victor and other aircraft, and has distilled some of his vast knowledge into this volume. But not only operating aspects, as he has collected a comprehensive archive covering the Victor's design and development story, mainly from those who were there – Godfrey Lee, effectively the 'Father of the Victor', Hedley Hazelden, Chief Test Pilot on the first flight, and many others, and lucidly presents it.

That valuable contribution is enhanced by reference to many Technical Manuals, Reports, Specifications and Brochure, all combining to make this a most valuable contribution to our Aviation Heritage literature.

The collection of statistical data is probably unique, and is usefully supplemented by a careful selection of illustrations.

The amount of ground covered by the Author is clear from the extensive quoted bibliography, but in fact his researches went further, and his experience as a Crew Chief for the aircraft (still continued with XL231 'Lusty Lindy' operating at Elvington) is very evident in the scope and detail in the data presented.

I feel sure this is a book which will be on most serious aviation historian's bookshelf, and will quickly get dog-eared with use, but I hope the aircraft enthusiast will also use it – at least he will know that this is the real, unassailable 'gen' compiled by someone who knows the aircraft inside out.

A.H. Fraser-Mitchell
Sometime Chief Aerodynamicist Handley Page Ltd
Vice President, Handley Page Association

January 2005

INTRODUCTION AND ACKNOWLEDGEMENTS

Over the past 40 years or so, many books have been written on the Handley Page Victor and the V Force aircraft in general. This book is not in the same vein as those. It is written as a Data File and subdivided into sections dealing with specific variations of this unique aircraft. It is intended as a reference book and you do not have to read all of it, just the relevant items that appeal to you. The accuracy of data in this book is backed up by the source material, which I have quoted the main items in the bibliography. It is by no means the definitive history of this aircraft as a considerable amount of very interesting data is not available for a variety of reasons by a few organisations for strange excuses.

I would like to produce a second edition within the next few years containing additional information on this book and the Victor in Service with the Royal Air Force from 1957-1993. Contributions for it are welcomed from all readers, no matter what they contain, and should be sent to the publisher.

I would like to thank the following for their assistance and guidance over the years in the course of developing the Data File.

The following members of the Handley Page Association:
Harry Fraser-Mitchell, Peter Cronbach, John Allam, Spud Murphy, Peter P. Baker, Jock Still, John Rudeforth, Alan Dowsett, John Harding, John Smith, Chris Scivyer, Brian Bowen, Mike Wilson, Harry Rayner, David Blades and Steve Mills. Finally, to all those members who I have spoken to over the past many years.

The following past Members of Handley Page Ltd and the Handley Page Association:
Godfrey Lee, Hedley Hazelden, Ian Bennett, Bob Williams, Gordon Roxborough, Reginald Stafford, Charles Joy, R.H. Sandifer, Dr G.V. Lachmann, W.H. MacRostie, C.O. Vernon, F.R.C. Houndsfield and John Tank. For being allowed access to the articles they wrote for the HP Bulletin nearly 50 years ago and in particular to Ray Funnell for access to his archives.

From the Royal Air Force:
Aircrew
Air Vice Marshal John Herrington, Flt Lt Pancho Painting, Flt Lt Eric Anstead, Flt Lt Alan Fisher, Air Commodore 'Spike' Milligan, Flt Lt Terry Filing, Sdn Ldr Jerry Mudford, Flt Lt Ken Norman, Air Commodore David Bywater, Flt Lt Alan Gardener, Sdn Ldr C.R. 'Pop' Miles, Sdn Ldr M Reade, Wing Commander Dave Griffiths, Flt Lt David Coleman, Group Captain Tony Ringer, Sdn Ldr Gordon Stringer, Flt Lt R.T. Hayward, Flt Lt John Bussey, Sdn Ldr Tim Mason, Sdn Ldr Al Stephenson, Sdn Ldr Bob Tuxford, Sdn Ldr Tony Cunnane, Wing Commander Barry Neal, Flt Lt Al Skelton, Wing Commander Bob Prothero, Flt Lt John Ledger. All the Victor captains and crews I flew with on the Mk 1 and Mk 2 Tanker Fleet as their Crew Chief.

Crew Chiefs
Bill Swann, David Haylett, John Kent, Sid Harding, Dave Parsons, Robbie Honnor and Brian Martin.

Ground Crew
Dennis Robinson, Gordon Stringer, Jim Jones, Jim Gosling, Paul Goss, Duncan Curtis, Mick Crooks, Dave Wynn-Jones, Don Williams (Australia), Robin Cooper, Stan Jones, Pete Claydon, Tony Regan, Rick Gill and Doug Gawley. Also, thanks go to all those whose names I have failed to remember.

Finally, my grateful thanks go to the following from many walks of like for their interest in the Victor and assisting in many ways:
Andre Tempest (Owner Victor XL231 'Lusty Lindy'), Martin Garland and BAE Systems Woodford Heritage Centre, Graeme Rodgers (NZ), Garry O'Keefe, The Victor Association, Ken Ellis, Jarrod Cotter and Duncan Cubbitt of *Fly Past.*

Cover credits:
The Front Cover: First Prototype of the HP 80 WB771 flown by Sdn/Ldr Hazelden on a test flight 1953. *Authors Collection via HPA*
The Back Cover: Top Picture: Victor B1 XA918 second production aircraft on development flying: *Authors Collection via HPA*
Second Picture: Victor B1 XH592 15 Squadron arriving at RAAF Richmond, Sydney NSW Australia on the 20/6/61 after a high speed run from England and on the last leg from Darwin beating the record time by 20 minutes. Captained by Wing Commander Tony Ringer seen here descending from the aircraft, the time from England was 19hours. *Photo and data via Graeme Rodgers New Zealand*
Third Picture: Front Cabin of Victor B1A(K2P) XH648 57 Squadron now with the IWM at Duxford. *Heather Brooks*
Fourth Picture: Victor K1A XH618 57 Squadron RAF Marham 1972. *Authors Collection*
Bottom Picture: HP 80 WB771 Banking to Port with Wheels down, Flap both nose and main down and airbrakes open. *Authors Collection HPA*

ABBREVIATIONS

AAPP	Airborne Auxiliary Power Plant
A&AEE	Aircraft and Armament Experimental Establlishment
AAR	Airborne Air Refuelling
AC	Alternating Current
ADF	Automatic Direction Finding
AEO	Air Electronics Officer (RAF Aircrew)
AMU	Air Mileage Unit
ARC 52	UHF Radio
ARI	Airborne Radio Installation
AVCAT	Aviation Jet Fuel (used by Royal Navy on Carriers)
AVTUR	Aviation Jet Fuel (Jet A1)
AVTAG	Aviation Jet Fuel JP4 Wide Cut Gasoline type fuel
AwC or AWC	Awaiting Collection
C of G	Centre of Gravity
CAT 3/Cat 3	Category 3 (Aircraft Repair Status)
CAU	Cold Air Unity
C(A)	Controller of Aircraft (Military CAA)
CL	Buffet Boundary Measurment
CRE	Central Reconnaissance Establishment
c/s	Call Sign
C/T	Continuation Training
CWP DC	Contractors Working Party (HP or HAS)
DC	Direct Current
DF	Direction Funding
DOR	Director of Operational Requirements
DTD	Directorate of Technical Development
DV	Direct Vision (small opening windows in the cabin)
EAS	Estimated Air Speed
ECM	Electronic Counter Measures
FEAF	Far East Air Force (RAF)
FI	Fatigue Index
FSII	Fuel System Icing Inhibitor
G4B	Aircraft Compass System Mk 1 Victor
GP	General Purpose
GPU	Ground Power Unit
HDU	Hose Drum Unit
HF	High Frequency
HLBSP	High Level Blue Steel Profile
HP	High Pressure/Handley Page
HZ	Hertz (frequency of electrical power)
IAS	Indicated Air Speed
IFF	Identification Friend or Foe
ILS	Instrument Landing System
IMN	Indicated Mach Number
IRT	Instrument Rating Test
JARIC	Joint Airborne Reconnaissance Intelligence Centre
JIB	Joint Intelligence Branch
JPT	Jet Pipe Temperature
JMC	Joint Maritime Control
KVA	Kilo/Volt/Amps

KW	Kilowatt
Ldg	Landing
LL	Low Level
LLBSP	Low Level Blue Steel Profile
LV	Low Voltage (24/28VDC)
M.A.P.	Ministry of Aircraft Production
Mcrit	Critical Mach Number
MF	Medium Frequency
MFS	Military Flight System (used in Mk 2 Victor/Vulcan)
Min Tech	Ministry of Technology
MOA	Ministry of Aviation
MRR	Maritime Radar Reconnaissance (H2S+ R88 Camera)
M.U.	Maintenance Unit (RAF)
MV	Medium Voltage
NBC	Navigation Bombing Computer
NBS	Navigation Bombing System (H2S+NBC)
N/F	Not Flown
NGTE	National Gas Turbine Establishment
NM	Nautical Miles
OCU	Operational Conversion Unit
ODM	Operating Data Manual
PE	Pressure Error
PFCU	Powered Flying Control Unit
PR	Photographic Reconnaissance
PSI	Pounds Per Square Inch (pressure)
PTR 175	UHF/VHF Radio
QFI	Qualified Flying Instructor
R.A.E.	Royal Aircraft Establishment
RAT	Ram Air Turbine
RATO	Rocket Assisted Take Off
RBS	Radar Bombing System
RCM	Radio Counter Measures
RE	Royal Engineers
RPM	Revolutions Per Minute
RRF	Radar Reconnaissance Flight
Rtn	Return/Returned
RWR	Radar Warning Receiver
SARAH	Search and Rescue Aircraft Homer
SARBE	Search and Rescue Beacon
SBAC	Society of British Aircraft Constructors
SOC	Struck off Charge
SOO	Special Order Only (modifications)
SSR	Secondary Surveillance Radar
TEZ	Total Exclusion Zone (South Atlantic)
Tkr	Tanker
T/O	Take Off
TRU	Transformer Rectifier Unit
Trg	Training
TTF	Tanker Training Flight
TX/RX	Transmitter/Receiver (Radio/Radar)
U/C	Undercarriage
UDF	Ultra High Frequency Direction Finding
UHF	Ultra High Frequency
U/S	Unserviceable
VHF	Very High Frequency
VISRBS	Visual Radar Bombing System
VMMU	Victor Major Maintenance Unit
ZULU	Greenwich Mean Time

BIBLIOGRAPHY

V Force, Andrew Brookes, Book Club Associates, 1982
Crash, Andrew Brookes, Ian Allan, 1991
Handley Page Victor, Andrew Brookes, Ian Allan, 1988
RAF Nuclear Deterrent Force, Humphrey Wynn, HMSO, 1994
Handley Page Aircraft, C H Barnes, Putnam, 1976
Thunder and Lightening, Chris Allen, HMSO, 1991
Tests of Character, Don Middleton, Airlife
Aim Sure 75 Years of XV Squadron, Flt Lt T W Jones, Palka Druck, 1990
Jet Adventure, Geoffrey Norris, Phoenix House, 1962
Handley Page Bulletins, nos. 213, 220, 225, 228, 229, 230, 231
Handley Page Repair Reports
Handley Page Brochures, various, HP 80, Mk 1
Handley Page Victor Servicing School Notes Mk 1
Handley Page Test Pilots Flying Log 1952-1970
Handley Page Flight Test Observers Reports
Handley Page Victor Mk 1 Tanker Final Conference Report
Handley Page Victor Low Level Role Report
Handley Page Victor Wing Tip Fuel Tanks Report
Handley Page Victor Thrust Augmentation Report
A&AEE Boscombe Down/HP Test Pilot Reports, various
Royal Aeronautical Society Transcripts of Lecture (Victor)
The following Air Publications were used for checking data accuracy only:
AP 101B-1100 Victor All Marks
AP 101B-1101 Victor B Mk 1
AP 101B-1103 Victor B Mk 1A

Bomber Command/Strike Command Victor Servicing School Notes (all Marks)
Release to Service Data
My extensive collection of a wide variety of books, magazines and other records and data sources collected over thirty-five years.
Interviews and discussions with Handley Page Flight Test and Ground Test Staff, Aerodynamicists, Production Engineers and many production staff. A&AEE Test Pilots and Flight Test Engineers.

PART ONE

The HP 80
From its Concept to Flight

The Requirements that lead to the HP 80 and later the Victor

This article is based on the paper by G H Lee ARCS, BSc, DIC, FRAes Deputy Chief Designer of Handley Page in 1954 and presented to the Royal Aeronautical Society Handley Page Memorial Lecture on 26 May 1976.

'Unassailable Aerodynamical Logic' – an enduring theme for Handley Page Ltd

As for the most of the British Aircraft History, the jet age started for Handley Page in 1945, when the war had been won and we had the chance to consider properly the implication of jet propulsion, until then used only in the fighter installations. Two events in that year should be recorded.

1. The setting up by the Ministry of Aircraft Production of the Swept Wings Advisory Committee, comprising of representatives of the official Establishments [RAE etc] and the aircraft manufacturers.
2. In September-October sent a team, to Germany to find out about the German work on tailless and swept wing aircraft.

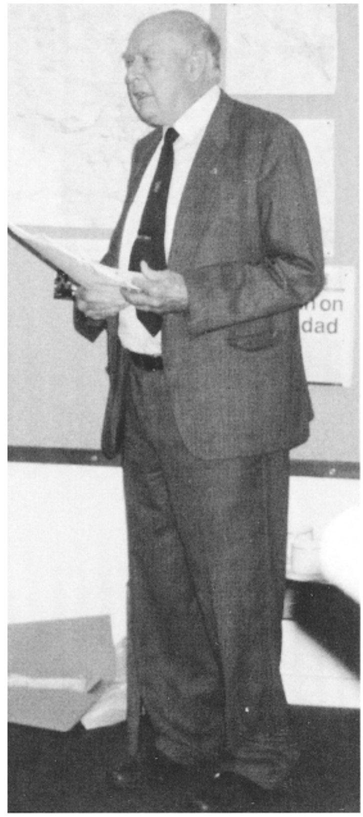

The late Sir Frederick Handley Page. Author's collection

In June 1945 Sir Frederick Handley Page was confident that a replacement for the Avro Lincoln would be needed and as the specification for the twin engine jet bomber had been issued it seemed logical to Sir Frederick that the 4 engine aircraft would be next. On the 14th June 1945 he issued a private and confidential memorandum address to R.S. Stafford, Frank Ratcliffe and Godfrey Lee in this he requested an immediate investigation of two classes of bomber one of 100,000lb all up weight with four turbojets of the size of the AJ65 (Avon) or two of twice that size the other a 60,000lb aircraft with two AJ65 engines and he suggested that they should have wings incorporating a 40 degree sweep.

The real start of the Victor design was in the course of the next few months actually undertaken in September-October when a visit to the German aeronautical research establishments at Gottingham and Volkenrode with a MAP fact finding team was undertaken by Godfrey Lee as the representative of Handley Page. It was, as part of this visit that the concept of the swept wing as a means of enabling an aircraft with reasonably thick wings to fly at high subsonic speeds without drag rise first became understood. From this there stemmed the realisation that by combining a swept wing with a jet engine one could have an efficient high subsonic speed aeroplane capable of carrying a good payload over a long range.

Work on this concept began at Handley Page in about November 1945

In January 1946 after work on the HP72 heavy transport had been abandoned, the designations HP72A and HP75A were used as a cover for Godfrey Lee's investigations into the possible jet propelled high-speed bomber of 90,000lb all up weight. The HP 75A with a front rider plane was quickly ruled out in favour of the 72A with 45 degree swept wings and wing tip rudders having a small swept tail plane and elevators to balance nose down pitching moments caused by either flap lowering at low speed or compressibility at high speed. With no operational requirement yet promulgated by the Air Staff to guide him, Godfrey Lee put forward an inspired proposal on the 25th February 1946, for a design of 2100sq ft, 122ft span, aspect ratio 7, wing loading 43lb/sq.ft to carry a 10,000lb bomb at 520 knots true air speed over a still air range of 5,000 statute miles; the wing root thickness/chord ratio was to be 16%, with a 9 ft diameter body accommodating a crew of four in a pressurised nose compartment. Avon (AJ65) engines were larger than the ideal size for this aircraft and Godfrey Lee suggested scaling them down to 5,600lb. Two days later Reginald Stafford approved this proposal and instructed C.F. Joy the Chief Draughtsman to prepare a brochure for submission to the Principal Director of Technical Development (Stuart Scott-Hall) by the end of March 1946; this brochure was to demonstrate the projects effectiveness as a bomber. At this stage the number HP 80 was allocated and so started the HP80/Victor project way back in March 1946.



The late Godfrey Lee, 'Father of the Victor'. Heather Brooks

The brochure was issued to the Director of Operational Requirements Group Captain Silyn-Roberts and with his deputy Group Captain Cooper they visited HP Cricklewood on the 19th July 1946 to discuss the third draft which had been issued in June 1946 of the Air Staffs requirements for a long range bomber mainly derived from the Handley Page proposal, but containing several operational innovations. These included the visual bombing facility as a back up to the possible delay and or failure of the radar bomb sight, a Flight Engineer's station, unless the engine controls could be simplified, Electronic Counter Measures operator in a separate cabin near the tail, reached by a tunnel from the main cabin and if possible a jettisonable main pressure cabin. A bomb bay load of 30,000lb was to be carried with normal tanks full, but bomb bay tanks were to be allowed to achieve maximum range with a 10,000lb bomb.

Members of the Telecomunication Research Establishment (TRE) visited HP Cricklewood on the 2nd November 1946 to discuss radar equipment, the main feature being the H2S Mk 9 Scanner 6ft long and rotating on a vertical axis within a large radome below the flight deck floor, in addition were Gee and Rebecca Mk4 for short-range navigation, IFF and ECM, the latter requiring a tail parabolic scanner of 18inch diameter facing aft, the estimated total weight of the radar equipment was 1,500lbs and all aerials would be suppressed. The TRE wanted the H2S scanner to be pressurised but this was virtually impossible and the idea was abandoned. It later came to the notice of C.F.Joy that the DOR insisted that the crew cabin being as small as possible to reduce the vulnerability, even if it were at the expense of crew comfort and that the whole pressure cabin should be jettisionable because the use of ejection seats at 50,000ft and 500mph was considered likely to be fatal. The whole cabin would be let down on large parachutes with the crew strapped in 25g seats falling nose first and relying on the nose structure to absorb the shock of impact

Two pilots were required and it was agreed that locating the ECM operator in the tail was impracticable because of the large size of the proposed nuclear weapon, which might be 6 ft in diameter and up to 30 ft long. The Air Staff intentions were made known by Stuart Scott-Hall when he visited HP Cricklewood on the 25th November 1946; they wished to replace the AVRO Lincoln in 5 years time by a four jet bomber capable of delivering a 10,000lb nuclear weapon at 500mph from a height of 45,000ft the still air range being 3,500miles; as a later development the range would have to be increased to 5,000 miles and the operational ceiling to 50,000ft these data being formally promulgated in the Air Staff Operational Requirement No. 230. Godfrey Lee estimated all up weight to be 90,000lb for 3,500 miles using a swept wing and 121,000lb for a conventional straight wing. A further meeting was held with the Principal Director of Technical Development on 14th January 1947. After Handley Page had submitted their proposal to meet OR230, the official view was that both the structure weights and drag estimates were optimistic, so that the design cruising speed would not be released. The DOR now wanted the cruising speed to be raised to 575mph which meant that the all up weight also would have to rise to 100,000lb in order to attain the 3,500 miles still air range or 120,000lb for 4,000miles. Therefore tenders would be called for to meet the revised specification B35/46 which had been finalised on 1/1/47 and approved by the Director of Aircraft Research and Development on the 24/1/47 and issued with OR 230 on 24/3/47. In view of the large wind tunnel test programme involved, the prototype HP80 could not be expected to fly until 1951. Apart from the exploration of the new problems of tip stall, high lift sections, stability and various methods of boundary layer control, a firm choice between tailed and tailless types still had to be made. Charles Joy proposed to begin the drawing office programme on the 1/10/47 allowing 21months until June 1949 for the basic layout and 30 months to March 1950 for the completion of the powered flying control system. All drawings for the first prototype would be completed by June 1951 and the extra drawings for the fully equipped prototype by March 1952. The target date for the first flight of the flying shell was March 1952 and for the fully equipped aircraft September 1952. It was a tremendous programme for the small design team but not impossible, so the HP80 tender was submitted.

On the 28th July 1947 Sir Fredrick Handley Page received a telephone call from Stuart Scott-Hall stating that the HP80 was to be ordered along with the AVRO 698 subject to the confirmation of the high-speed wind tunnel test results to approve the theoretical basis of the design.

We were started on the 'Victor'

The Basic Design Concept

Specification B35/46 called for an aircraft capable of carrying a considerable bomb load (10,000lb) over a range of 1,500 miles from a base that might be anywhere in the world. The aircraft will be required to attack targets at great distance inside enemy territory. And it must be assumed that it will be tracked by radar and other methods for a large part of its flight. It must therefore be capable of avoiding destruction by making the inevitable attack from ground and air launched weapons difficult.

To achieve this the aircraft must have the following:

1. A high cruising speed which should be such that the attacking fighters will have to

fly at a speed at which they might become unmanoeuvrable.
2. The design must be such that the aircraft can turn rapidly and without loss of height or much loss of speed when at maximum cruising height. The height being 35,000 to 50,000ft.
3.The carrying of adequate warning devices to detect the approach of ground launched weapons and the proximity of approaching aircraft.
4. The carrying of defensive equipment such as jamming devices for guided missiles.
5. The size of the pressure cabin must be as small as possible.
6. Visual and electronic bomb-aiming positions are required.
7. Maximum performance is the ultimate aim and must not be sacrificed for ease of maintenance.
8. It must be possible to operate from existing Heavy Bomber airfields at the maximum loaded weight which must, therefore, not exceed 100,000lb.
9. The aircraft must be suitable for large-scale production. It is stated in the Specification that the economic production of 500 aircraft at a maximum of 10 per month was proposed.

HP 80/Victor Specification and Design Concept

The combination of sweep and range seemed to us to lead to the need to have both high sweep (or fairly high sweep) and moderately high aspect ratio. For us combining high sweep and high aspect ratio gave rise to the tip stall problem. Therefore the Crescent wing was evolved. We came to the crescent wing by arguing that the high sweep was essential at the root for structural reasons and to provide adequate stowage for engines and undercarriage. It was then argued that if we reduced the sweep over the outer parts of the wing we would reduce at the tip where it mattered, the adverse effects from sweep that gave rise to tip stall. In particular it was expected that this would reduce the trouble from the outwardly drifting boundary layer over the rear of the wing, it being assumed that the boundary layer from the highly swept parts of the wing would stream off the wing before reaching the wing tip. We had to accept a weight penalty from the thin outer wing of about 22 degrees sweep and 6% t/c at the tip but felt that since this part of the wing is the least highly loaded the extra weight was acceptable; stowage problems did not arise in the outer wing. We decided that to go from 53 degrees to 22 degrees at one kink was too sudden so we put in an intermediate section at about 35 degrees.

The final sweep on production aircraft after further wind tunnel testing at 1/4 chord was to end up as 47.5 degrees at station 60-212 the inner wing, 40.5 degrees at station 312-330 the intermediate wing and 32 degrees at station 330-660 the outer wing.

We first intended that the HP 80 should be to all intents and purposes, tailless, since we thought we had enough sweep to do this. We had wing-tip fins and rudders and pitch control was obtained from symmetrical deflections of the elevon (we knew that tip stall was better with elevons up). To help balance the nose down pitching moment from the big Fowler flaps we introduced a small all moving swept tail plane mounted above the fuselage on a very short fin; this was to be moved so that the trailing edge up when the flaps were lowered.

However there were worries about the bad effect of tip fins on tip stall and some fears, not clearly defined that these tip fins might lead to asymmetrical conditions with objectionable yawing moments under some unspecified conditions, possibly at high Mach number

Because of this feeling it was decided to delete the tip fins and go for a conventional fin and rudder. Having got this far we also went for a 'conventional' tail plane and elevator. We put this on top of the fin primarily to get it out of the way of the jet efflux and also because we wanted to avoid the fairing and structural problems of a tail part way up the fin. We new at this time that this arrangement was bad from the tip stall point of view but we decided that we could fix this with nose flaps or something similar.

Having got a thick wing root with a maximum depth of approximately 6 ft we decided to put the engines inside the wing immediately outboard of the fuselage to save nacelle drag and to avoid any serious yawing moment from a cut engine, thus easing the design requirements for the fin and rudder. The undercarriage retracted into the wings thanks to a 4 wheeled 8 tyred bogie outboard of the engines.

Because of the way in which the engines and the undercarriage were installed the centre wing main structure was limited to a torque box ending at about 30% chord. At the fuselage side this torque box had a large kink and passed across the fuselage in a span-wise direction.

There was an important aerodynamic advantage to this centre wing box structure. Because of the high sweep, the centre wing spar structure was well forward of the C of G of the aeroplane when it crossed the fuselage. This meant that all the moveable military load (bombs or reconnaissance crates) was aft of the rear spar and thus we could mount the wing centrally on the fuselage with consequent drag and Mcrit (Critical Mach Number) advantages; further the whole fuselage cross section was available for useful load fuel at the top and military stores below thus minimising the cross sectional area diameter to 10ft.

Wing Design – High Speed

The aim was a constant critical Mach number across the span. After an arbitrary choice of taper ratio initially about 2.5 to 1 but later increased to about 4 to 1 and sweep we had at our disposal the following items by means of which we could effect the super velocities so as to get the desired critical Mach number.

1. Fairing Shape and Thickness,
2. Camber.
3. Twist

When we got our first wing designed a model was tested in the old RAE high-speed wind tunnel. (Which was no longer in use over 30 years ago) The results showed the drag rise coming in too early round about Mach 0.8 I understand. There was at that time evidence that the trouble was on the outer parts of the wing. It was a mixture of pressure plot data and indications of shock wave positions so we reduced the thickness of the outer wing by 2% chord throughout making the necessary changes to the shape of the intermediate wing, which remained unaltered at its inboard end. This fixed it and we went from there. At the wing root we got a favourable interference from the mid wing arrangement. One can I suppose, argue that if one looks at the wing fuselage intersection in plan there is an obvious wasting of the intersection line, remember it is a 6ft thick wing passing centrally through a 10ft diameter fuselage and thus there is automatically a good root fairing. We actually thought of it rather differently though the result is the same. What we said was that if you plotted, along the length of the fuselage, the cross-sectional area of the fuselage outside the wing you then had the distribution of the added area.

Low Speed

As design proceeded there was continual pressure for more wing depth at the root for stowage of engines, undercarriage etc. This led, by insidious steps to the gradual increase in the root cord until the taper ratio had increased to about 4:1 and the inner kink on the trailing edge had been eliminated: the aspect ratio was now down to about 6. When we at last got a model of this into the low speed wind tunnel the pitch-up at stall was terrible. We tried all sorts of leading edge devices with out much success.

Drastic measures were called for so we decided to increase the chord of the outer wing by a 20% forward extension: this new leading edge ran inboard to intersect the leading edge of the intermediate wing much further inboard than it formally had; the outer kink was now about half-way from the fuselage side to tip instead of ⅔ as originally. This combined with a droop nose flap on the new larger outer wing gave an acceptable answer then anyway. The nose flaps were, I think, hinged at about 12.5% chord from the leading edge and went down about 45 degrees. An automatic control system was designed based on the signal provided by a pressure ratio switch which made an electrical contact when the differences in the pressure coefficient between holes on the top and bottom surfaces of the wing reached a pre-set value. The nose flap was lowered by the stored energy of a hydraulic accumulator and came down in a second. This quick action was necessary to beat the increase in Chord Line (CL) raising was slow and the hydraulic pumps had to recharge the accumulator to full pressure before the flaps retracted so that it might be ready for action again. This was later demonstrated to be acceptable by flying at high Mach numbers with nose flaps down.

Aerodynamic Controls

We started the design in 1946 and had to design the biggest aeroplane that we had ever done, with swept wings and a flight envelope going up to a pretty high subsonic Mach number. In these circumstances we decided that manual controls were ìoutî so we went for duplicated power operated controls with no manual reversion. The aileron jacks were independent, i.e. not connected across the wing from port to starboard, so we put in a fixed upwardly deflected tab to cut down bo and b.; to reduce b2 we also had a geared tab. Rolling power on the Victor is very high because when we changed over from elevons to ailerons and elevator we did not reduce the size of the ailerons and so they are larger than normal. The rudder had a geared tab. We gave up the idea of an all moving tailplane for mainly structural reasons (the HP 88 had such an item) and went instead for a very small fixed tail-plane just something to hold the hinge brackets with a very large elevator. The elevator had an enormous horn balance (the outer 60% of the span I should guess) and was deliberately overbalanced for all normal flight conditions. We did this so as to reduce the hinge movement (so saving size and weight of the jack.) at maximum flight M; positive and negative movements were about equal in magnitude and it seemed to work all right. Service experienced seems to justify our decisions as the Victor has flown at Mach numbers in excess of 1.0 on a few occasions. Although the prototype did a lot of flying without auto stabilisation, we ultimately added first a yaw damper and then a Mach trimmer. These were more important on the B2 versions with the Conway and the greater altitude capability.

Fuselage

There is not much more to add to what has already been said in connection with the wing design. We made a very smooth pointed nose with the windscreen faired into the lines without the usual step. This kept down the local shock waves and gave a very quiet cockpit. The bulge or chin below the nose resulted from putting the radome under the bomb aimer.

Engine Air Intake

Right from the start we knew that swept wing leading edge intake was going to be difficult but we went ahead with it because of the very encouraging results obtained from A.V.A. Gottingham with such an arrangement. We had the wind tunnel test report by a man called Scheerer I think or else A. Walz.

For the Mk 1 with the Sapphire engines we just sliced off the nose section of the wing section and contrived to keep the engine air intake entirely within the original profile. The problems were to get good efficiency throughout the large range of inlet velocity/flight velocity ratios and to avoid shock waves at high Mach numbers through a fairly large range of incidence. There was the tendency under static conditions for the air to be concentrated in the outer corner of the intake; it came out as a long thin triangle, with rounded corners, due to the high thickness taper on the inner wing. The need to supply two engines added more complications. We decided on a single inlet with division into the two separate trunks well back in the wing when we had got the air behaving nicely. The absence of a central division on the leading edge reduced the length of the intake; if we had to push the intake for the outer engine still further outboard we would have been in real trouble with the extreme outer corner, for the wing depth would have been very small indeed.

Starting with the German results and with much wind tunnel testing (many pressure plots on the lips) we got it acceptable, including the engine out cases. Later it was discovered that during the take off run there was quite a large supersonic patch at the outer corner of the intake; the tolerant Sapphire did no more than lose a bit of thrust under those conditions.

Dive Brakes (later called Air Brakes)

These were formed from sections of the fuselage near the rear on each side of a roughly trapezoidal plate swung forward and outwards leaving a gap between the leading edge of the air brake and the fuselage side. At full deflection it had moved out about 60 degrees. Since the above arrangement resulted in a convex face of the air brake facing forward we put strakes on the top and bottom edge to increase drag. At first the strakes were of equal depth but there was a pitching moment when the brakes were deployed; we cured this by making the top strake a lot bigger than the lower one.

These air brakes worked very well; they gave good braking without pitch or undo buffet at all Mach numbers up to the maximum. The pilots liked it so much that they used them for speed control on the final approach; they set up a reasonable thrust and adjusted the speed /angle of descent with the air brakes as one would on a glider since this was more precise than operation of the throttles.

Structural Design

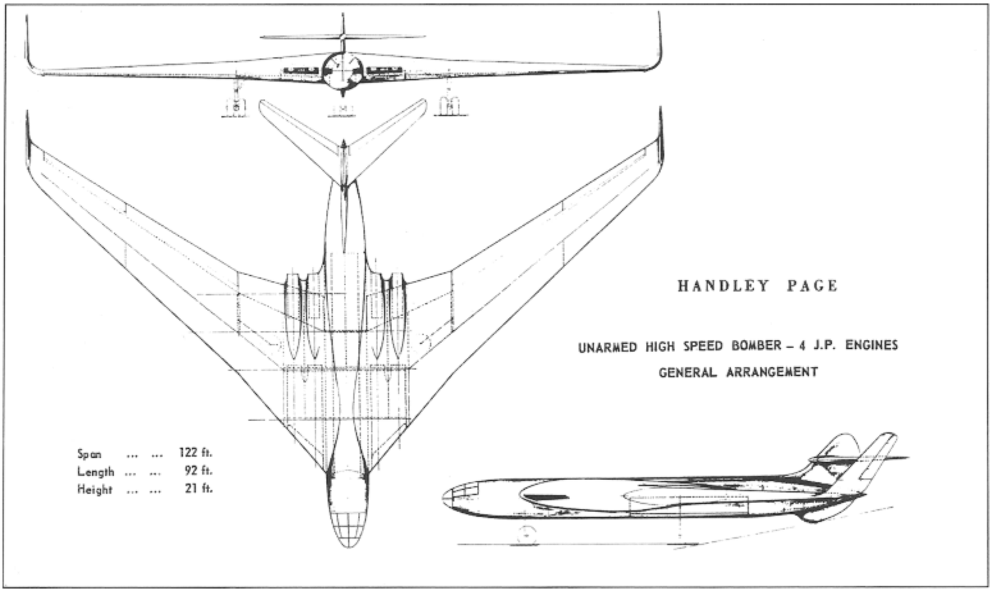
We are committed to a thin wing (or relatively thin) and this lead to quite a high bending end loads. Because of high flight Mach number we imposed a quite stringent waviness criterion to avoid the risk of local areas having little shock waves.

We decided quite early to use sandwich construction which, because of its bending stiffness and strength, could carry end load (the main bending end-load) without the elastic in-flight buckling typical of conventional skin/stringer construction and which could also take internal (fuel tank) and external pressure loads without significant distortion. (*For a complete description of the structural design of the Victor by the then Assistant Chief Designer (Structures*) R H Sandifer)

Flutter on the Victor

From the start of the design we paid much attention to flutter. We were concerned firstly with the problem of estimating flutter derivatives for a swept wing where the mach number went well beyond the critical, and secondly, we had two other problems, the flutter characteristics of a crescent wing and a T tail, both new to Handley Page.

We tackled the problems on a broad front, calculation, wind tunnel test, ground resonance test and finally flight test; mixed up with this there was also a dropped model or two to try and get high M conditions. The calculations owed much to help received from the Flutter Section of the SME Department of the RAE and the use of the RAE analogue flutter computer. The wind tunnel tests were similar to those carried out by the Boeing Aircraft Company, since we had seen their model building technique on a visit to Seattle in 1949. The Boeing models consisted of a light-alloy skeleton to provide the elastic properties, the aerodynamic shape



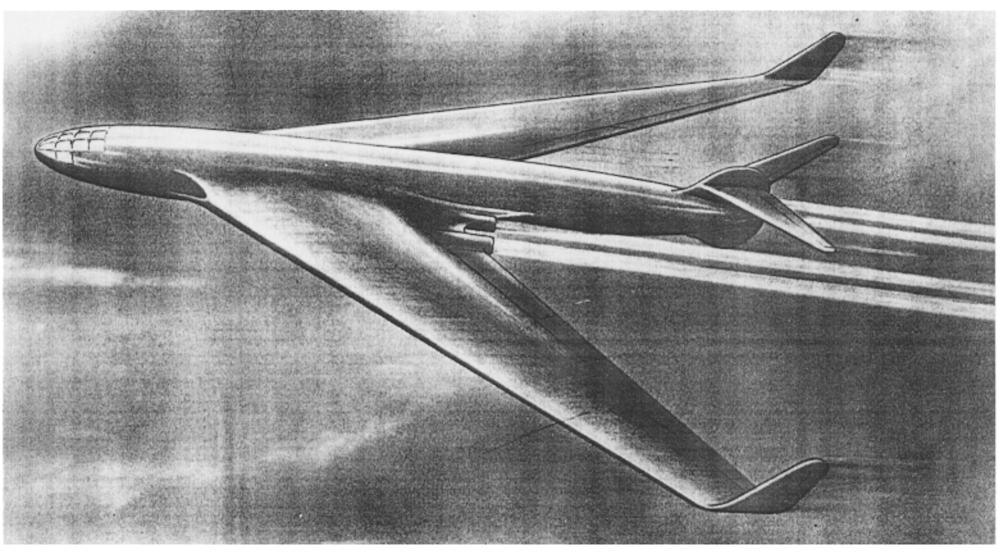
Unarmed High Speed Bomber

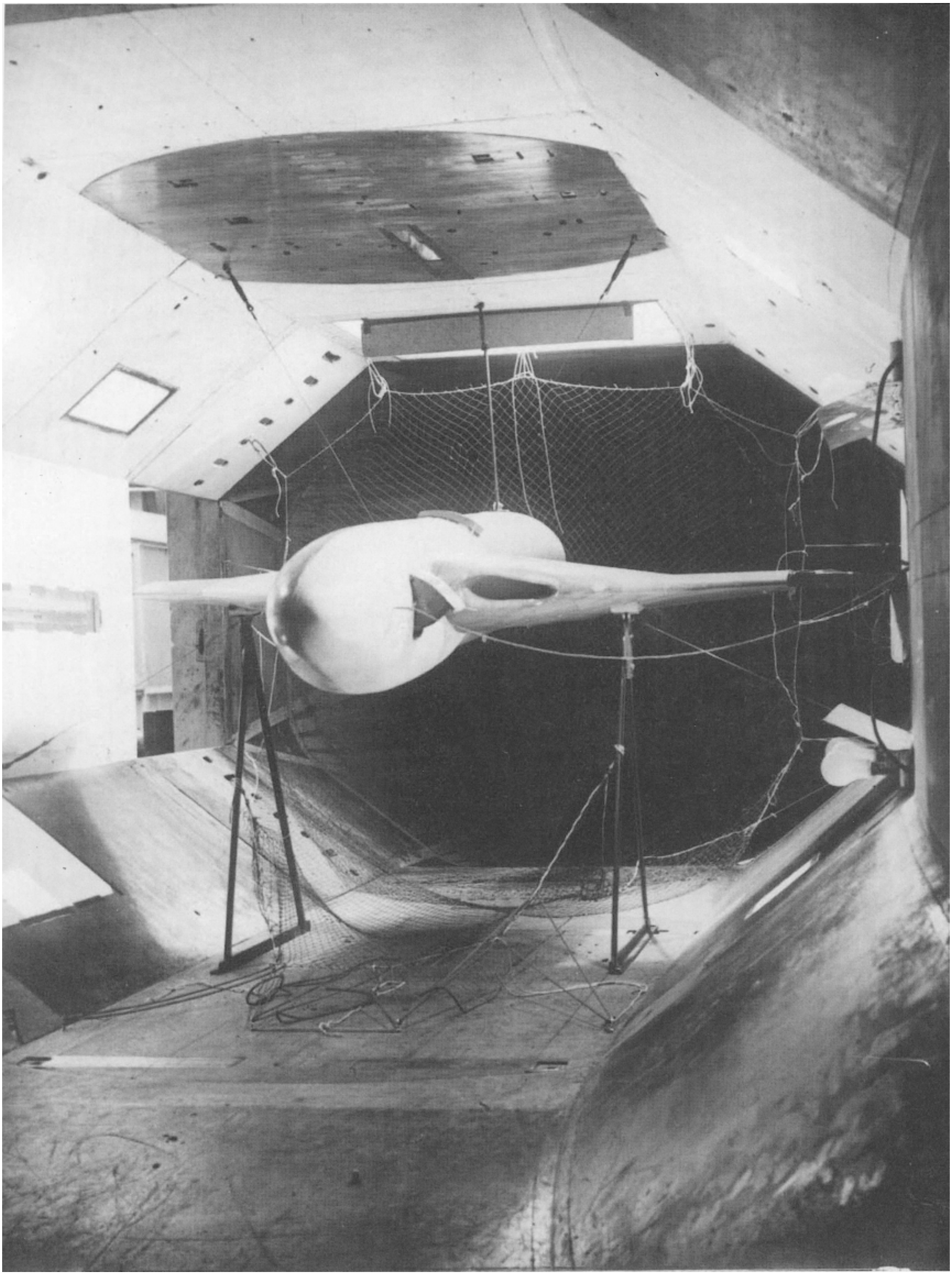
being formed by numerous balsa wood boxes, the gaps between them being sealed by very thin rubber membranes while the mass distribution was brought up to that required by the addition of weights within the contour. Handley Page adopted this technique for the low speed wind tunnel models. As far as the wing was concerned we were entirely successful. On the tail unit, however, despite all that we did, there was a flutter incident with fatal results to the crew. The accident happened during a low altitude high speed run at Cranfield for the purpose of calibrating the static pressure orifice; tail unit flutter occurred and this component broke away.

To begin with this accident was very puzzling because we had assessed (or checked) the flutter speed by three independent means and each time the result showed that the flight programme could be safely undertaken. These three checks were:

1 An assessment of the flutter speed based on low-speed wind tunnel tests.
2 The calculation of the flutter speed using ground resonance tests results.
3 We did rudder jerks up to speeds slightly higher than that attained when flutter occurred.

Unarmed High Speed Bomber in Flight, Model 1.





HP 80 Wind Tunnel Test 1947-48.

After some exhaustive tests the investigation showed that increased fin torsional stiffness and increased stiffness of the fin-tail plane joint was the remedy for the flutter trouble; we therefore built a stiffer fin. In fact we built two versions of the stiffer fin, because we decided that the first version had not been sufficiently stiffened.

SECRET
MINISTRY OF SUPPLY
PRINCIPLE DIRECTORATE OF TECHNICAL DEVELOPMENT
This document is the property of H.M. Government
SPECIFICATION NO B35/46

MEDIUM RANGE BOMBER
This specification is to be regarded for contract purpose as forming part of the Contract Agreement and being subject to the same conditions
Approved by: H Grinsted Director of Aircraft Research and Development
Date: 24.1.47

I – GENERAL
1.01 This specification is issued to cover the design and construction of a medium range bomber for worldwide use by the Royal Air Force
1.02 The operational requirements are stated in Appendix B to this specification.
1.03 This specification gives only the particular requirements for the type in amplification of the current general design requirements stated in:
(i) AP970 with Amendments up to and including AL 38
(ii) Aircraft Design Memoranda, Standardization Design Memoranda, and Standard Instruction Sheets current to the 1st November 1946
(iii) Specification No DTD. 1208(Issue IV) and amendments 1-5 inclusive thereto.
And these requirements shall be completely fulfilled except where varied by this specification, or where the prior written consent of P/DTD (A) has been obtained
1.04 It is essential that the design of the aircraft be suitable for economic production of at least 500 aircraft at a maximum rate of not less than 10 per month.
1.05 Subsequent chapter references in this specification are to AP 970 (as amended by AL 38) in all cases.

II DESIGN REQUIREMENTS
Engines
2.01 Precautions shall be taken to prevent the entry of debris into the air intake.

Engine Failure on Take Off
2.02 In the event of a single engine failure at any stage of the take off the pilot shall either be able to pull up safely without damage, or be able to continue the take off.
In either event the operation must be completed within 150% of the take off distance specified in Appendix 'B'. In the event of the take off being continued it shall not be necessary for the pilot to operate trimmer, flap, and undercarriage or throttle controls until he has reached a height of 100ft.

Emergency Escape
2.03 The provisions for emergency escape by the crew shall be in accordance with JAC Paper 339

Protection of Landing Flaps
2.04 The design shall be such as to minimise damage to any part of the aircraft by water, mud, or stones thrown up by the wheels.

Twin Contact Tyres
2.05 Provision shall be made to allow for the correct operation of the nose wheel unit with a twin contact tyre of suitable pressure so should shimmy occur, a twin contact tyre can be fitted without any modification other than a wheel change being necessary.

Cockpit Colour
2.06 The pilots and bomb aimer's stations shall be finished internally in matt black. The only variation permitted is the use of red for marking emergency controls and exits.

Fire Prevention
2.07 Installation of any combustion heaters or auxiliary power plants shall be in accordance with JAC Paper 336.

Pressure Cabin

2.08 A pressure cabin shall be installed in accordance with Chapter 718 for which p = 9.0lbs .per square inch.

2.09 With the aircraft on the ground the pressure of the air in the cabin shall be raised to 9lbs.per square inch. With the pressure supply cut off the time taken for the pressure to fall from 9.0 to 4.5 lbs. per square inch shall be noted and shall be not less than one minute.

III EQUIPMENT

General

3.01 Equipment shall be fitted or provided for in accordance with the Appendix 'A' to this specification.

IV – STRENGTH AND STIFFNESS

Stressing Weight

4.01 Strength calculations for the take off and flight cases (W2 of Chapter 305) shall be based upon the maximum all up weight of the aircraft when carrying the following.

(i) The tare weight items shown in column 10 of the Appendix A and such removable non standard parts as will be necessary for the contractor to supply and fit in order that the military load may be carried.

(ii) The removable military load defined in Appendix 'A' and approximate to the duties of paragraph of the Appendix 'B'.

(iii) The fuel and oil appropriate to the range of paragraph 12 of the Appendix 'B'

4.02 Strength calculations for landing (W1 of Chapter 305) shall be based upon the take off weight less the weight of bombs and half of the total fuel.

Main Flight Cases

4.03 The requirements of Chapter 201 shall be satisfied at the weight W2, with the basic flight envelope of that chapter having the following values: n1 = 2.7

VD = speeds corresponding to Mach numbers up to and including 0.95 but need not exceed 435 knots EAS

VB = 0.8VD or the maximum speed in level flight which ever is the greater.

4.04 The design shall be such that following take-off the above value of n1 will increase to at least 3.0 by the time one quarter of the still air range specified in paragraph 12 has been has been achieved, and will not subsequently fall below this value.

Parking and Picketing

4.05 The design shall be in accordance with JAC Paper 325, except that the factor will be 1.5 and the wind speed 65knots (75mph)

V TESTS

Contractor's Flight Trials

5.01 Prior to the delivery of the first aircraft, it shall be certified to the P/DTD that:

(a) The aircraft has been subjected to a schedule of flight tests agreed at a meeting to be held by AD/RDL2 approximately one month before the first flight. This schedule will in general be based upon Parts 9 and 10 of AP970 current at that time.

(b) The above-mentioned tests have shown the aircraft as safe to be flown by authorised Service Pilots

APPENDIX 'B' TO SPECIFICATION B35/46

1. The Air Staff require a medium range bomber land plane capable of carrying one 10,000lb bomb to a target 1,500 nautical miles from a base which may be anywhere in the world. The aircraft will be required to attack targets at great distance inside the enemy territory and it must be assumed that it will be plotted by radar and other methods for a large part of its flight. I t must, therefore be capable of avoiding destruction by making the inevitable attack from ground and air launched weapons difficult. To this end it must have:

(a) A high cruising speed – the cruising speed shall be such that attacking fighters will have to fly at a speed at which they will tend to become unmanoeuvrable.

(b) Manoeuvrability at high speed and high altitude – the design must be such that the aircraft can turn rapidly without loss of height or much loss of speed when at maximum cruising height.

(c) A high cruising height – The cruising height must be such that ground launched weapons can only be guided at long range and such that the design of the intercepting enemy aircraft will be difficult.

(d) Capacity for carrying adequate warning devices – these will be needed to detect the approach of ground launched weapons and the proximity of opposing aircraft to be effective the warning device must have long range and may therefore be large. Adequate provision must be made for mounting such a warning system so that it can scan the required field.

(e) Capacity for carrying defensive apparatus – Such as proximity fuses exploders and homing or guided missile jamming devices.

2. The size of the pressure cabin must be as small as possible.

3. Visual and electronic bomb aiming positions are required

4. Maximum performance is the ultimate aim and must not be sacrificed unduly for ease of maintenance

5. It must be possible to operate this aircraft from existing H. B. type airfields and the maximum weight when fully loaded ought, therefore, not to exceed 100,000lbs. The Air Staff is to be informed if the weight will be exceeded

6. The aircraft must be suitable for large-scale production in war.

PERFORMANCE

7. The performance requirements apply to operation in all parts of the world

Speed

8.The aircraft must be capable of cruising at maximum continuous cruising power at heights from 35,000ft to 50,000ft. At a speed of 500 knots.

9. The maximum speed in level flight should be as high as possible but it is not essential that it should exceed the cruising speed.

10. The Flying characteristics must not become dangerous when the speed temporarily rises above the top level speed in the course of combat or other manoeuvres and the Mach No increases to a maximum of 0.90 but a speed restriction is acceptable below 25,000ft.

11. The aircraft will be required to fly under all weather conditions. For this reason it must be capable of comfortable slow speed during the landing approach. The final approach speed should not exceed 120knots and good manoeuvrability must be maintained at this speed.

Range

12. The Maximum operational radius of action with a 10,000lb bomb load must be 1500 miles. To attain this still air range of 3,350 nautical miles at a height of 50,000ft with a 10,000lb bomb carried on the outward and return flight is required.

Climb

13. The aircraft must be capable of reaching 45,000ft with the full load less two and a half hours fuel. The ability to climb above this height is desirable but not essential.

Ceiling

14. The aircraft must cruise at 50,000ft with full load less two and a half hours fuel. The ability to climb above this height is desirable but not essential.

Take Off

15. At sea level under tropical, conditions, the aircraft must clear a 50ft screen within 1500 yards from rest in still air with a cross wind of up to 20 knots at right angles to the take off path. To achieve this rocket take off equipment would be acceptable.

(The development of the RATOG was required to cover this requirement).

Landing

16. The aircraft must be capable under tropical conditions of landing in cross winds of up to 20 knots and coming to rest within 1,400 yards after crossing a 50 ft screen in still air with half the permanent fuel load and no bombs or within 1,700 yards with full fuel/bomb load. When landing with the full fuel/bomb load a slight reduction in the normal safety factors would be acceptable. The Air Staff will accept fuel jettisoning to enable the landing requirements to be met subject to the operation not talking more than 5 minutes. (The use of the brake parachute system was therefore necessary and in addition the fuel jettison system was not installed until the use of under wing tanks on the Mk B2 in RAF service and the conversion to the tanker role for the Mk 1 aircraft when the jettison facility was from the MK 20B pods and the main jettison system terminating in the Mk 17HDU fairing lower extension pipe with the K2 initially using the fuselage jettison facility however it was rendered inoperative and the underwing tanks used along with the Mk 20B pods)

Flight with one or more engines stopped.

17. The aircraft must meet current Air Staff requirements regarding engine failure on take off. It must be capable of maintaining 45,000ft with one engine stopped and 30,000ft with two engines stopped when carrying full load less one hour's fuel. The stopping one engine must not reduce the range by more than 20%.

ARMAMENT

18. The aircraft will rely upon speed, height, and evasive manoeuvre for protection. It will not carry orthodox defensive armament but will be equipped with early warning devices, radar counter measurers to deflect a beam on which a ground or air launched weapon may be launched.

19. A new range of bombs will be carried designed for stable flight frommaximum operational height and speed of this aircraft.

20. The aircraft is required to bomb at is operational ceiling in all weather conditions and therefore the majority of bombing will be with the target hidden by cloud or darkness. It is necessary therefore to carry the new radar bombing equipment under development, which makes use of all radar and D.R navigational data to feed the bombing computer. When the target can be seen, however, a visual bombsight, fed from the same bombing computer, will be used and must be fitted in a position to afford the maximum clear view.

Bombs

21. Capacity is to be provided for a total bomb load of 20,000lb composed of bombs of the following dimensions.

Type	Max Diam.	Overall Length	Distance C.G from nose
10,000lb H.C.	40inch	290inch	80inch
6,000lb H.C.	32inch	225inch	63inch
1,000lb H.C.	16.5inch	110inch	30inch
Special Bomb	60inch	290inch*	80inch*

*First estimate only

22. As an alternative, capacity must be provided for carrying a bomb of the dimensions as shown under 21(Special Bomb) and additional fuel which may be carried in detachable tanks in the bomb cells to meet range requirement stated in paragraph 12 above provided these tanks can be installed or removed in not more than 5 hours.

23. The opening of the bomb doors or other method of release of bombs must not appreciably alter the speed or trim of the aircraft so that it would affect bombing accuracy.

24. It must be possible to release bombs at any speed at which the aircraft is capable of flying. Clearance is required to enable bombs to be released when diving or climbing at an angle of 15degrees or with up to 10 degrees of side slip

Bomb Sights

25. This aircraft will be required to bomb from all heights up to 50,000ft using either visual or electronic bombsights. Provision is to be made for fitting N.B.C. with visual sighting head.

26. The bomb selecting and fusing are to be at the navigation /blind bombing station.

27. Bomb release and jettisoning switches are to be fitted at the pilot's station, the visual bombing position and at the navigation /blind bombing position.

Space is to be made available for bomb guiding equipment.

Bomb Loading

28. Performance must not be prejudiced by designing to use existing bomb handling gear.

Photography

29. Provision must be made for carrying a vertical camera and illuminating apparatus for night photography in order to record the fall of bombs and release points. Photographic recording of the readings of electronic bombsights will be required.

CREW STATIONS

30. The crew will consist of five:

1st Pilot,

2nd Pilot (under training),

2 Navigator/bomb aimer/radar operators,

1 Wireless /Warning and Protective Device Operator

Pressure Cabin

31 The crew are to be accommodated in one pressure cabin. The cabin is to be large enough to allow each member of the crew to move from his seat during flight. The cabin pressure should not be below the equivalent of 8,000ft on the flight to and from the target but may be reduced to the equivalent of 25,000ft in the combat area. Particular importance is attached to keeping the size and hence the weight and vulnerability of the pressure cabin as small as possible. No equipment that can be remotely controlled is to be carried in the cabin. Cabin pressure, humidity and temperature are to automatically control. To reduce fatigue, the maximum crew comfort must be provided.

Pilots Station

32. The pilot must have the best possible view as specified by AP970 and in particular he must have a good view downwards over the nose of not less than 15degrees from the horizontal in level flight. His seat is to be as comfortable as possible. It is too adjusted for height and in a fore and aft direction. The slope of the back is to be adjustable and it is to have folding armrests.

33. The engine instruments are to be visible to the pilot. These are to be kept to the absolute minimum and no instrument is to be provided which is not essential for the correct operation of the aircraft. Instruments required for maintenance check or to indicate something about which the pilot can do nothing in flight are to be excluded. If instruments not required during flight are necessary for pre flight running up and ground test, they are to be provided on a separate and preferably detachable panel outside the pressure cabin. All fuel cocks are to be in reach of the pilot. Engine starting must be from the pilot's seat. Fuel contents and gallons gone meters are to be visible to the first pilot and navigator.

Navigators Stations

34. The two Navigator/bomb aimer/radar operators should be accommodated at a combined station. This station should be as comfortable and quiet as possible and will be required to contain all the navigation instruments, radar navigation controls and indicators, electronic bomb aiming presentation and other radio equipment as detailed in para 62.

Visual Bombing Station

35. A visual bombing station readily accessible from the navigation station is to be provided. The clear field of vision must be 10 degrees aft of vertical to horizontal forward and as wide as lateral, view as possible.

Wireless Operators Station.

36. The Wireless Operators Station will contain all attack warning devices and controls for counter measure devices such as proximity fuse exploders. It must be as comfortable as possible.

PROTECTION

Warning Devices

37. Radar warning devices to detect the launching and approach of ground or air launched weapons or opposing aircraft must be provided to cover at least the whole lower and rear hemispheres.

Crew

38. An appreciation is required of the loss of performance entailed by providing armour against attack by weapons capable of producing fragments equivalent to 0.5 inchA.P. Ammunition and also to provide protection from 0.5 inch gun attack within a 60 degrees including angle from a stern is required. A decision on the requirement for this armour will be made after appreciation for each design submitted has been studied by the Air Staff.

Fuel Tanks and Pipelines

39. (a). Self-sealing is not required but tanks not easily damaged in a crash are to be provided. Neither the tanks nor tank compartments must contain anything capable of acting as a wick for the fuel. Self-sealing pipelines are not required.

(b). Tank purging by inert gas is required for all tanks.

(c) Tanks must be so arranged or compartmented that one whole does not cause the loss of more than 10% of the remaining fuel.

Fire Protection

40. An approved type of fire extinguisher system is required for the engine and tank compartments.

NAVIGATION

41. In order that continuous accurate navigation may be possible over the great distances involved it is essential