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The College of Aeronautics

DEPARTMENT OF AIRCRAFT DESIGN

'Short' S.C.7 Turbo-Skyvan Mk.II

Economics of the Crop-Spraying Role

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Summary

Short Bros. and Harland Ltd. have carried out a brief preliminary study of the Turbo-Skyvan for crop-spraying and have derived payload data and operating costs on a provisional basis[1].

Further studies have been carried out by the College to assess the Turbo-Skyvan on the basis of economic comparison with typical available aircraft operating on agricultural work and this report deals with the detail of these comparisons.

Conclusions are that under European small-field conditions[3], the Skyvan only becomes competitive when advantage is taken of its versatility to provide a single operator with a number of roles, one of which would be crop-spraying, thereby increasing utilisation to more realistic figures (1500 and 2000 hrs/yr. have been investigated, in addition to the average 'crop-spraying only' utilisation of 400 hrs/yr).

Under Afro-Asian operating conditions, with larger fields and greater areas[4], the above comments are still substantially true but, when the higher utilisations are considered, the Skyvan is cheaper to operate and has a higher application capacity than its assumed competitors.

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1.0 Introduction

The Mk.II Turbo-Skyvan has a high sales potential as a versatile, rugged, high-performance light freighter with good short-field characteristics and the ability to achieve rapid conversion from role to role.

One of the envisaged roles is that of crop-spraying and the following study examines the economic aspects on a comparative basis with current single-purpose fixed-wing agricultural aircraft and with multi-purpose rotary-wing aircraft used for agricultural purposes.

Fixed utilisations of 400 hours/year have been assumed for the comparison. However, whilst this would be a reasonable figure for the single-purpose machines, it is clearly unrealistic when applied to the 'Skyvan'. Higher total utilisations have therefore been considered also (1500 and 2000 hours/year) on the assumption that an operator would wish to exploit versatility to the full and use the aircraft in alternative roles during that period of the year when crop-spraying is not required.

The economics of both liquid spraying and granular spreading have been examined under small-field conditions in Europe and also under the conditions of larger fields and greater areas generally applicable in Afro-Asian countries.

A rotary-wing aircraft is included in the comparison and, although its utilisation is also capable of being increased considerably in other roles, it has been treated as single-purpose for this particular investigation. Advantages of the helicopter are undoubtedly great when applied to small-field conditions; ferry flights are shorter and turning times less, hence a higher output per acre can be expected. The advantages are, however, not so apparent when applied to larger fields due, in part, to payload restrictions but also due to inherent instability which aggravates pilot fatigue to a considerably greater extent than that applicable with fixed-wing aircraft.

For the above reasons, therefore, the 'Hiller' helicopter has not been used in the Afro-Asian liquid spraying and granular spreading comparisons. The 'Skyvan' has been compared only with the 'Snow' S.2 C and the 'Pawnee' PA.25-235 for this role since these are considered to be typical of valid competitive aircraft.

European field sizes are extracted from ref.3 and the quoted typical area of 10 acres used in the calculations. A subsequent detailed examination of actual campaigns conducted in the U.K. and Europe[4] tends to indicate that this is a minimum figure and that the average is actually of the order of 30 acres. This increase will favour the 'Skyvan' and the fixed-wing aircraft generally when compared with the helicopter. However, it will make little difference to the comparison with each other since all are considered at the same datum. 30 acres is still a small field and the above statements re greater helicopter efficiency under these conditions remain valid. For these reasons, therefore, the calculations using ref.3 figures are considered to be sufficiently accurate for comparative purposes.

2.0 Cost Analysis (Table 2)

2.1 General

The analysis is based on a utilisation of 400 hrs/yr. in the crop-spraying role. Variations will be applicable of course from year to year since utilisation is governed, to a large extent, by weather limitations. However, 400 hours seems to be generally accepted in the U.K.[2] and Europe as an average realistic figure for any given year and appears to apply to Afro-Asian countries also.[4] Total utilisations of 1500 and 2000 hours are also considered, however, with the Skyvan (see Introduction), in order to give a more realistic indication of overall costs with a multi-purpose aircraft of this type.

Two main factors are analysed:- 'cost of aircraft' and 'cost of supporting services'. Aircraft cost is sub-divided into variable cost (maintenance, spares, C.of A., fuel and oil) and fixed cost (depreciation, insurance, hangarage and interest) and the supporting services assumed to be pilot cost, ground support, overheads and markers. A 'flight efficiency' factor[3] is also introduced in order to take account of non-productive flying in any given year due to crew-training, check-flights etc.

Cost figures for the comparison are derived from the following sources:-

'Hiller' 12 E 'Snow' S2.C. Piper 'Pawnee' PA 25-235	Ref.4.
Short 'Turbo-Skyvan'	Ref.1 Used as a guide and augmented for the higher utilisations.

Ref.4 gives figures derived from actual spraying operations (for the fixed-wing aircraft - the 'Hiller' helicopter is not necessarily an actual cost but is derived from the same source) conducted by the companies quoted in ref.4. and can therefore be considered as realistic information current in 1964.

Ref. 1 is used as the basis for cost reasoning on the 'Skyvan' and this is examined in detail in the following paragraphs:-

2.2 Cost Reasoning - Turbo-Skyvan

2.2.1 Maintenance and spares

Maintenance costs will reduce with utilisation to the figures indicated in the table. Engine servicing will remain at the same figure per engine hour, likewise engine overhaul, although this may increase due to increased hours. The 'overhaul' figure is based on a developed engine

life of 1500 hours which would clearly be exceeded with both 1500 and 2000 hour periods. However, the figure takes into account unscheduled overhauls and one replacement engine. Similar comments apply to prop. overhaul and replacement.

In general, therefore, the figures for engine and prop. overhaul will not be substantially different for the higher utliisations since, although the total cost would probably be greater, it would be spread over an increased number of hours.

Airframe materials are costed for a total aircraft life and the figure is enhanced by including spray equipment and radio maintenance for the crop-spraying role although, in fact, radio is seldom used in crop-spraying operations.

2.2.2 Certificate of Airworthiness

C. of A. cost for a 400 hour utilisation is assumed to be 7/6d per hour giving a total of £150 (300 man hours). This is roughly equivalent to a check 3 and seems reasonable for 400 hours flying (505 actual). It is also in line with other published figures[3]. The figure quoted in ref.5 gives 120 per cent of a check 4 as the basis (for 1200 hours annual utilisation) but the check 4 man-hour content in ref.1 is very different from that quoted in ref.5 and covers a 2-year period (840 man-hours in ref.1 - 280 man-hours in ref.5). Assuming ref.1 to be realistic (and also assuming that the C. of A. penalty is not included in the quoted ref.1 figures) 120 per cent is 1008 man-hours over a 2-year period. Annual C. of A. cost therefore, on this basis, is 504 man-hours (£252) and constitutes something between a check 3 and a check 4. This seems reasonable for the higher utilisations and is the figure used in the table.

It is appreciated that a man-hour rate of 10/- for labour is fairly low - particularly when applied to trained engineers working overseas under field conditions. However, both European and Afro-Asian cases are being compared, in the general sense, using a single cost breakdown, hence an average European rate is assumed for the purpose of general comparison and included in the variable cost column.

2.2.3 Fuel and oil

This will not be substantially different whatever the role. Ref.1 figures are quoted as £5.9/hour and £5.48/hour according to the particular sortie pattern. However, we could expect to do better if longer distances are covered in the alternative roles during considered utilisation periods. No mention is made of oil in the reference and, in order to take this into account, a pessimistic overall figure of £6.0/hour has been assumed in the table.

2.2.4 Depreciation, hangarage and interest

Depreciation is assumed to be applicable over a period of 5 years to a residual value of 20 per cent [4]. The figure is spread over the different utilisations and is accordingly a direct ratio. When the higher utilisations are considered however, there will be an increase in capital cost since items not required for the crop-spraying role will be required for other roles within the total periods. The actual differences will be fairly marginal though in terms of shillings/acre hence the ref.1 figure has been assumed throughout.

Hangarage and interest, which is taken as a combined figure of 7 per cent [4], is also a direct ratio in the same way.

2.2.5 Insurance

The single-purpose crop-spraying aircraft with a limited utilisation apparently tolerate a penalty of 15 per cent on an annual basis, therefore the 'Skyvan' must

clearly be considered at the same datum condition when operated in the crop-spraying role. Higher utilisations (including a crop-spraying role) mean, logically, that the insurance company is underwriting a greater risk even though the bulk of total flying hours is carried out in a role which would not normally have such a high loading. Enquiries have been pursued with a major aviation insurance company and their opinion (for the hypothetical case) is that the 15 per cent premium applicable to the aircraft in its crop-spraying capacity will cover use in other roles regardless of utilisation. It is assumed therefore, that this is the case and the 15 per cent total is ratioed accordingly over the higher utilisations, resulting in the figures indicated.

2.2.6 Pilot cost

This is assumed at £5.0/hour (including expenses) for a specialist pilot engaged on crop-spraying. A figure of £3.5/hour is quoted in ref.1 for 800 hours flying as an average. However, comparisons of pilot cost with other types of aircraft used on agricultural work tend to indicate that £5.0 is a more realistic figure. There will be some variation, of course, since pilot cost in Africa, for example, is greater by approximately 20 per cent. However, with a single cost breakdown it is not possible to cater for zonal differences and the figure is considered to be a reasonable average.

When utilisation is increased to 1500 hours, another pilot will be required on the basis that when a crop-spraying facility is wanted a specialist pilot will be engaged for the purpose, and when the aircraft is flying in a normal role, e.g. freighting, the balance of 1100 hours will be flown by a permanent pilot retained on an annual basis. The permanent pilot is costed at £4.0/hour (allowing for expenses) and the combined rate spread over the utilisation period, giving the overall figure indicated in the table.

A similar reasoning is applied to the higher utilisation of 2000 hours however, the balance of 1600 hours could not be flown by a single pilot. Two permanent pilots would be required in addition to the crop-spraying specialist but, again, the hourly rate would probably be constant irrespective of the 'sharing' aspect. Hence £4.0/hour is still a valid figure for the balance.

One other point is the fact that, for the three utilisations of 400, 1500 and 2000 hours; actual flying times (when the efficiency factor is considered) are 505, 1770 and 2325 hours respectively. On a total flying hour basis therefore (as opposed to productive flying hours), the rates would accordingly be reduced to £3.96, £3.48 and £3.52. This compares with the ref.1 figure except for the specialist agricultural role.

2.2.7 Ground support

This figure takes account of equipment depreciation and operating cost together with salaries of ground personnel. A blanket figure for labour of 2 hours ground time for each flying hour is assumed and this gives a standard labour cost of £1.0 at the 10/- rate. Depreciation of equipment for the crop-spraying role assumes a capital cost of £8,750[4] with a rate similar to that of the aircraft, i.e. over 5 years to a residual value of 20 per cent. When this is combined with the labour charge, it results in the figure of £4.5/flying hour for the 400 hour period. If we now assume that the utilisation period is 1500 hours, 1100 in roles other than crop-spraying, then ground equipment cost will increase accordingly and the figure assumed is £20,000. This would also apply if the utilisation was 2000 hours. Labour is again costed at £1.0 and the final ground support figures arrived at as indicated in the table.

2.2.8 Overheads

Cost of supervision, survey and administration is assumed to be £2.8/hour over the 400 hour period[4].

A subsequent investigation of costs during recent campaigns[4] tends to indicate that the figure is low and that £3.5 would be more realistic. However, costs of this nature are changing continuously and would require to be applied in the particular rather than the general context if complete accuracy is to be guaranteed. £2.8 has been used, therefore, as a known figure in 1964 and applied to all aircraft used in the comparison.

The balance of utilisation over 1500 and 2000 hours with the 'Skyvan' will result in a considerable increase, particularly if the passenger carrying role is considered. The overheads are accordingly trebled, resulting in the quoted figures when spread over the utilisation periods.

2.2.9 Cost of markers

Markers are not normally required in Afro-Asian areas but the cost breakdown, again, is not separated for the two zones of operation considered and, since they are usually used in both the U.K. and Europe the charge of £2.4/hr. for the crop-spraying period of 400 hrs.[4] is applied to all aircraft and spread over the additional 'Skyvan' utilisations as a direct ratio.

2.3 Flight Efficiency Factor

2.3.1 FerryingTime

Ferrying times to and from base and operating site are mainly a function of aircraft speed. The figures quoted are based on ref.3 and augmented accordingly. The 'Skyvan' is increased from 50 to 100 hours for the higher utilisations since there will be an additional penalty to take account of flying to and from different bases for particular roles. Operators in the U.K. for example, may wish to crop-spray in the Sudan. Utility flying in both freight and passenger-carrying roles will also be higher.

2.3.2 Crew training

An arbitrary figure of 10 per cent productive flying is assumed for familiarisation, practice etc. although it is appreciated that this figure will vary between companies and, again, according to the particular zone of operation; it will also be dependent upon the quality of pilots employed. A top-grade, specialist pilot for example, will not require the same degree of practice on 'dummy runs' etc. as a pilot with less experience. The top-grade man on the other hand, will be difficult to find and because of his 'scarcity' value will no doubt cost a great deal more to retain.

Since we are considering the general case, the 10 per cent figure, although perhaps a little high, caters for the 'worst' condition and is therefore assumed to be valid for this reason.

2.3.3 Check Flights

Air testing for the purpose of checks after maintenance depends upon the maintenance cycle for the particular aircraft. 15 hours is assumed, again on the basis of ref.3, for the 400 hour crop-spraying utilisation although, when examined in conjunction with the maintenance cycle of ref.1 for the 'Skyvan', it does seem a little excessive. 20 and 25 hours respectively for the higher utilisations is considered to be reasonable since radio, for example, would require more air-test time in both the freight and passenger roles.

3.0 Liquid Spraying (Tables 3-8: Figs.1-4)

Application rates of from 1-5 imperial gallons/acre are considered in the analysis since these appear to be valid figures depending upon the type of operation[6]. The Baltin-Amsden formula[7] is used to assess performance per hour, taking account of variables applicable with both the considered aircraft and the particular area of operation (European or Afro-Asian).

A number of assumptions are inevitably made, particularly with the 'Skyvan', in order to arrive at the formula figures however, these are considered to be as realistic as possible and the tendency is to err on the pessimistic rather than the optimistic side.

Rates are analysed for both European and Afro-Asian conditions and related costs with 400 hours utilisation considered for all aircraft, together with the two higher utilisations of 1500 and 2000 hours in the case of the 'Skyvan' (Figs.1 and 3). Capacities are also compared on the basis of time/spray cycle, again under both European and Afro-Asian conditions (Figs.2 and 4).

4.0 Granular Spreading. (Tables 9-14: Figs.5-8)

When granular spreading is considered, the pattern of cost/capacity is substantially similar to that of liquid spraying. The 'Skyvan' is slightly less efficient in fact, in the 'crop-spraying only' role (400 hours utilisation) since the percentage increase in swath width is less (25 per cent greater than with both 'Snow' and 'Pawnee' with a single venturi spreader compared with approximately 40 per cent greater for liquid spraying).

The venturi-type spreading unit (there are other types but the venturi is most common) relies on the slipstream to distribute material at the rear to a swath width of between 6 and 16 yds[6]. Swath width varies with speed of air through the spreader, hence with aircraft speed and engine power and, of course, with fertiliser rate of flow.

We could expect to achieve close to the maximum swath width with the 'Skyvan', using a single venturi. However, since we have a twin-engine layout it would be sensible to exploit the advantages by engineering two venturis into the system, one to each engine. Such a system is in fact advocated by Air Commodore Wheeler in his paper in ref.8.

This method gives an immediate benefit of approximately 18 ft. (assumed as 15 ft. to allow for inefficiencies) extra swath width when applied to the 'Skyvan', an increase of the order of 33 per cent over the single venturi and 66 per cent over the single-engined 'Snow' and 'Pawnee'. There are physical problems of course but the layout of the aircraft is such that it should be possible to embody a dual venturi system using spreaders specially designed for the purpose.

The comparison is carried out therefore, using single and dual spreaders and considering the 'agricultural role only' for the 'Skyvan', together with the higher utilisations of 1500 and 2000 hours under both European and Afro-Asian conditions. Application rates between 50 and 250 lbs/acre[6] are assumed for the cost comparisons (Figs.5 and 7) and capacities also examined as in liquid spraying (Figs.6 and 8).

5.0 Conversion Penalties

Examination of the detail of conversion from, say, freighting to crop-spraying indicates that a penalty of 10 per cent utilisation (on the basis of 400 hours/year in the crop-spraying role) would be fairly realistic. This gives 40 man-hours and, with the working space available in the 'Skyvan', would probably mean approximately two days on the ground. If the conversion could be phased with a maintenance cycle then the penalty would be very nominal indeed.

Stripping of the aircraft and systems, necessary for the crop-spraying role, does not seem to be difficult, with the possible exception of de-icing. Insufficient detail is available to form a firm opinion on this but the assumption is that it is no more difficult to strip than other systems on the aircraft. The basic design philosophy of simplicity and ease of maintenance has been applied to a high degree, generally, hence the assumption is considered to be valid.

Installation of the spraying/spreading system will probably be the major time-consuming item and a substantial part of the design effort will require to be directed towards rapidity and ease of component fitment with maximum prior provision embodied on the airframe.

6.0 Discussion

It is clear from the analysis that the Turbo-Skyvan is uneconomic when used in the crop-spraying role on a single-purpose basis (Figs.1,3,5 and 7) The high capital cost is such that an average crop-spraying utilisation of 400 hours/year cannot spread the economic penalty sufficiently to make it an attractive proposition, in spite of the relatively high carrying capacity. Treating the aircraft on a single-purpose basis, however, is not really sensible since its main attraction is versatility coupled with a facility for rapid conversion from role to role. Taking advantage of this facility therefore gives an altogether different picture and, when the capital cost is spread over a realistic utilisation, the aircraft in a crop-spraying role is at a considerable advantage over other single-purpose agricultural aircraft on a cost/acre basis and can, by virtue of its greater capacity, cover larger areas in a given time.

Under European conditions for example, with a 2000 hour total annual utilisation and spraying liquid at the 2 gallon/acre rate (fig.1) the 'Skyvan' costs 23 per cent less/acre to operate than the 'Snow' and approximately the same as the 'Pawnee' but with spray rates in acres/hour greater by 21 per cent and 31 per cent respectively. The fixed-wing aircraft generally, however, cannot compete with the helicopter under these short-field conditions since, even with higher utilisations on the 'Skyvan', costs/acre are one per cent more and spray rates 34 per cent less than the 'Hiller'.

When, on the other hand, Afro-Asian field conditions are examined at the same utilisation (fig.3) and again spraying liquid at the 2 gallon/acre rate, the 'Skyvan' costs 33 per cent less/acre than the 'Snow' and 30 per cent less than the 'Pawnee' but with spray rates greater by 37 per cent and 76 per cent respectively.

This considerable increase in capacity in an area in which the Skyvan is undoubtedly most likely to be used highlights an advantage which is of great importance. Specialist agricultural pilots are in extremely short supply therefore any aircraft which can offer the facility of greater area coverage with the same pilot effort must be attractive to an operator. As an illustration of this aspect the increases in terms of spray rates, mean realistically that 3 'Skyvans' can cover the same area as 4 'Snows' in a given time and hence 3 pilots are required instead of 4. Similarly 2'Skyvans' can cover 18 per cent more area than 3 'Pawnees', again one less pilot is required and in both cases the 'Skyvan' cost/acre is less, even with the intermediate 1500 hour utilisation. Considerably less, in fact, when the 2000 hour period is assumed.

When large-field Afro-Asian conditions are considered, therefore (and the pattern is similar for both liquid spraying and granular spreading) the 'Skyvan' at realistic utilisations, is cheaper to operate and has a considerably higher spraying/spreading capacity than any of the sample aircraft compared in this analysis.

7.0 Conclusions

Under European conditions as a single-purpose crop-spraying aircraft, at an average 400 hours utilisation the 'Turbo-Skyvan' is not an economic proposition. When advantage is taken of the aircraft's versatility however, and utilisations are increased to fulfil a multi-purpose role in the hands of a single operator, the 'Skyvan' is not only

cheaper to operate but is also more efficient in terms of acres/hour than the specialist fixed-wing agricultural aircraft used in the comparison. European short-field conditions generally, however, tend to favour the rotary wing machine since turning times are of primary importance.

When large-field conditions applicable in Afro-Asian countries are considered, the 'Skyvan' again, although not really competitive at the unrealistic 'crop-spraying only' utilisations, is both cheaper and considerably more efficient than its assumed competitors when the multi-purpose role philosophy is applied to achieve the full design potential. A major advantage accruing from higher efficiency is the reduction of pilot effort required for the same spray coverage. Under the present conditions of acute specialist pilot shortage, this is an important factor which will clearly be seriously considered by any potential operator.

Engineering aspects of liquid spraying and granular spreading installations will require further detail design study however, the aircraft is eminently suitable for rapid conversions of this type and, on the basis of a general appraisal, the problems appear capable of solution if the necessary design effort is directed towards this end.

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Table 1. Particulars of Aircraft [9]

Type	Span	Length	A.U.W.	Disposable Load	Max. Fuel		Payload lbs.		Fuel-Max. Payload		Speed m.p.h		Ground run	Rate of Climb	Engine Power
	ft.	ft.	lbs. max	lbs.	lbs.	galls	Max. Fuel	Max.	lbs.	galls	Cruise	Stall	ft	ft/min	H.P.
Snow S2.C	42½	27½	5,700	2472	372	51½	2100	2400	72	10	105	72	900	800	600
Piper Pawnee PA25-235	36	25	2,900	1250	238	33	1012	1200	50	7	105	62	800	630	235
Hiller 12E	35½ dia.	41	2,800	846	274	38	572	800	46	6½	90	-	0	740	305
Turbo-Skyvan*	64	40	12,500	5197	1800	225	3397	4600	597	75	173	80	860	1300	630x2

* Derived from 'Short Turbo-Skyvan' Operating Data Ref.SE/53 Issue 2. Nov. 1965.

Table 2 Cost Analysis (Cost of Flying/Hr.)

Aircraft Type		Snow S2.C	Pawnee PA25-235	Hiller 12E	Turbo-Skyvan		
Source of Cost Information		Ref.4	Ref.4	Ref.4	Ref.1 - Augmented		
Utilisation Hrs/yr.		400	400	400	400	1500	2000
		£. s. d	£. s. d	£. s. d	£. s. d	£. s. d	£. s. d
Maintenance	Variable Cost	No Breakdown	No Breakdown	No Breakdown	5.19.5	5.14.0	5.13.5
Spares					1.19.9	1.19.9	1.19.9
C. of A.					0. 7.6	0. 3.4	0. 2.6
Fuel and Oil					6. 0.0	6. 0.0	6. 0.0
	Totals	12.10.0	8.12.0	11.12.0	14. 6.8	13.17.1	13.15.8
Depreciation	Fixed Cost	No Breakdown	No Breakdown	No Breakdown	46. 0.0	12. 5.4	9. 4.0
Insurance					43. 2.6	11.10.0	8.12.6
Hangarage and Interest					20. 2.6	5. 7.4	4. 0.6
	Totals	11.16.0	6. 0.0	26. 0.0	109. 5.0	29. 2.8	21.17.0
Pilot Cost		4.12.0	4.12.0	4. 8.0	5. 0.0	4. 5.4	4. 4.0
Ground Support		4. 0.0	4. 4.0	4. 0.0	4.10.0	3. 2.8	2.12.0
Overheads		2.16.0	2.16.0	2.16.0	2.16.0	2. 4.9	1.13.7
Cost of Markers		2. 4.0	2. 4.0	2. 4.0	2. 4.0	0.11.9	0. 8.9
	Totals	37.18.0	28. 8.0	51. 0.0	138. 1.8	53. 4.3	44.11.0

Table 2(a) Flight Efficiency Factor[3]

Ferrying Time	80	80	90	50	100	100
Crew Training	40	40	40	40	150	200
Check Flights	15	15	15	15	20	25
Hours/Year	135	135	145	105	270	325
Efficiency	66.25%	66.25%	63.75%	73.75%	82.00%	83.75%
Cost of Productive Flying per Hour	57. 4.0	42.17.4	80. 0.0	187. 4.6	64.17.9	53. 3.9

'Baltin-Amsden' Formula[7]

$$t = \text{Minutes/Acre} = \frac{TrQ}{Qf} + \frac{165}{bv} + \frac{4840Tw}{60bL} + \frac{120aQ}{VQf} + \frac{60C}{VF}$$

(Filling) (Spraying) (Turning) (Ferrying) (Dist. Factor)

$$T = \text{Minutes/Spray Cycle} = \frac{tQf}{Q}$$

Table 3. Formula Comparisons European - Liquid.

	Snow S2.C	Pawnee PA25-235	Hiller 12E	Turbo-Skyvan
Tr mins	7	7	3	11
Q lbs	50,40,30,20,10	-	-	-
Qf lbs	2250	1100	685	4000
b yds	18	18	12	25
v m.p.h	90	90	80	120
Tw secs	45	45	10	55
a miles	3	3	1/4	3
V m.p.h	105	105	90	175
C miles	3/4	-	-	-
F acres	10	-	-	-
L yds	220	-	-	-

Table 4. Summary of Spray Rates and Costs. European - Liquid

Dosage Rate Imp./Gals./Acre.	Snow S2.c		Pawnee PA25-235		Hiller 12 E		Turbo-Skyvan			
								400	1500	2000
	Acres /Hr.	Shills /Acre	Acres /Hr.	Shills /Acre	Acres /Hr.	Shills /Acre	Acres /Hr.	Shills /Acre	Shills /Acre	Shills. /Acre.
5	46.4	24.7	39.1	21.9	77.8	20.6	57.0	65.7	22.8	18.7
4	48.1	23.8	41.6	20.6	83.1	19.3	58.9	63.6	22.0	18.1
3	50.0	22.9	44.5	19.3	89.0	18.0	60.9	61.5	21.3	17.5
2	52.0	22.0	48.0	17.9	95.8	16.7	63.0	59.4	20.6	16.9
1	54.2	21.1	51.9	16.5	104.0	15.4	65.1	57.5	19.9	16.3

Above results are plotted in Fig.1.

$$\text{Acres/Hr.} = \frac{60}{t}$$

$$\text{Shillings/Acre} = \frac{\text{Shillings/Flying Hour}}{\text{Acres/Hour.}}$$

Table 5. Capacity Comparisons European - Liquid

Dosage Rate Imp.Galls/Acre (Average Payload)	Snow S2.C		Pawnee PA25-235		Hiller 12E		Turbo-Skyvan	
	Hrs/ Cycle	Acres/ Cycle	Hrs/ Cycle	Acres/ Cycle	Hrs/ Cycle	Acres/ Cycle	Hrs./ Cycle	Acres/ Cycle
5	0.97	45.0	0.56	21.9	0.18	14.0	1.40	79.8
4	1.17	56.3	0.66	27.5	0.21	17.5	1.70	100.1
3	1.50	75.0	0.82	36.5	0.26	23.1	2.19	133.4
2	2.16	112.3	1.15	55.2	0.36	34.5	3.18	200.3
1	4.16	225.5	2.12	110.0	0.66	68.6	6.14	399.7

Above results are plotted in Fig.2

$$\text{Hours/Spray Cycle } T = \frac{tQf}{60Q}$$

No. of Acres/Spray Cycle = (T x No. of Acres/Hour)

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Table 6. Formula Comparisons Afro-Asian - Liquid

		Snow S2.C	Pawnee PA25-235	Turbo-Skyvan
Tr	mins	7	7	11
Q	lbs	50,40,30,20,10	-	-
Qf	lbs	2250	1100	4000
b	yds	18	18	25
v	mph	90	90	120
Tw	secs	45	45	55
a	miles	2	-	-
V	mph	105	105	175
C	miles	1	-	-
F	acres	90	-	-
L	yds.	1750	-	-

Table 7. Summary of Spray Rates and Costs. Afro-Asian - Liquid

Dosage Rate Imp.Galls/Acre	Snow S2.C		Pawnee PA 25-235		Turbo-Skyvan			
						400	1500	2000
	Acres /Hr.	Shills /Acre	Acres /Hr.	Shills /Acre	Acres /Hr.	Shills /Acre	Shills /Acre	Shills /Acre
5	139.5	8.2	93.0	9.2	190.5	19.7	6.8	5.6
4	154.6	7.4	107.0	8.0	211.3	17.7	6.1	5.0
3	173.4	6.6	126.1	6.8	237.2	15.8	5.5	4.5
2	196.7	5.8	153.1	5.6	270.3	13.9	4.8	3.9
1	227.3	5.0	194.8	4.4	314.1	11.9	4.1	3.4

Above results are plotted in Fig.3.

$$\text{Acres/Hr.} = \frac{60}{t}$$

$$\text{Shillings/Acre} = \frac{\text{Shillings/Flying Hour}}{\text{Acres/Hour.}}$$

Table 8 Capacity Comparisons Afro-Asian - Liquid

Dosage Rate Imp.Galls/Acre (Av. Payload)	Snow S2.C		Pawnee PA25-235		Turbo-Skyvan	
	Hrs/ Cycle	Acres /Cycle	Hrs/ Cycle	Acres /Cycle	Hrs./ Cycle	Acres /Cycle
5	0.32	42.4	0.24	22.3	0.42	80.0
4	0.36	55.7	0.26	27.8	0.47	99.3
3	0.43	74.6	0.29	36.6	0.56	132.8
2	0.57	112.1	0.36	55.1	0.74	200.0
1	0.99	225.0	0.56	109.1	1.27	398.9

Above results are plotted in Fig.4.

Hours/Spray Cycle $T = \frac{tQf}{60Q}$

No. of Acres/Spray Cycle = (T x No. of Acres/Hr.)

Table 9 Formula Comparisons European - Granular

	Snow S2.C	Pawnee PA25-235	Hiller 12E	Turbo-Skyvan	
				Single Venturi	Dual Venturi
Tr mins	7	7	3	11	11
Q lbs	250,200,150,100,50	-	-	-	-
Qf lbs	2250	1100	685	4000	4000
b yds	12	12	10	15	20
v mph	90	90	80	120	120
Tw secs	45	45	10	55	55
a miles	3	3	1/4	3	3
V mph	105	105	90	175	175
C miles	3/4	-	-	-	-
F acres	10	-	-	-	-
L yds	220	-	-	-	-

Table 10 Summary of Spray Rates and Costs European - Granular

Application Rate lbs/Acre.	Snow S2.C		Pawnee PA25-235		Hiller 12E		Turbo-Skyvan							
									400		1500		2000	
	Acres /Hr.	Shills /Acre	Acres /Hr.	Shills /Acre	Acres /Hr.	Shills /Acre	Acres/Hour		Shills/Acre		Shills/Acre		Shills/Acre	
							Single	Dual	Single	Dual	Single	Dual	Single	Dual
250	22.0	52.0	15.2	56.4	32.6	49.1	26.3	31.3	142.4	119.6	49.4	41.5	40.5	34.0
200	24.0	47.7	17.3	49.6	37.6	42.6	28.4	34.2	131.9	109.5	45.7	38.0	37.5	31.1
150	26.5	43.2	20.0	42.9	44.4	36.1	30.7	37.7	122.0	99.3	42.3	34.4	34.7	28.2
100	29.5	38.8	23.8	36.0	54.1	29.6	33.6	42.0	111.4	89.2	38.6	30.9	31.7	25.3
50	33.3	34.4	29.3	29.3	69.3	23.1	36.9	47.4	101.5	79.0	35.2	27.4	28.8	22.4

Above results are plotted in Fig.5.

$$\text{Acres/Hour} = \frac{60}{t}$$

$$\text{Shillings/Acre} = \frac{\text{Shillings/Flying Hour}}{\text{Acres/Hour.}}$$

Table 11. Capacity Comparisons — European - Granular

Application Rate lbs/Acre (Average Payload)	Snow S2.C		Pawnee PA25-235		Hiller 12E		Turbo-Skyvan Single Venturi		Turbo-Skyvan Dual Venturi	
	Hrs/ Cycle	Acres /Cycle	Hrs/ Cycle	Acres /Cycle	Hrs/ Cycle	Acres /Cycle	Hrs/ Cycle	Acres /Cycle	Hrs/ Cycle	Acres /Cycle
250	0.41	9.0	0.29	4.4	0.08	2.7	0.61	16.0	0.51	16.0
200	0.47	11.3	0.32	5.5	0.09	3.4	0.71	20.2	0.59	20.2
150	0.57	15.1	0.37	7.4	0.10	4.6	0.87	26.7	0.71	26.7
100	0.76	22.4	0.46	11.0	0.13	6.9	1.19	40.0	0.95	40.0
50	1.35	45.0	0.75	22.0	0.20	13.7	2.17	80.1	1.69	80.1

Above results are plotted in Fig.6.

Hours/Spray Cycle $T = \frac{tQf}{60Q}$

No. of Acres/Spray Cycle = (T x No. of Acres/Hr.)

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Table 12. Formula Comparisons Afro-Asian - Granular

	Snow S2.C	Pawnee PA25-235	Turbo-Skyvan	
			Single Venturi	Dual Venturi
Tr mins	7	7	11	11
Q lbs	250,200,150,100,50	-	-	-
Qf lbs	2250	1100	4000	4000
b yds	12	12	15	20
v mph	90	90	120	120
Tw secs	45	45	55	55
a miles	2	-	-	-
V mph	105	105	175	175
C miles	1	-	-	-
F acres	90	-	-	-
L yds	1750	-	-	-

Table.13 Summary of Spray Rates and Costs Afro-Asian - Granular

Application Rate lbs/Acre	Snow S2.C		Pawnee PA25-235		Turbo-Skyvan 400				1500		2000	
	Acres /Hr	Shills /Acre	Acres /Hr	Shills /Acre	Acres/Hr		Shills/Acre		Shills/Acre		Shills/Acre	
					Single	Dual	Single	Dual	Single	Dual	Single	Dual
250	45.0	25.4	24.9	34.4	57.7	61.6	64.9	60.8	22.5	21.1	18.4	17.3
200	53.3	21.5	30.2	28.4	67.9	73.3	55.2	51.1	19.1	17.7	15.7	14.5
150	65.3	17.5	38.3	22.4	82.3	90.4	45.5	41.4	15.8	14.4	12.9	11.8
100	84.3	13.6	52.4	16.4	104.5	117.9	35.8	31.8	12.4	11.0	10.2	9.0
50	118.3	9.7	83.1	10.3	142.9	169.0	26.2	22.2	9.1	7.7	7.4	6.3

Above results are plotted in Fig.7.

$$\text{Acres/Hr.} = \frac{60}{t}$$

$$\text{Shillings/Acre} = \frac{\text{Shillings/Flying Hour}}{\text{Acres/Hour}}$$

Table 14. Capacity Comparisons Afro-Asian - Granular

Application Rate lbs/Acre (Average Payload)	Snow S2.C		Pawnee PA25-235		Turbo-Skyvan			
					Single Venturi		Dual Venturi	
	Hrs/ Cycle	Acres /Cycle	Hrs/ Cycle	Acres /Cycle	Hrs/ Cycle	Acres /Cycle	Hrs/ Cycle	Acres /Cycle
250	0.20	9.0	0.18	4.4	0.28	16.2	0.26	16.0
200	0.21	11.2	0.18	5.5	0.29	19.7	0.27	19.8
150	0.23	15.0	0.19	7.3	0.32	26.3	0.30	27.1
100	0.27	22.8	0.21	11.0	0.38	39.7	0.34	40.1
50	0.38	45.0	0.26	21.6	0.56	80.0	0.47	79.0

Above results are plotted in Fig.8.

Hours/Spray Cycle $T = \frac{tQf}{60Q}$

No. of Acres/Spray Cycle = (T x No. of Acres/Hr.)

FIG. 1. COMPARISON OF OPERATING COSTS

EUROPEAN CONDITIONS :-

FIELD LENGTH – 220 YDS.

AREA – 10 ACRES

DIST. BETWEEN FIELDS – 0·75 MILE

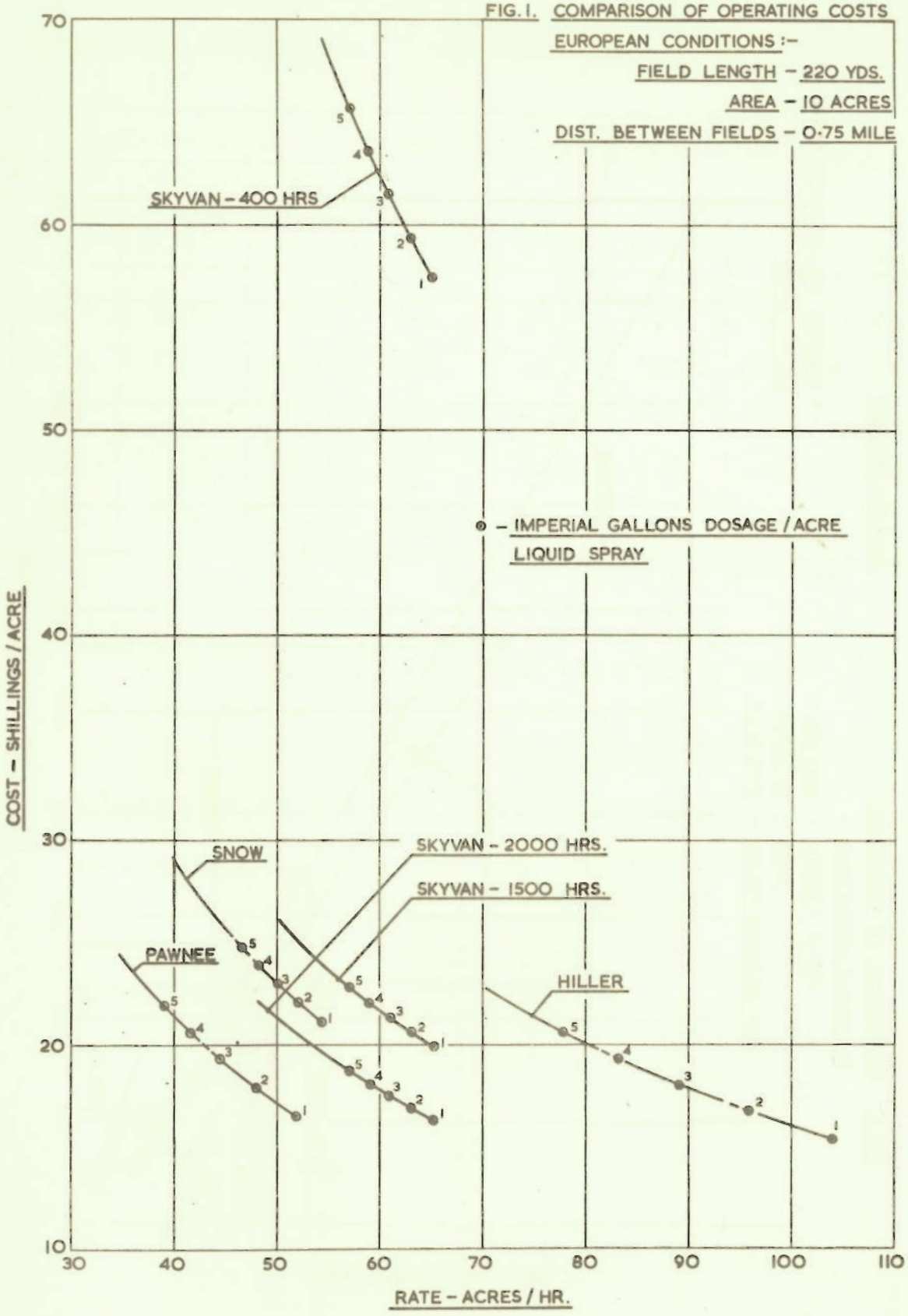


FIG. 2. COMPARISON OF CAPACITIES

EUROPEAN CONDITIONS :-

FIELD LENGTH - 220 YDS.

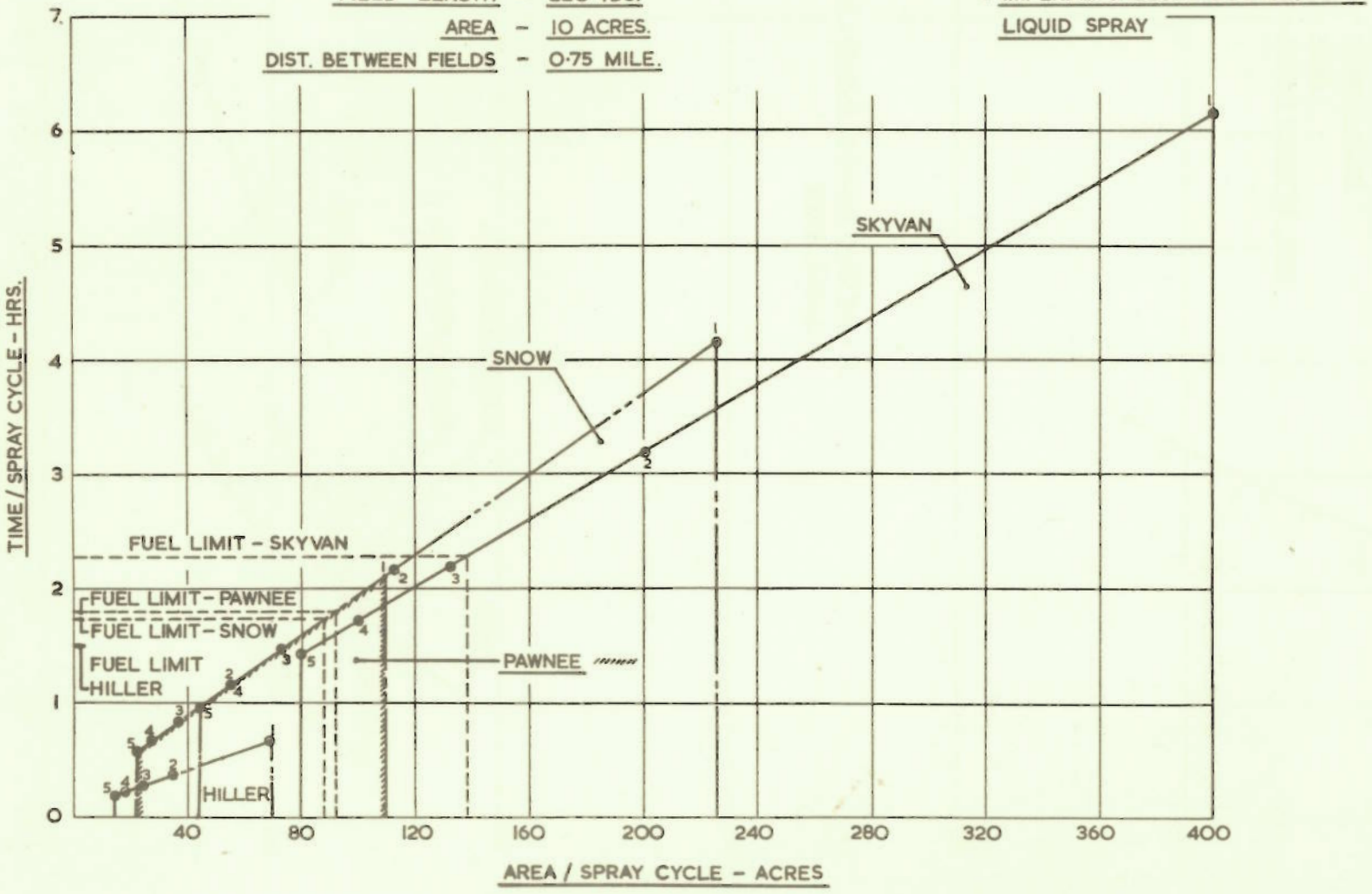
AREA - 10 ACRES.

DIST. BETWEEN FIELDS - 0·75 MILE.

AVERAGE PAYLOAD

⊙ IMPERIAL GALLONS DOSAGE/ACRE

LIQUID SPRAY



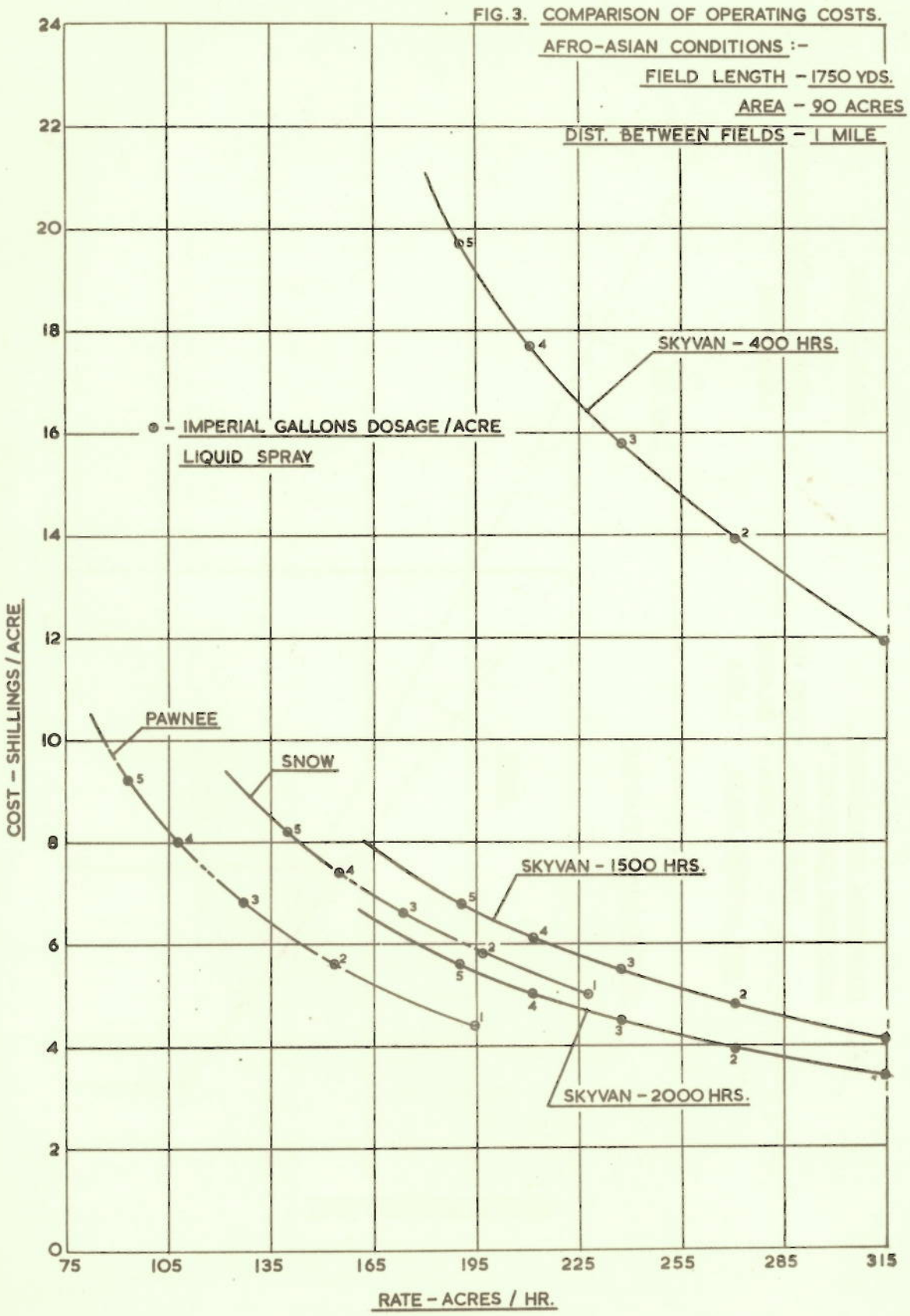

FIG. 3. COMPARISON OF OPERATING COSTS.
AFRO-ASIAN CONDITIONS :-
FIELD LENGTH - 1750 YDS.
AREA - 90 ACRES
DIST. BETWEEN FIELDS - 1 MILE
SKYVAN - 400 HRS.
⊙ - IMPERIAL GALLONS DOSAGE / ACRE
LIQUID SPRAY
PAWNEE
SNOW
SKYVAN - 1500 HRS.
SKYVAN - 2000 HRS.
COST - SHILLINGS / ACRE
RATE - ACRES / HR.
0
2
4
6
8
10
12
14
16
18
20
22
24
75
105
135
165
195
225
255
285
315

FIG. 4. COMPARISON OF CAPACITIES

AFRO-ASIAN CONDITIONS :-

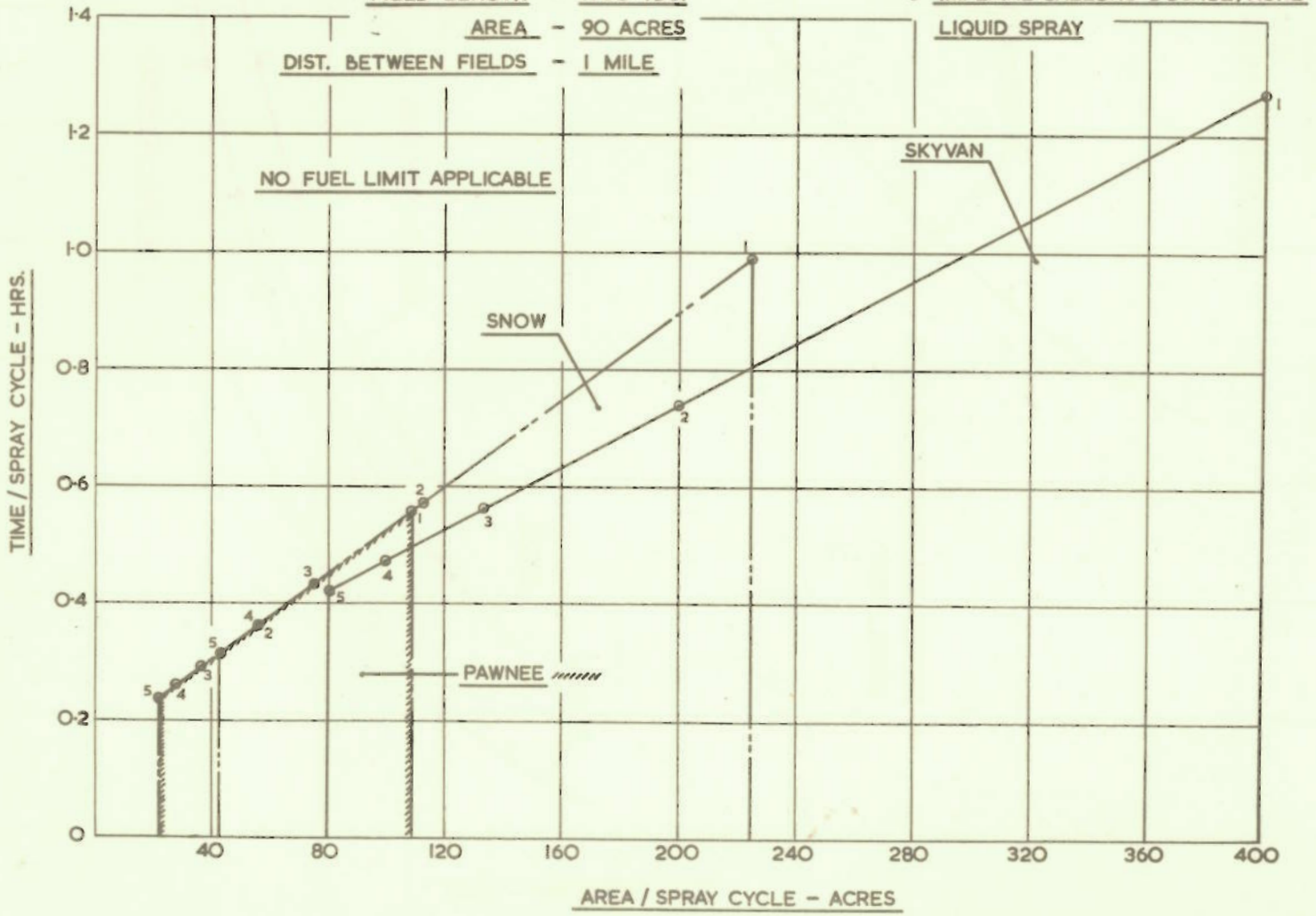
FIELD LENGTH - 1750 YDS.

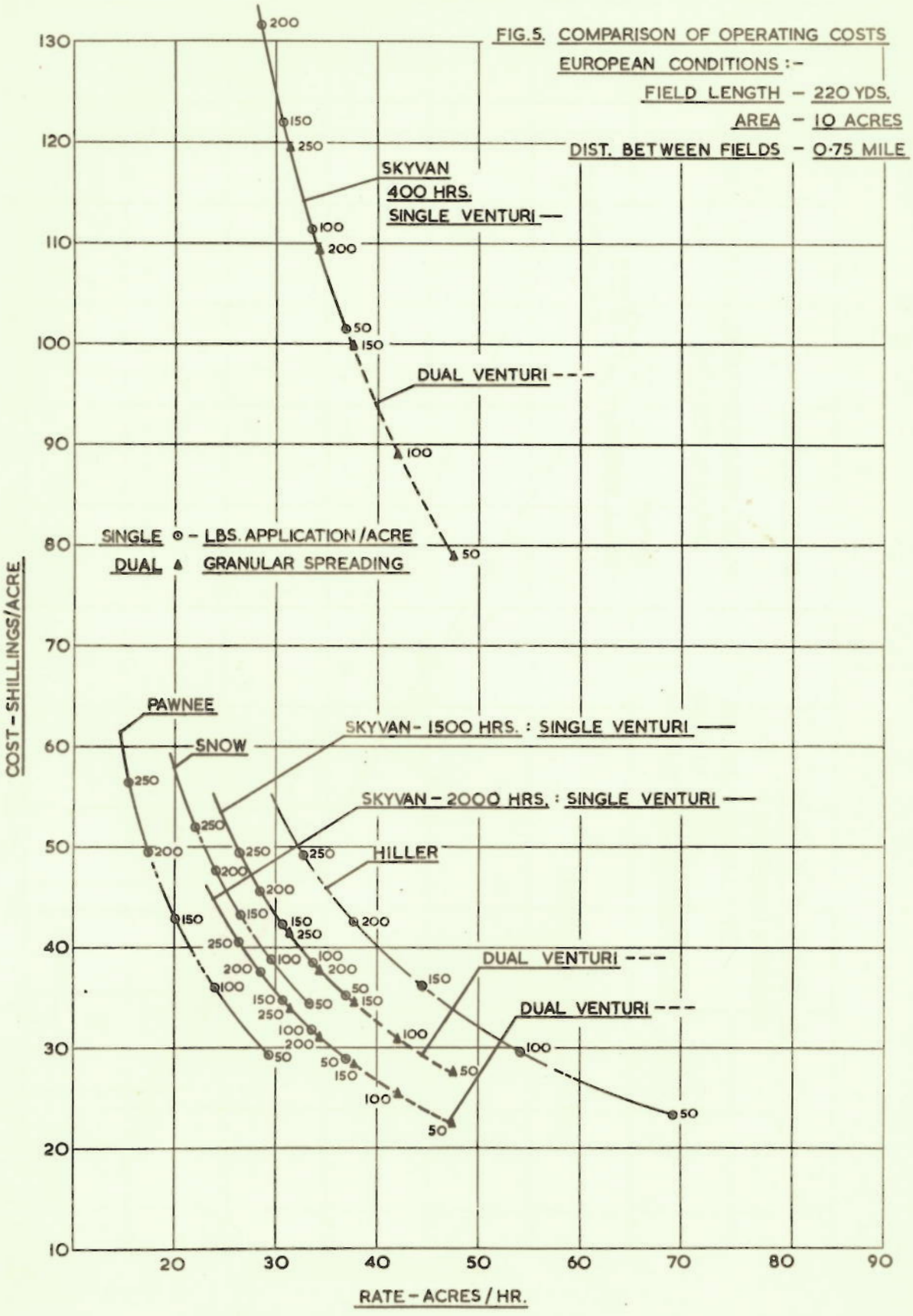
AREA - 90 ACRES

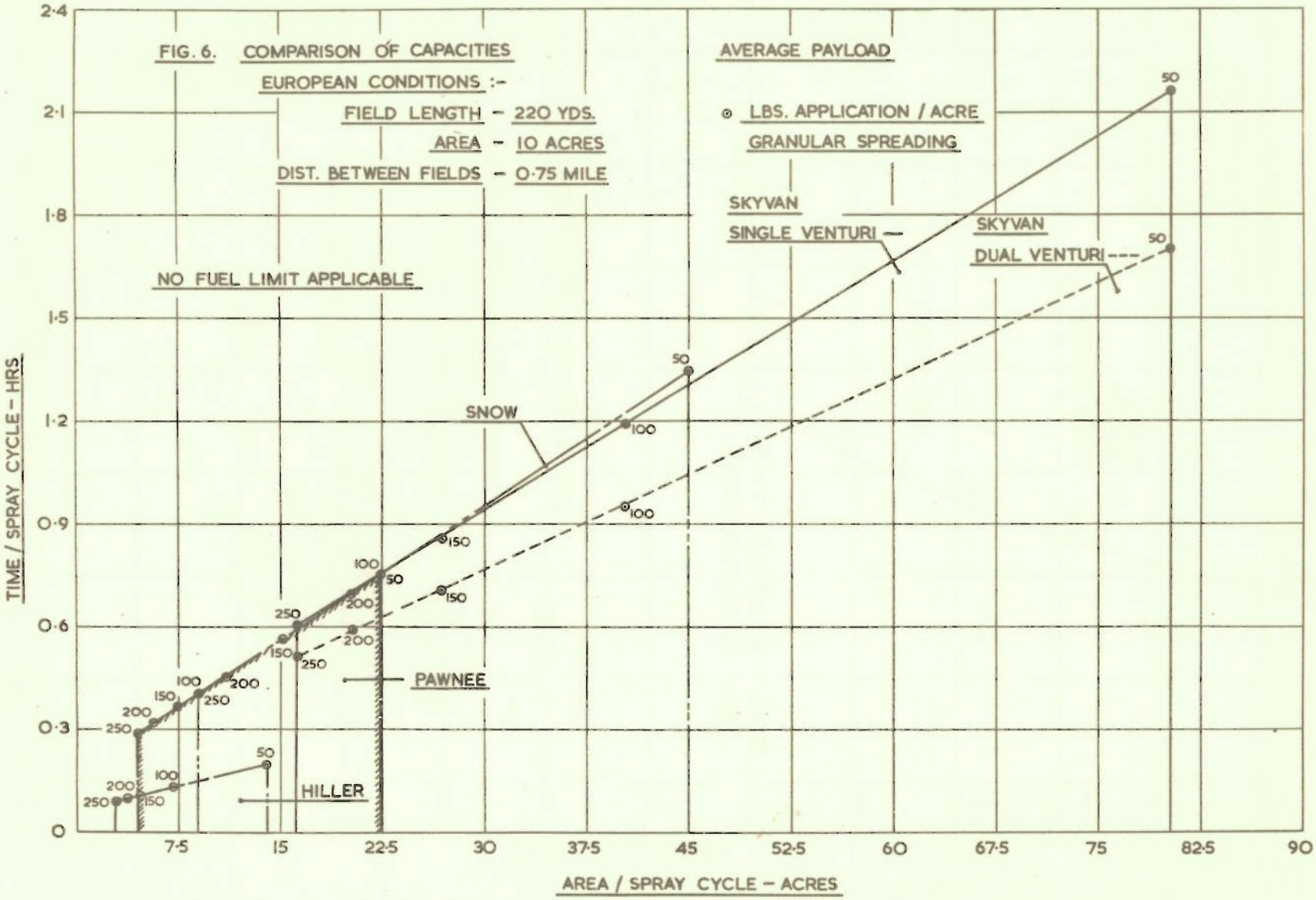
DIST. BETWEEN FIELDS - 1 MILE

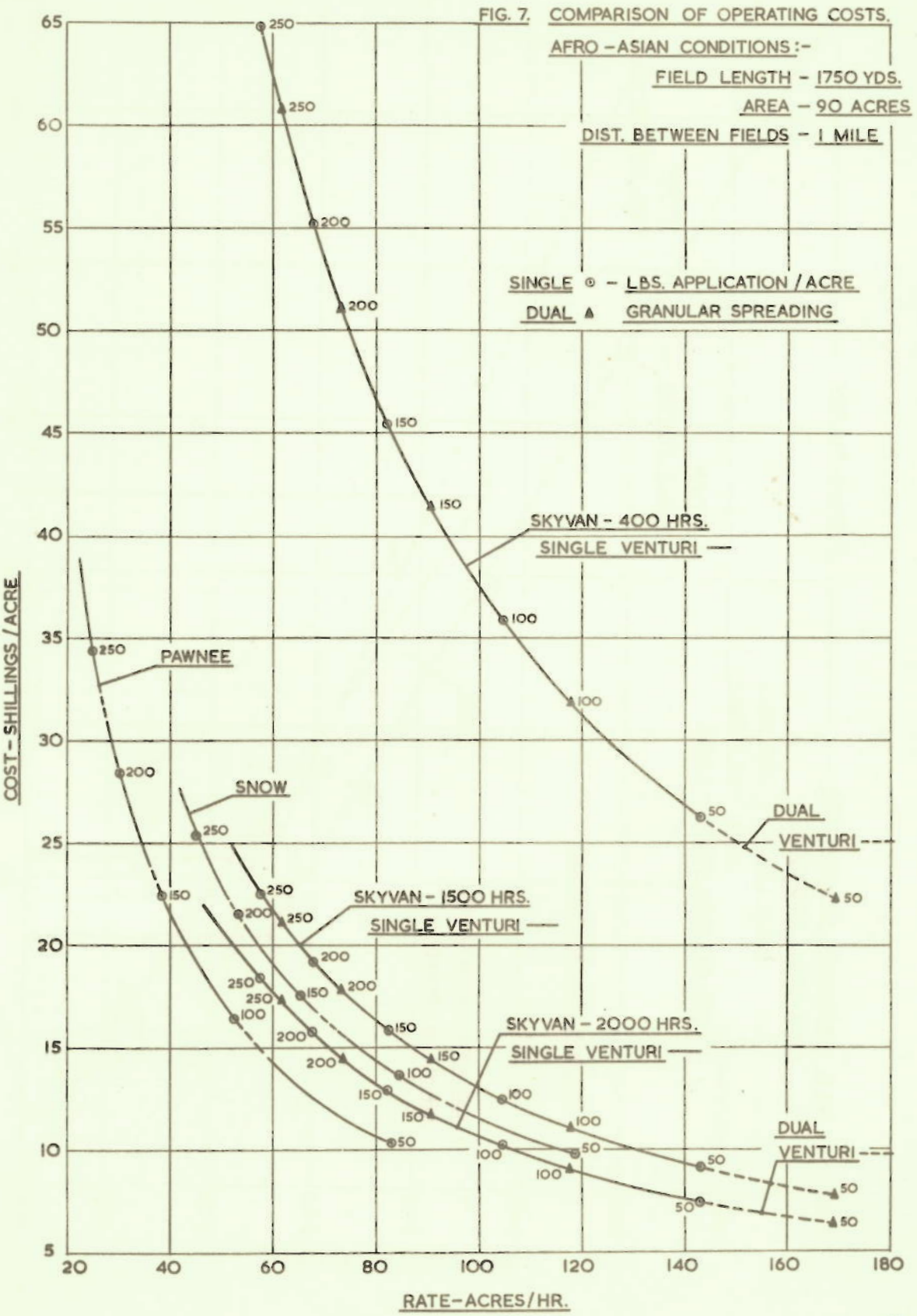
AVERAGE PAYLOAD

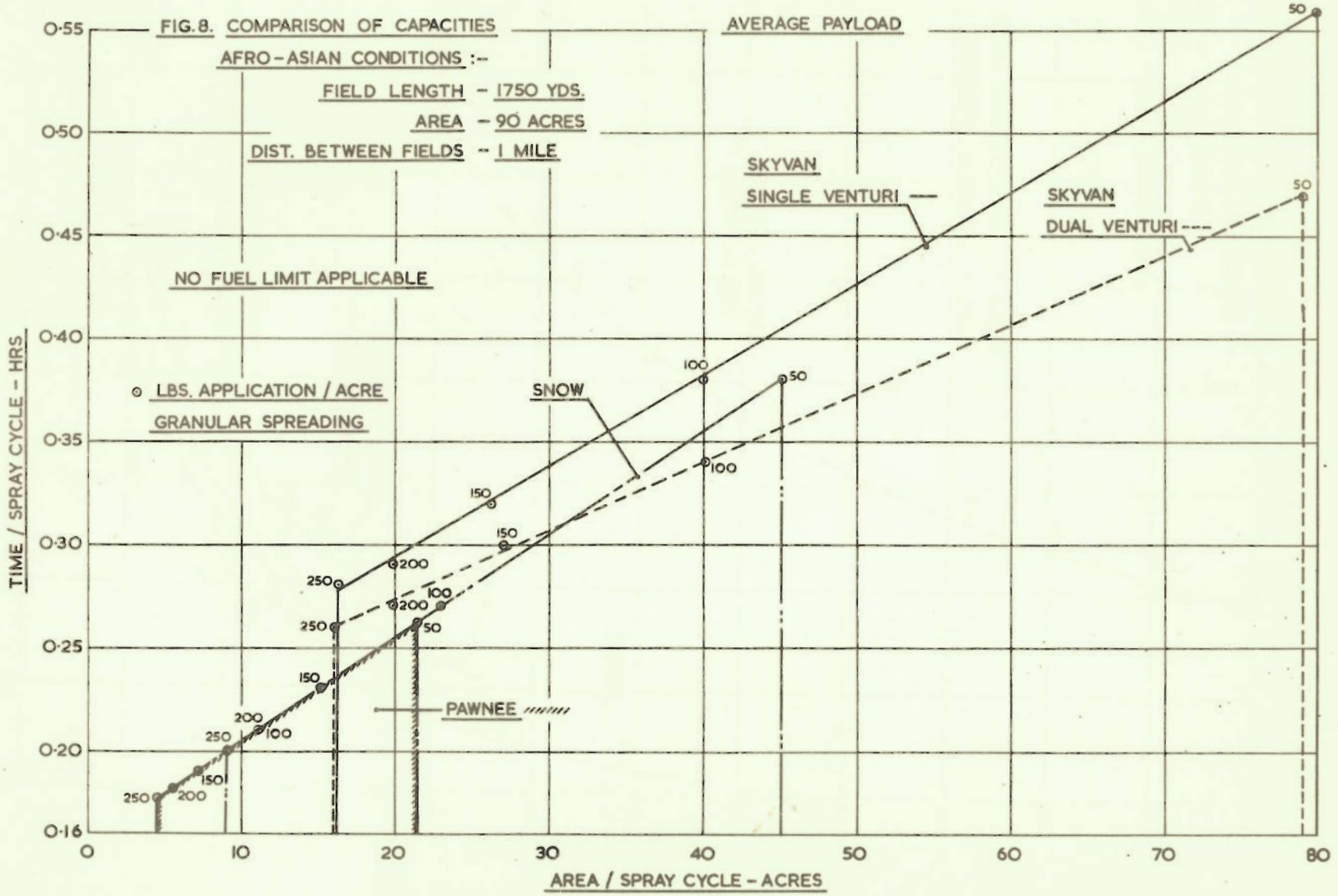
⊙ IMPERIAL GALLONS DOSAGE/ACRE LIQUID SPRAY




FIG.5. COMPARISON OF OPERATING COSTS
EUROPEAN CONDITIONS :-
FIELD LENGTH – 220 YDS.
AREA – 10 ACRES
DIST. BETWEEN FIELDS – 0·75 MILE
SKYVAN 400 HRS. SINGLE VENTURI
DUAL VENTURI
SINGLE ⊙ – LBS. APPLICATION/ACRE
DUAL ▲ GRANULAR SPREADING
PAWNEE
SNOW
SKYVAN – 1500 HRS. : SINGLE VENTURI
SKYVAN – 2000 HRS. : SINGLE VENTURI
HILLER
DUAL VENTURI
DUAL VENTURI
COST – SHILLINGS/ACRE
RATE – ACRES/HR.
10
20
30
40
50
60
70
80
90
100
110
120
130


FIG. 6. COMPARISON OF CAPACITIES
EUROPEAN CONDITIONS :-
FIELD LENGTH – 220 YDS.
AREA – 10 ACRES
DIST. BETWEEN FIELDS – 0·75 MILE
NO FUEL LIMIT APPLICABLE
AVERAGE PAYLOAD
⊙ LBS. APPLICATION / ACRE
GRANULAR SPREADING
SKYVAN
SINGLE VENTURI
SKYVAN
DUAL VENTURI
SNOW
PAWNEE
HILLER
TIME / SPRAY CYCLE – HRS
AREA / SPRAY CYCLE – ACRES
2·4
2·1
1·8
1·5
1·2
0·9
0·6
0·3
0
7·5
15
22·5
30
37·5
45
52·5
60
67·5
75
82·5
90


FIG. 7. COMPARISON OF OPERATING COSTS.
AFRO-ASIAN CONDITIONS:-
FIELD LENGTH - 1750 YDS.
AREA - 90 ACRES
DIST. BETWEEN FIELDS - 1 MILE
SINGLE ⊙ - LBS. APPLICATION / ACRE
DUAL ▲ GRANULAR SPREADING
SKYVAN - 400 HRS.
SINGLE VENTURI
PAWNEE
SNOW
SKYVAN - 1500 HRS.
SINGLE VENTURI
SKYVAN - 2000 HRS.
SINGLE VENTURI
DUAL VENTURI
DUAL VENTURI
COST - SHILLINGS / ACRE
RATE - ACRES / HR.
65
60
55
50
45
40
35
30
25
20
15
10
5
20
40
60
80
100
120
140
160
180


FIG. 8. COMPARISON OF CAPACITIES
AVERAGE PAYLOAD
AFRO-ASIAN CONDITIONS :-
FIELD LENGTH - 1750 YDS.
AREA - 90 ACRES
DIST. BETWEEN FIELDS - 1 MILE
NO FUEL LIMIT APPLICABLE
SKYVAN
SINGLE VENTURI
SKYVAN
DUAL VENTURI
LBS. APPLICATION / ACRE
GRANULAR SPREADING
SNOW
PAWNEE
TIME / SPRAY CYCLE - HRS
AREA / SPRAY CYCLE - ACRES
0·55
0·50
0·45
0·40
0·35
0·30
0·25
0·20
0·16
0
10
20
30
40
50
60
70
80
250
200
150
100
50