PROPOSAL FOR A GAS - TURBINE PROPELLED ALL-WING AIRCRAFT OF CIRCULAR PLAN FORM

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#2

APL/1952
WE NOW HAVE A
VEHICLE FOR THE ENGINE
(CIRCULAR PLAN FORM)

APRIL 1952

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PROPOSAL FOR A GAS TURBINE PROPELLED ALL-WING AIRCRAFT OF CIRCULAR PLAN FORM

1. INTRODUCTION

The following study examines an unorthodox engine-airframe combination - in its essentials.

It does not attempt to explore the full potentialities of the new layout envisaged; but is confined to one example - a piloted aircraft of the smallest practicable size.

A thorough investigation even of this in a reasonably short time is only possible with a design team concentrated on the project.

The tentative figures and conclusions make such an investigation a matter of signal urgency.

Proposal for a Gas-Turbine Propelled All-Wing Aircraft of Circular Plan Form

2. BACKGROUND

The supersonic aircraft now on the drawing board may expect around 500 lb. S.L. static thrust per sq. ft. frontal area or around 700 lb. with afterburning.

> IN THE REGION OF 850 LB. S.L. STATIC THRUST PER SQ. FT. OF FRONTAL AREA IS EXPECTED WITH THIS AIRCRAFT WITHOUT AFTERBURNING.

Take-off, climb and ceiling depend on thrust/weight ratio. A ratio sea level static thrust per lb. gross take-off weight of around 0.70 will be considered high.

> IN THE REGION OF 2.0 LB. SEA LEVEL STATIC THRUST PER LB. OF GROSS TAKE-OFF WEIGHT IS EXPECTED FOR THIS AIRCRAFT, WITHOUT AFTERBURNING.

The importanse of the proposed design is that

> THESE RATIOS CAN BE SIMPLY AND PRACTICALLY REALIZED IN ONE STEP WITH A MODERATE ENGINEERING EFFORT

while at the same time other considerable advantages result. The most significant of which is that

> THIS LAYOUT PRESENTS A GOLDEN OPPORTUNITY FOR ATTEMPTING BOUNDARY LAYER CONTROL BY SUCTION.

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3. LEADING PARTICULARS

Gross take-off weight	16,500 lb.
Wing area.................................	490 sq.ft.
Wing loading at take-off..................	33.7 lb/sq.ft.
Wing loading with $\frac{1}{2}$ fuel	28.0 lb/sq.ft.
Span......................................	25 ft.
Root chord	25 ft.
Tip chord.................................	0
Standard mean chord.......................	19.6 ft.
Sweepback.................................	Variable
Aspect ratio..............................	1.275
Thickness chord ratio	
at centre line.................	0.10
at tip	0
Taper ratio	00
S.L. (SEA LEVEL) static thrust/take-off weight	1.916
/frontal area..........	850 lb/sq.ft.

Proposal for a Gas-Turbine Propelled All-Wing Aircraft of Circular Plan Form

4. GENERAL DESCRIPTION

GENERAL ARRANGEMENT

Two alternative schemes are presented. Scheme 1 (GA.1) employs a more nearly conventional gas turbine engine form and is outlined in the body of this paper. Scheme 2 (GA.2 and Appendix I) is preferred.

GENERAL ARRANGEMENT

Referring to GA. drawing 1,. The fuselage is submerged in a circular wing with a raised canopy around the pilot's head. The engine comprises a single rotor assembly, carrying compressor blading above and turbine blading below. Air is drawn into the compressor through a porous catch area comprising about 50% of the upper wing surface and flows radially through a multiple stage compressor into a single peripheral combustion chamber, the compression being assisted by centrifugal force.

Two sets of guide vanes into and out of the combustion chamber are separated by a ring-plate from which fuel burners project tangentially.

Part of the combusted gases expand across the turbine blades and out through an exhaust annulus producing a small (residual thrust) lift force. The rest, producing the main thrust, exhaust from a slot out of the outer perimeter of the combustion chamber, the direction of flow being controlled by linked shutters either predominantly radially around the whole perimeter - when direct lift is required - or generally aft for forward propulsion, each shutter then being at a different radial angle as shown by the drawing.

A halo ring, supported at intervals around the periphery, except that it is faired to the wing at the front, directs the exhaust gases downwards for vertical lift and also serves to control the aircraft attitude. (Section 7)

Underneath the rotor, between turbine exhaust and central bearing and also above it as indicated, approximately 700 Imperial gallons of fuel are carried.

The wing is 10% thick on the centre line. A 12½% biconvex circular arc aerofoil is drawn on a 20 ft. chord and produced by a wedge to 25 ft. There is thus a 2½ feet plus the canopy in which to sit the pilot.

With full fuel and equipment but with no military or payload the gross take-off weight of this aircraft is estimated to be 16,500 lb. of which 5,600 lb. is fuel (Section 6 and Appendix IV).

Proposal for a Gas-Turbine Propelled
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5. THRUST AND DRAG

Boundary layer suction is employed for the following reasons:

1. A large profile drag reduction is known to be possible (Ref. I). At supersonic speeds wave drag produced from the wing surface will also be reduced. A substantial reduction is possible (Ref. II).

An excursion into the possible effects of suction at supersonic speeds is beyond the scope of this paper.

2. The opportunity provided by the unique position of the engine air intake.

3. A positive advantage in available thrust at high supersonic speed is conceivable. It is clear (from Ref. 2 for instance) that a forward facing intake is an embarrassment at very high speed. The ram temperature rise added to the compressor rise limits the quantity of fuel which can be burned in front of the turbine. Thrust is only produced by burning fuel and disappears altogether below M = 3.0. It seems likely that intake air would be at lower than equivalent ram temperature.

4. If the engine can take all its air through the wing surface, 100% exclusion of foreign bodies is ensured.

5. A hot sharp-edged leading edge is not likely to collect much surface roughness in flight.

6. A large proportion of the total surface area of the aircraft can be sucked (Appendix I). There are no moving control surfaces on the wing, and there is no other surface but the wing.

7. By controlling the out-flow, induced draf co-efficient may be reduced. Note: The jet efflux should be a further assistance

The engine design would no doubt need to make proper allowance for a suction intake. Hence it is desirable to aim for it from the beginning.

The radial flow compressor proposed borrow its attributes from both the centrifugal and axial types.

A plain centrifugal compressor results in a massive impeller The aim is to reduce the tip speed to around 700 ft/sec. If 1,400 ft./sec is assumed to be a normal figure, centrifugal stresses will be roughly one quarter of typical values. (Stress varies approximately as the square of tip speed).

5. THRUST AND DRAG (continued)

There seems no reason why the proposed compressor and turbine should not be as efficient as an axial type, compression ratio at a given tip speed presumably depending to a large extent on the number of stages. A five stage compressor is drawn. Clearly, in Scheme 1, the number of turbine stages can also be increased if necessary.

The similarity of functioning between this engine and a typica gas turbine is quite marked. An empirical approach to thrust and consumption figures appears to be justified for a first approximation (Ref. 3)

Intake, compressor and turbine area are drawn about six times the equivalent areas on a typical 6,000 lb . engine. The S.L. stat thrust is conservatively assumed to be 32,400 lb. (6x6000 x 0.9) and no credit is taken for the effect of Reynolds number on compre sor and turbine efficiendes (ref. 3.) A typical variation of stati thrust with altitude is drawn. (Figure 1).

This represents sweeping assumptions about the thrust of a very large engine. But the aim of the present paper is to point to the possibilities and more detailed work on thrust is beyond its scope. It is a sine qua non that engine and aircraft design proceed together.

Thrust and Mach Number are plotted in co-efficient form (based on the wing area) on Figure 2 which also shows estimated profile draf co-efficient C_Do. Three curves of thrust co-efficien are shown, based on assumptions of the variation of thrust with speed (Figure 3). Curve 'A' is thrust at S.L. , Curve 'B' represen thrust above the tropopause assuming a rapid fall off in thrust above M = 1.4 and curve 'C' for comparison, assumes thrust is invariant with speed.

Subsonic drag without suction is estimated with fair accuracy at C_{Do} = 0.0075.

Thickness chord ratio varies across the span (Figure 4). However, the decreasing sectional thickness is matched by a decreasing Reynolds number (as the chord shortens).

A first estimate of supersonic drag assumes C_{Do} = .026 (3.5 tim the subsonic value) and is invariant with speed. An optimistic est mate assumes CDo = .013 (1.75 x subsonic) and takes credit for reduction in wave drag at the higher Mach Numbers. This is probabl not unrealistic if suction is accounted for. Ref. 4 test points ar shown. These tests were made at infinite saspect ratio and low Reyn number, the theory of Ref. 5 indicates the effect of Reynolds numbe Refs. 6, 7, 8, 9, were considered in compiling these estimates.

Drag efficiency factory (Figure 5) is made to fit assumptions o maximum lift-drag ratio (Appendix III). L/D max. subsonic was assumed to be 9.0 and supersonic 4.0, without credit for boundary layer control. For comparison range assuming L/D max. supersonic = 7.0 was evaluated. The variation of specific range with L/D max. and C_{D_o} is depected graphically on Figure 7 (Appendix III).

6. PERFORMANCE AND WEIGHT SUMMARY (See also Appendices III and IV)

Performance (Standard Conditions)

Maximum level speed (low drag estimate in brackets)

Sea level.. 995 mph (1300) Fig
36,090 to approximately 50,000 ft..............1110 (1360)

Approximate time from start to

36,000 ft. .... 1.6 mins (fig.
60,000 ft. .... 4.0 mins

Ceiling (from take-off at max. Gross Weight,
Climbing at 95% max. thrust)................... 63,000 ft. (fi

Range at minimum drag speeds with allowance for take off, climb, descent and land and 10% fuel reserve. Cruising at 85% max. thrust.

1. Subsonic at 42,000 ft. - mean cruise alt.... 1,030 miles(L/D_m
2. Subsonic at 65,000 ft. - mean cruise alt.... 850 miles(L/D_m
3. Supersonic at 60,000 ft. mean cruise alt ... 850 miles(L/D_m
4. Supersonic at 71,000 ft. mean cruise alt.... with favourable lift - drag ratio achieved by suction.. 1,800 Miles(L/D_m

WEIGHTS

	lb	lb.
Fuselage and wing structure	1,362	
Porous skins..................................	425	
Power plant...................................	7,100	
Other extra to structure	1,793	
		10,68
Pilot...	200	
Full fuel (700 gallons).......................	5600	
Oil...	20	
		5,82
Maximum take -off weight		16,50

A synthetic weight estimate was made based on Scheme 1 The power plant weight was, however, also determined empirically (See Appendix IV for details.)

Proposal for a Gas-Turbine Propelled All Wing Aircraft of Circular Plan Form

7. CONTROL AND STABILITY

A single control surface in the form of a halo situated in the jet stream and supported at intervals around the periphery can, it is believed, be made to perform the necessary control and trim functions and has a satisfactory simplicty.

In order to deflect the jet stream downwards all the control rods (GA.1) are simultaneously pulled by rotating their attachement points in the cockpit.

The shutter setting is selected before increasing the pitch of the halo to direct the thrust mainly radially, but slightly forward to compensate for the fixed part of the halo at the front. Assuming that $C_L = 0.4$ for the halo and the dynamic pressure in the jet efflux is 2,250 lb. sq.ft. ($\rho = .0001$ V = 1,500 ft/sec.) 20,000 lb. lift is produced and the load on the halo is 900 lb./sq. ft.

For forward thrust the shutter position is changed to direct the thrust principally aft resulting in a forward climb then the halo is brought to a new trim position.

Differential movements are obtained by moving the control stick, when the rods flex the halo in the appropriate sense. Power operation is envisaged with a trim control to place the stick central, at any trimmed condition. The large nose up moment due to the CP and CG positions at subsonic speed is balanced by a downward trim on the "elevator" part of the halo.

This scheme should enable the disc to rise vertically in a horizontal attitude. Alternatively a perhaps unpleasant form of take-off with the disc normal to the ground is conceivable. In this case both the ability to hover and the linking of the shutters go overboard. A gain in simplicity for a small aircraft; but the landing problem appears awkward.

A normal take-off is not ruled out; besides weight and complication wheels would displace fuel. However, the high thrust weight would give a very short take-off and assuming C_L max. = 1.3 and a landing loading of 20 lb/sq.ft., stalling speed would be 78 mph. Control surfaces or spoilers are also possible.

Proper investigation of all the possibilities is outside the scope of this paper.

Circular plan form is characterized by high C_L max. at very large angles of attack up to 45° and a sudden stall (ref 9). With a sharp L.E. the stalling charceteristics may be vicious but this is regarded as acceptable if a controlled vertical take-off and landing can be achieved. It is notable that L/D max. for the circu Plan form occurs at a low angle of attack. (Ca. 5°).

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7. CONTROL AND STABILITY (continued)

In the rotor itself, which is estimated to weight approximately 3,800 lb. and to have a moment of inertia of about 4,000 slug-ft.^{2}, a powerful stabilizing agent is available. For a couple at right angles to its axis of spin a gyroscope behaves like a body of veryy large inertia; therefore, an applied pitching moment on the aircraft will result in a slow roll; inherently damped, and harmless by comparison with unwanted pitching.

A 66 ft/sec gust encountered at a forward speed of 135 mph at 80% of max. RPM is calculated to produce a rate of roll of 12.5 deg. per . sec. neglecting damping and inertia in roll.

Occasionally there may be some form of nutatory motion or porpoising. Analysis of this problem appears to be very complicated and is not attempted here.

The pilot's canopy and dorsal extension will provide directional stability.

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8. SUMMARY AND DISCUSSION

The advantages may be summarized:

1. High-thrust/frontal area leading to high speed.

2. High thrust/weight leading to vertical take-off and landing, no airfield problems, no undercarriage. Very high rate of climb and ceiling.

3. Ability to employ a simple scheme of porous suction, possibly leading to big increases in specific range, conceivably simplifying engine design for supersonic speeds.

4. Gyroscopic stability, eliminating dangerous longitudinal trim changes, especially in the transonic region.

5. Good mass distribution leading to low structure weight.

6. Aero-elastic problems reduced to very minor proportions, with large saving in structure weight.

7. No waste space. Every cubic inch of spare volume filled with fuel.

8. Perfect suitability for pressure cabin.

9. No stall problem. Sharp L.E. reduces wave drag; sharp hot L.E. seen as assistance for boundary layer control.

Against all this is the fact that there is only one engine and that stability and control principally depends upon it continuing to function (Appendix III).

The commonsense view highlights the possibilities. The following points it up:

1. This is a flying engine, excellently shaped for this purpose.

2. The engine is designed around the aircraft, not vice versa. The built in power reaches a logical maximum.

3. The widom of upping the thrust without regard to fuel efficiency is open to question. Here we have:

(a) An efficient engine of high compression radio.

(b) An efficient aircraft with virtually a minimum of drag-producing surface area and low wave drag.

(c) The opportunity for increasing the overall efficiency of the two in combination - by boundary layer suction.

8. SUMMARY AND DISCUSSION (continued)

(d) A very efficient structural shape, giving, inter alia, more fuel for the same weight.

We feel we have only scratched the surface of a very large subject. This paper has been composed in a hurry, - the reason is apparent from the concluding remarks.

Nevertheless it appears that a practical aircraft can be made which,

occupying less room than a North American F.86 Sabre, or a de Havilland Vampire,

and requiring no airfield;

can reach 70,000 ft. from a standing start in about 4 minutes and then (taking the optimistic view),

cruise for about 1,500 miles at a speed of over 1,000 miles per hour,

before descending to base.

It is not difficult to visualize a bigger aeroplane like this; probably using a thinner wing section, but still with two or three times the range; with room for a full crew; making use of a high angle of attack for radar scanning etc.

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9. CONCLUSION

The "flying saucer" controversy has been the subject of much ridiculous conjecture. Use of the term has, therefore, deliberately been avoided so far; in order that the rader may as far as possible approach this paper without bias.

This is a simple engine-airframe combination and it seems to have something of great significance to offer.

It will have become apparent to the reader before now that it is indeed a "flying saucer". If it is workable this compels belief that a large proportion of the reports about these things - many of them corroborative - are true. Upon reflection it seems quite certain that aircraft of this nature are being developed behind the Iron Curtain, probably by German brains (Ref. 11). Recent observations in the Korean theatre of war lend force to this startling conclusion. (Appendix V).

The military value ofsuch an aircraft is uncertain but it appears to be enormous. In order to find out, an enthusiastic investigation of this layout - on its merits - and public money to direct the necessary engineering effort ought to be forthcoming. Perhaps something is already being done on these lines. It looks as though it will work.

It also looks as though the Russians have got the jump on the Free World by at least two years. It is hoped that time will not be wasted in debating this point.

J.C. M. Frost
T. D. Earl

......April 1952......

APPENDIX I - ALTERNATIVE SCHEME

Scheme 2 is illustrated by GA 2. Air is drawn through both upper and lower wing surfaces into the central intakes of a double sided impeller which is driven by an inflow turbine in between. The turbine exhaust gases are collected into two non-rotating annu above and below the rotor in the centre with vents at the side and on both upper and lower surfaces.

It is possible to direct the gases out of two vents only in these annuli and into jet pipes protruding from the wing, the one behind the pilot and the other symmetrically underneath. However, in spite of the useful residual thrust it seems likely that the final nozzles would be unacceptably large. A generous weight allo ance for cockpit refrigeration has been included (APPENDIX IV)

Scheme 2 is preferred to Scheme 1 for the following reasons:

1. The main rotor is a much better structure.
2. The intake is double sided so that both wing surfaces can be sucked.
3. The inflow turbine promises good efficiency.
4. The almost complete symmetry makes for greater ease of manufacture.
5. The turbine blading and exhaust is cooled by the incoming air to some extent.
6. The flow through the combustion chamber promises good cooling of the combustion chamber walls.

APPENDIX II - ENGINE FAILURE

The probability of engine failure cannot be overlooked. The aircraft depends largely on the engine for its stability and control. Catastrophic vibration may result from damage to the rotor. Nevertheless, there is a fair possibility of retaining control after loss of thrust, with the ordinary airflow across the control halo. Stability will be a doubtful quantity (although the rotor will take a long time to slow down) but an unstable aircraft is not necessarily an uncontrollable aircraft. These aspects can no doubt be clarified by detail investigation.

If control can be maintained down to slow speed, a forced landing without power should not be exceptionally hazardous because of the low stalling speed.

It is considered undesirable to try to design reserved systems or other ingenious devices. The overall safety level is probably better if the pilot or even possibly the pressurized cockpit is provided with a parachute.

It is a - propos to note here that this particular size of aircraft ought to be producible with military equipment for less than $200,000.00 a piece. (Approximately $20/lb. empty weight). Furthermore, this price appears unfavourably weighted as it makes no allowance for savings on concrete runway construction.

APPENDIX III - PERFORMANCE

For a circular plan form, fundamentally,

$$L/D_m = \sqrt{\frac{e}{C_{Do}}} \qquad (1)$$

where e = drag or span efficiency factor which takes into account devi-iation from the parabolic in C_{Do} vs C_L

C_{Do} = profile drag co-efficient

also

$$V_L = \frac{15.75}{b}\sqrt{\frac{D_{min}}{C_{Do}}} \qquad (2)$$

where
V_L = minimum drag speed (level flight) (m.p.h. EAS)
b = span (ft.)
D_{min} = minimum drag (lb.)

and

$$\frac{V_L}{V_S} = \sqrt{\frac{C_{Lm}}{2\ L/D_M\ C_{Co}}} \qquad (3)$$

where V_S = stalling speed (m.p.h. EAS)

C_{Lm} = maximum lift co-efficient

and

$$R = \frac{15.75}{b.c.\sqrt{C_{Do} \times D_{min} \times \sigma}} \qquad (4)$$

where
R = statute air miles /lb. of fuel @ V_L
c = specific consumption lb./lb. thrust/hr.
σ = relative density

Take off

an allowance of 30 secs. at max. RPM should be adequate. Assuming $c = 1.10$ the fuel used

$$= \frac{32400 \times 1.1}{3600} \times 30 = 297 \text{ lb.}$$

Climb (Fig. 8)

The following technique was assumed. It does not necessarily give minimum time to height or maximum distance/fuel to height,

APPENDIX III - Performance

Climb (continued)

1. Climb vertically to 1,000 ft. (maximum thrust)
2. Accelerate to $M = 0.9$ in level flight at 1,000 ft. (Maximum thrust).
3. Climb to 27,500 ft @ $M = 0.9$ and climb angle of 60° (varying throttle up to climb thrust at this altitude) Fig. I 1.)
4. Finish climb ½ $M = 0.9$ and climb thrust.

A part climb to ceiling, taking $L/D_m = 7$ supersonic and $C_{Do} = .013$ was also evaluated.

In evaluating the climb angle ($\sin\theta = \frac{T - D}{W}$) the induced drag should be factored by $\cos\theta$. The effect is not unduly large and has been neglected.

The distance covered in climb to high altitude was 50 miles and the fuel used (including take-off) 1,080 lb. For the subsonic cruise at low altitude, the distance to 36,000 ft was 20 miles and the fuel used 870 lb.

Range

For convenience range is evaluated at L/D_m. At any particular altitude maximum air miles per lb. is obtained at a higher speed than V_L. A further approximation was made in that the range was found by multiplying air miles per lb. at the mean cruising weight by the cruising fuel. 10% initial fuel was allowed as reserve and 500 lb. was allowed for descent and landing.

Cruising specific fuel consumption was assumed at 1.2 lb/lb thrust/hr. while using 85% maximum thrust, that is in all cases except the subsonic cruise at the lower altitude. Here the thrust required is only about 15% of the maximum and specific consumption was approximated at 1.6.

Descent was assumed to cover 100 miles in all cases and this was crediated to the range.

It is notable that V_L/V_S (from eq^n. 3) is unusually high. So that at $M = 0.9$ the stall (assuming $C_{Lm} = 1.0$ could be reached without buffet) at mean cruising weight is not reached before 80,000 ft.

Turning performance should benefit form this situation. The stability problem in a banked turn has not been examined.

APPENDIX IV - WEIGHTS

The detail estimate is as follows:

Structure

Fuselage	327	
Porous Skins	425	
Wing (Skins, Ribs, Stiffeners, etc.)	1035	
		1787

Extra to Structure

Power Plant:		
Combustion System	2520	
Rotor Assembly (including Bearing)	3780	
Guide Vanes	250	
Ringplate	150	
Fuel System	230	
Details	170	
		7100
Control System including Halo	453	
Hydraulics	110	
Electrics	160	
Radio	120	
Accessory Drive, etc.	160	
Cockpit Equipment	295	
Fuel System and Tanks	205	
Pressurization and Refrigeration	290	
		1793

Disposal Load

Pilot	200	
Full Fuel	5600	
Oil	20	
		5820
Maximum Take-Off Gross Weight		16500

APPENDIX V - PRESS REPORTS

The magazine "LIFE" for April 7, 1952 carries an article which collects together a number of reports of "flying saucers". It selects ten (10) incidents as evidence that they are not man-controlled flying machines; deliberately making out a "case for the interplanetary theory; the following extracts and comments are presented:

1. Lubbock, TEXAS - night of August 30 -

   .... an attempt to photograph .... 1/10 second exposure ....

   .... the Air Force, after the closest examination, has found nothing fraudulent about (the) pictures ....

   .... if the lights were flying at 5,000 ft... about 1,800 m.p.h. ....

   COMMENT The photographs as printed conform accurately to the proposed design. In a formation the light from the others would light the polished surface of the one. The heart shape also photographed fits with a blanked off area at the rear.

2. NEW MEXICO, 4:47 p.m. - July 10, 1947 -

   .... curious bright object, almost motionless .... clearly exhibited a sort of wobbling motion ....

   COMMENT It seems difficult to arrange for the centre of lift to be at the C.G. for hovering. If it is offset, nutation or a precession analagous to a top might be expected.

3. NEW MEXICO, 11 p.m. - Summer 1948 -

   .... silently overhead .... seemed to be quite low ... half a dozen "windows" clearly visible at the front and along the side .... glowed with the same blue-green colour .... had a touch of yellow in it.

   COMMENT Windows = exhaust nozzles. Possibility of using propane as fuel?

5. Officer in Command of the Radar Equipment that keeps watch over a certain Atomic Installation - one day in the fall 1949 -

   .... watching a radarscope that covered 300 miles .... five apparently metallic objects .... less than four minutes .. believes that in this instance he made a legitimate radar contact.

   COMMENT Say 200 miles in 4 mins. is 3000 mph M = 4.5. Sounds rather too fast for the high altitude stated to be observed on the scope. How is the altitude determined?

Appendix V - Press Reports

8. WONSAN, KOREA at 200 m.p.h. - January 29, 1952 - flying in B.29 -

.....20,000 ft. ....bright round orange object in the sky near the plane....flew with revolving motion, wore a halo of bluish flame .....3 ft. in diameter...

COMMENT Possibly a remote controlled missile. More likely larger and further away. Bronze with a high finish might appear orange.

10. Across the skies of ARIZONA - on the night of November 2, 1951 - a ball of kelly green fire -

.....exploded in a frightful paroxysm of light....without making a sound. At least 165 people saw the thing, hundreds more witnessed the flight of countless other fireballs, etc. Air Force established "project twinkle" to investigate them....for three months a crew kept vigil ....saw nothing.

......when asked to indicate most witnesses touched the colour band at 5,200 angstroms, close to the green of burning copper.

COMMENT Suggested to be extra terrestrial. An alternative explanation is that this/they, was/were sintered bronze porous wing surfaces burning furiously and unintentionally.

Almost without exception the reports of these things can be construed to show that the sighted object was a disc viewed from some angle or another.