

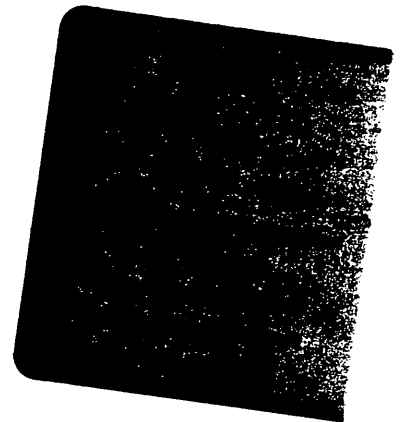
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⑥ OPERATION PINK ROSE
⑨ FINAL REPORT,

⑩ Robert W. Mutch ,
Craig C. Chandler ,
Jay R. Bentley ,
Clyde A. O'Dell
Stanley N. Hirsch .

APR 16 1993

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⑪ May 1967 ⑫ 12/19

U. S. Department of Agriculture - Forest Service

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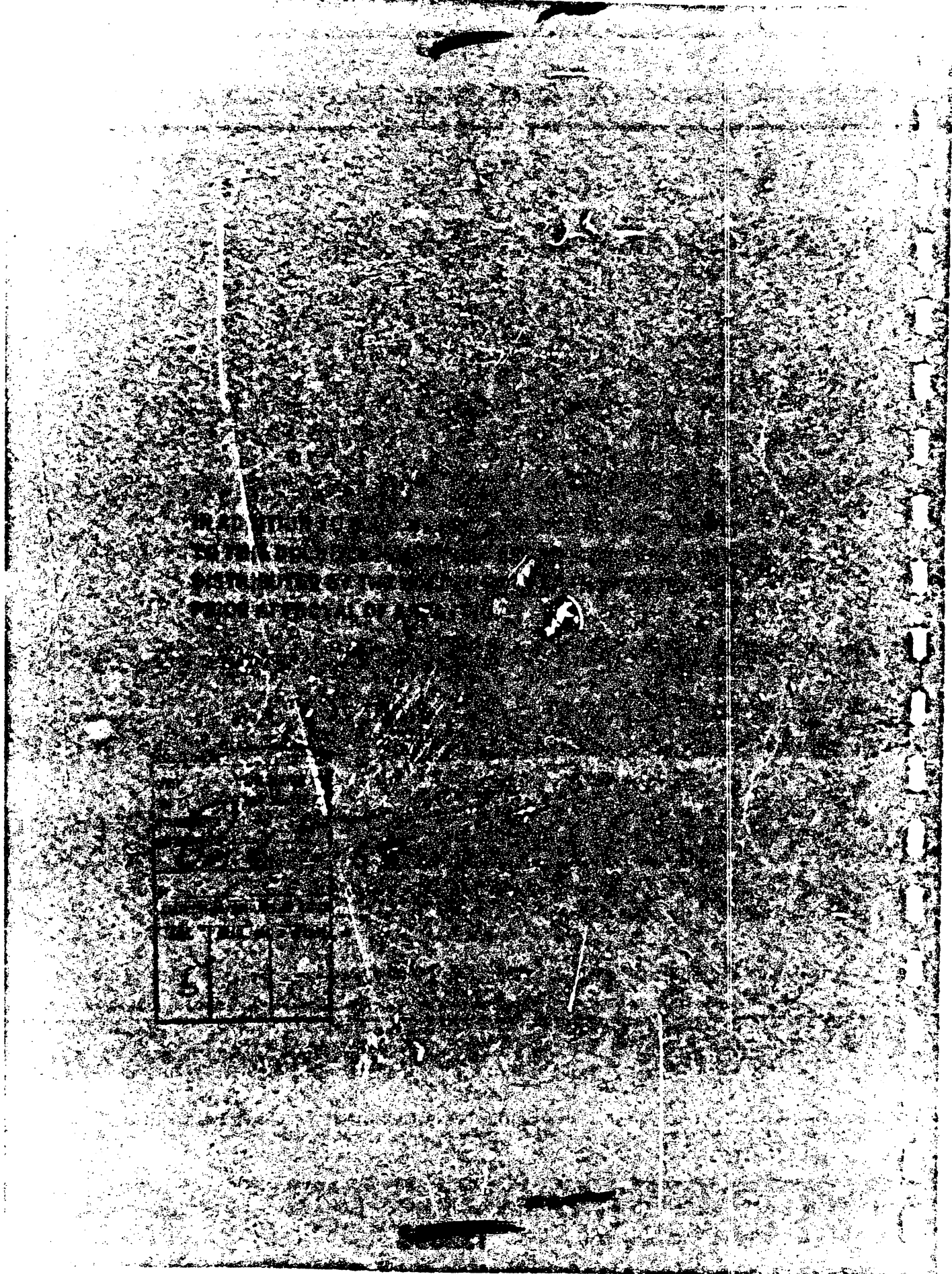
Remote Area Conflict

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- 12th Air Commando Squadron (Ranch Hand)
- 5th Special Forces Group
- 460th Tactical Reconnaissance Wing
- 600th Photo Squadron
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- Staff of the Saigon Botanical Park

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SUMMARY

In 1965, the Joint Chiefs of Staff requested that the Secretary of Defense initiate research to determine the feasibility of destroying large areas of forest or jungle growth by fire. Tests conducted in Vietnam in 1965 and 1966 (Operations SHERWOOD FOREST and HOT TIP) were inconclusive. A test series, code-named PINK ROSE, was conducted in 1967.

Three targets, each 7 km on a side (approximately 12,000 acres) were picked from representative jungle areas in War Zones C and D. Each area was double sprayed with hormone-type defoliant chemicals, and half of each area was also sprayed with a contact herbicide. On the first two targets, ignition was effected by saturating the target with 72,000 M-74 incendiary bomblets. This ignition density was doubled on the third target.

In no instance was an appreciable amount of forest canopy removed by the resulting fires. Measurement of the moisture contents of jungle growth following application of defoliants showed that leaves were being desiccated to acceptable levels, but that twigs retained sufficient moisture to prevent combustion. We conclude that current defoliant chemicals applied in the volumes and concentrations now in operational practice in Vietnam do not act as effective desiccants. Successful removal of Vietnamese jungle growth by fire will not be possible unless effective chemical desiccants can be developed.



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BACKGROUND

The dense vegetation canopies which are characteristic of tropical forest areas provide cover and concealment for the movement and activities of enemy forces. Following an aborted attempt (Operation SHERWOOD FOREST) on 31 March 1965 to burn tropical forest vegetation at Boi Loi Wood in Tay Ninh Province, Republic of Vietnam, ^{1/}CINCPAC requested that the Joint Chiefs of Staff expedite the development of techniques whereby large areas of tropical forest growth could be effectively destroyed. The Secretary of Defense was requested by the Joint Chiefs of Staff in December 1965 to initiate a feasibility study to determine techniques for chemically desiccating vegetation and destroying tropical forests by fire. The request was approved and active participation in this program by the Branch of Forest Fire Research, Forest Service, was initiated by the Advanced Research Projects Agency on December 20, 1965, under ARPA Order No. 818 (Project EMOTE).

The ARPA-Forest Service fire research program consisted of two parts:

1. Phase I - the technical support of an operational field test (HOT TIP) conducted by the armed forces in South Vietnam in 1966.
2. Phase II - the conduct of a three-to-five year research effort designed to describe the chemical treatment and flammability requirements of tropical forests so that forest vegetation might be operationally modified for incendiary attacks.

The culmination of Phase I occurred on 11 March 1966 with the HOT TIP operational trial of forest incendiarism on Chu Pong mountain in Pleiku Province. The target selected was of military interest and included an area of 21 square kilometers. Orange defoliant was sprayed over most of the area between January 24 and February 6. This dry season herbicide application delayed the onset of desired treatment effects, since the vegetation was physiologically dormant. Blue was applied on February 22 and 23 in an attempt to achieve maximum possible fuel desiccation.

^{1/}Brent, et al. Neutralization of Viet Cong Safe Havens: A Preliminary Study (U) Tech. Paper RAC-TP-191. 1965, 74 pp.

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Fig.1

**OPERATION SHERWOOD FOREST
BOI LOI WOODS, TAY NINH PROVINCE**

31 March 1965

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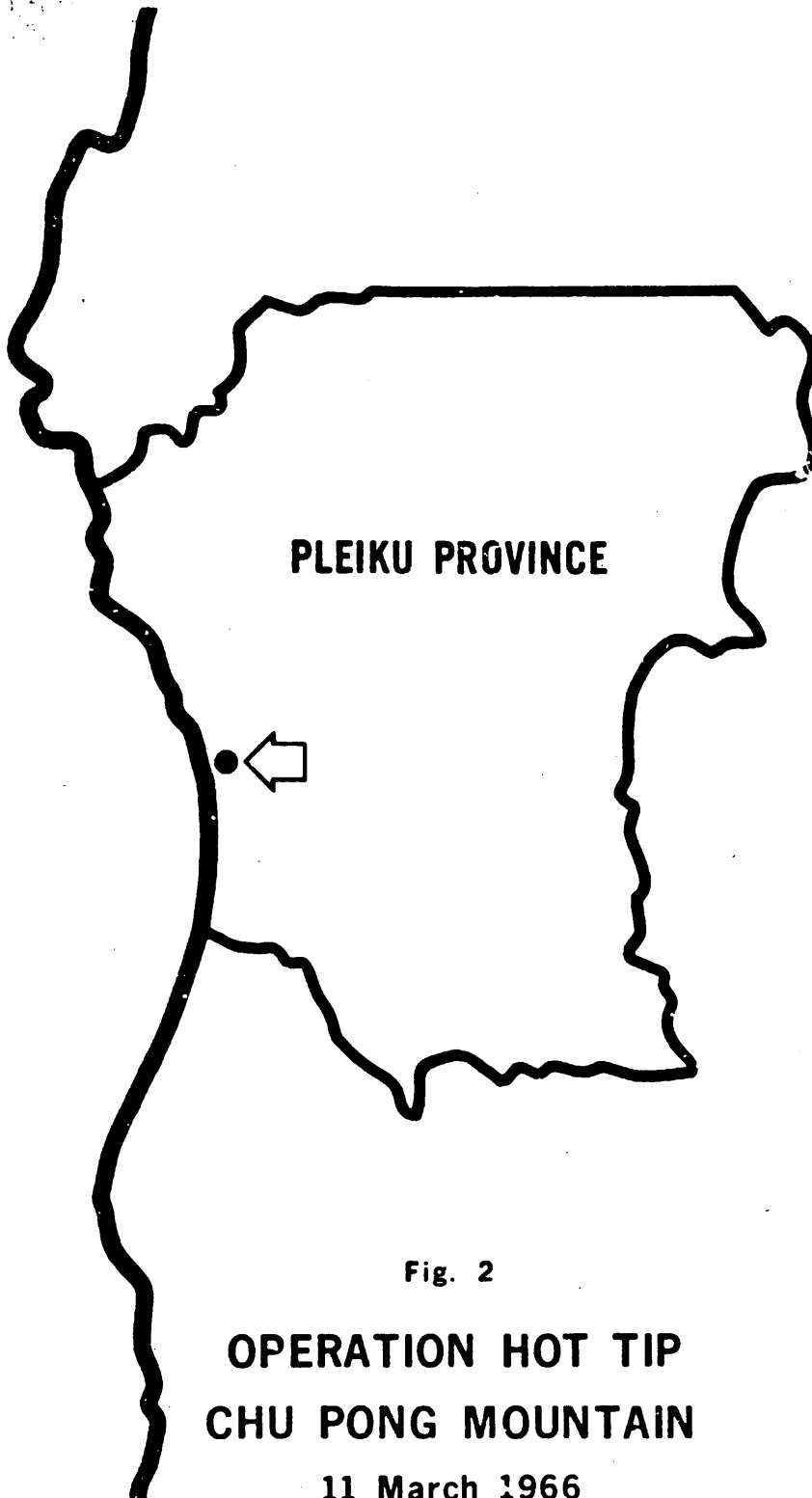


Fig. 2

**OPERATION HOT TIP
CHU PONG MOUNTAIN**

11 March 1966

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between 1400 and 1420 on 11 March 1966, fifteen B-52 aircraft dropped 255 M-35 incendiary bombs on the target area. This ignition strike was followed after 1430 by 11 napalm strikes along the upwind side of the target area. Many of the fire sets merged and developed a convection column reaching to 22,000 feet. Flames did not carry through the tree canopy except at ridgetops, nor were firestorm conditions produced, but the 17.5 percent mortality of the forest canopy was encouraging under the existing treatment conditions.

Although the results of HOT TIP on Chu Pong Mountain were inconclusive, information gathered during the operation warranted additional testing. Following the evaluation of HOT TIP, several operational changes were recommended for forest incendiary programs in Vietnam. These test plan changes involved chemical treatment, ordnance requirements, and weather requirements.

CONCLUSION

Tests were carried out in February 1966, at a site in the Central Highlands about 100 miles from the Chu Pong test area. Fuel moisture measurements were made of the test areas treated at different times:

1. November area -- Sprayed with Orange in late November 1965.
2. January area -- Sprayed with Orange on 24 January 1966.

Measurements from these two areas indicated that the moisture content of twigs less than 1/2 inch diameter remained at relatively high levels following chemical treatment and that their moisture content actually increased over time. The average moisture content of all samples on rain-free days in the November area was 85.9 percent; in the January spray area the average was 81.4 percent. Moisture contents of this magnitude indicated that the internal translocation systems of the vegetation were still functioning following chemical treatment. Thus, more than half of the fine fuels needed to carry fire into and through the forest canopy were too wet to burn.

W. J. G. et al. Forest Fire Research, Final Report, Phase 1, Vol. 1. Requirements for a Strategy of Destroying Forest/Jungle Growth by Fire, Forest Service, U.S.D.A., 54 pp.,

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DUC CO STUDY AREA

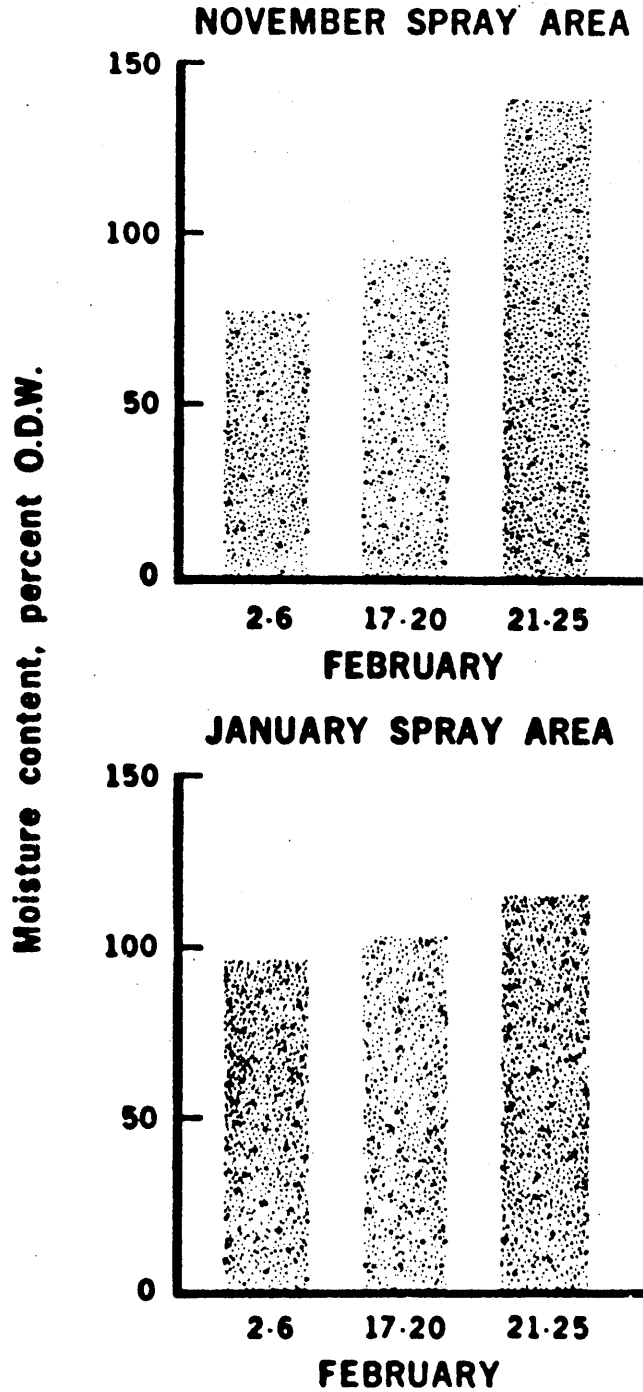


Fig. 3

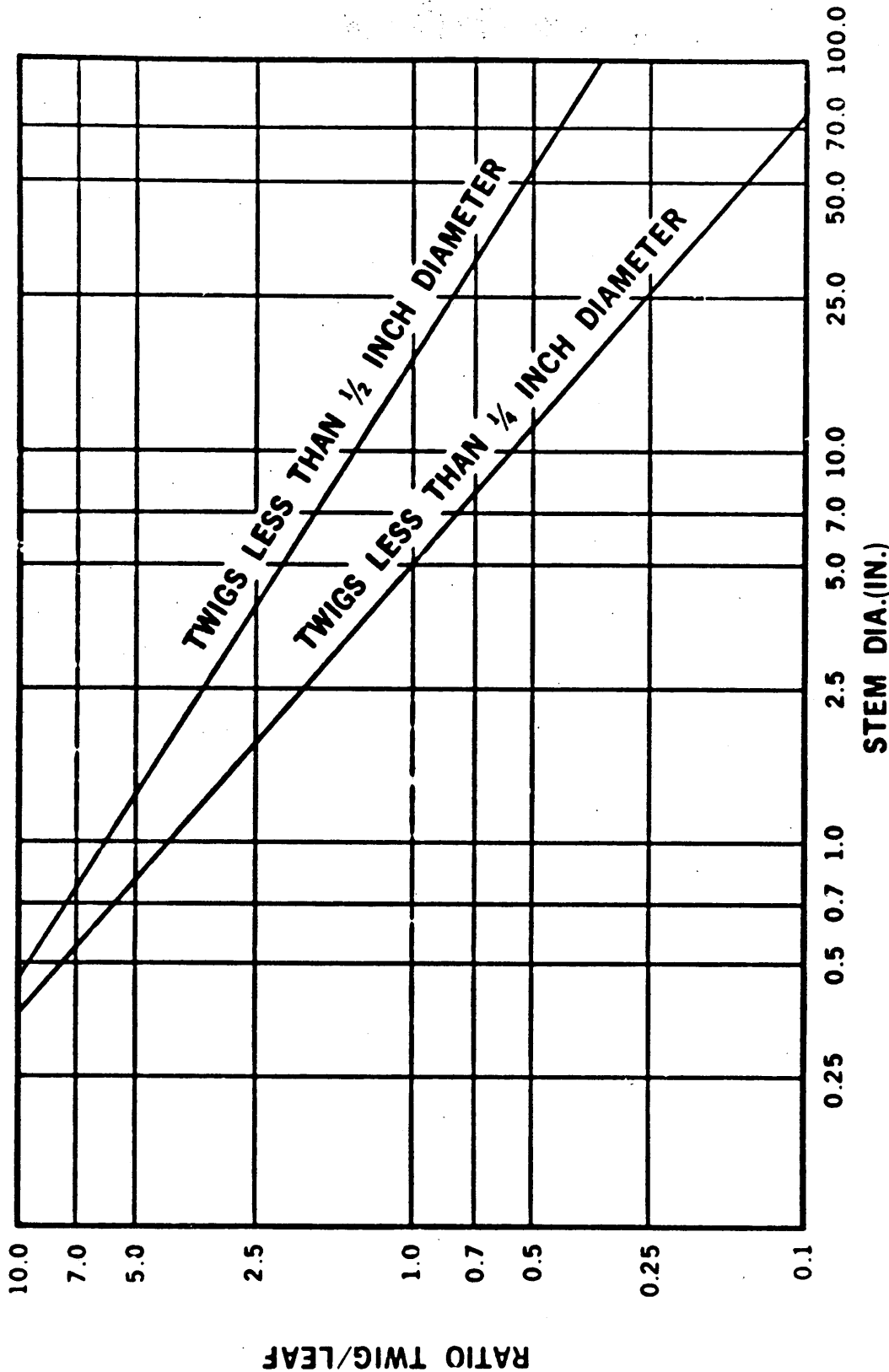
(Low Moisture Content Samples Excluded)
MOISTURE CONTENT OF DEFOLIATED VEGETATION

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Fig. 4

RELATIVE WEIGHTS OF LEAVES AND TWIGS



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Fig. 5

**MOISTURE CONTENT OF SMALL TWIGS REMAINED
TOO HIGH TO PERMIT COMBUSTION FOLLOWING
DRY SEASON CHEMICAL TREATMENT.**

OPERATION HOT TIP

March 1966

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In order to modify the moisture content of these critical stem and twig fuel components, the new guidelines were prepared to insure the following changes in chemical treatment procedures for forest incendiary operations:

1. An early application of Orange or White while the plants are physiologically active (prior to the onset of the dry season) to defoliate the upper canopy.
2. A repeat spray application approximately one month later with Orange or White to penetrate lower canopy layers.
3. A spray application of Blue, a contact desiccant, approximately 10 days prior to the strike date to desiccate those ground level species that were not susceptible to the hormone type chemicals.

INCENDIARY ORDNANCE

The ordnance plan for HOT TIP called for the mass ignition of the target area using closely spaced small fire sets. On the HOT TIP operation, the ignition pattern using M-35 clusters was fairly satisfactory within a strip but spacing between strips was too great. Consequently, ordnance requirements were recommended to provide an increase in ignition density and a reduction in spacing between aircraft strips. The recommendation specified at least one ignition per 8000 square feet of forest area and a contiguous pattern of flight strips to insure saturation of the target.

WEATHER REQUIREMENTS

Moisture content sampling during HOT TIP indicated a more rapid drying response of leaf litter and attached dead leaves following a rain shower than was expected. These results permitted the easing of restrictions in the weather specifications for burning tropical forest fuels. The HOT TIP specifications of 2 drying days being required after a light rain and 5 days after a heavy rain were lowered for PINK ROSE planning to 1 and 3 drying days, respectively. A light rain was redefined as one with less than .20 inch of rain instead of .10 inch. Specifications for a drying day were:

- (1) No rain has fallen in the preceding 24 hours.
- (2) Minimum relative humidity drops below 70 percent.
- (3) Afternoon cloud cover is less than $\frac{3}{8}$.

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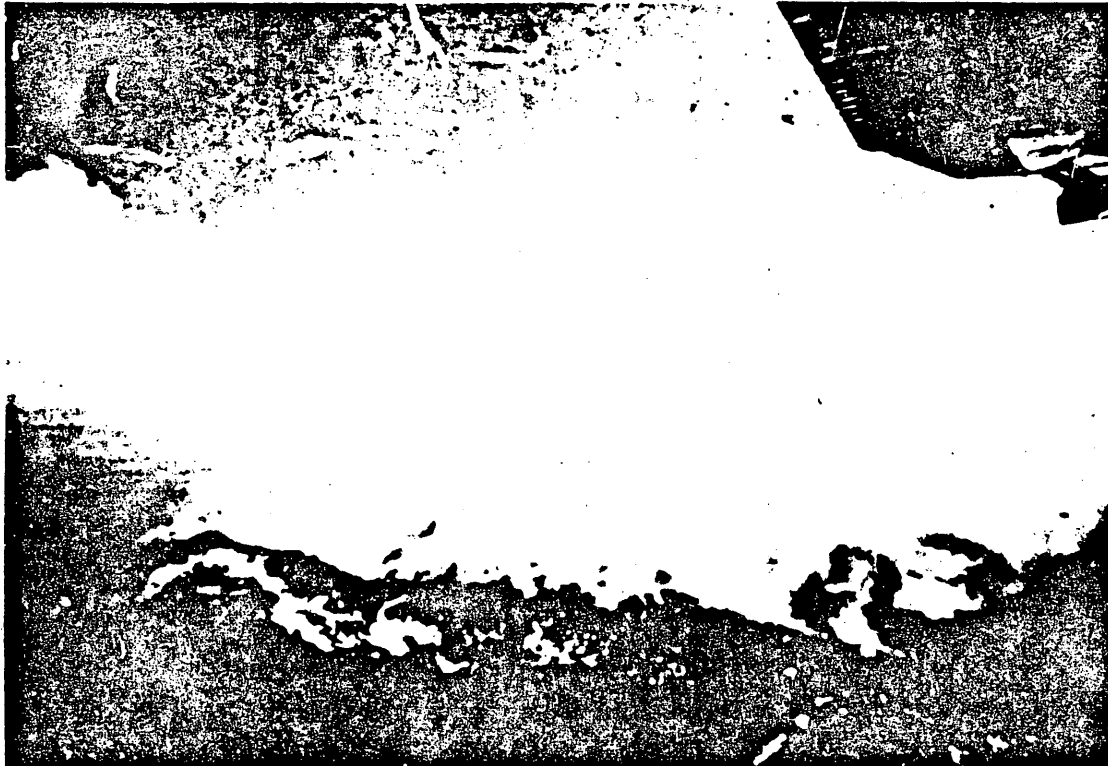


Fig. 6

**INCENDIARIES TENDED TO CLUSTER IN STRIPS
OPERATION HOT TIP.**

March 1966

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OPERATION PINK ROSE, 1967

As a part of Phase II of the ARPA sponsored Project EMOTE program, the Forest Service agreed to provide technical support to future forest incendiary operations. On 11 August 1966 CINCPAC approved the utilization of ARPA/Forest Service advisory services on Operation PINK ROSE, a full scale field test to study the feasibility of neutralizing Viet Cong safe havens by fire.

On 15-16 September 1966, two Forest Service representatives visited CINCPAC headquarters to discuss the status of Operation PINK ROSE. The outcome of this meeting was an outline for the preparation of PINK ROSE test and evaluation plan. On 30 October to 8 November 1966, a four-man Forest Service team worked in Saigon assisting the PINK ROSE project officer in preparing the test plan (see Appendix I).

Based on experience gained during previous incendiary attacks, PINK ROSE was planned as a definitive test of the hypothesis that tropical forest areas could be destroyed by fire utilizing only currently operational materials and techniques.

Selection of PINK ROSE Targets

Three tropical forest areas were selected for PINK ROSE incendiary tests in War Zones C and D. Areas A and B were located in War Zone C and Area C was located in War Zone D. The coordinates of the areas were defined as follows:

1. Area A - XT 5277, 5284, 5984, 5977
2. Area B - XT 0975, 0982, 1682, 1675
3. Area C - YT 3441, 3446, 4148, 4141

The three areas selected ranged in fuel conditions from marginally light and patchy (Area B) through optimum density and distribution (Area A), to such heavy triple canopy that successful desiccation appeared unlikely (Area C).

CHEMICAL PRETREATMENT

The initial defoliant spraying was completed as rapidly as possible in regular spray operations. Standard swaths were applied, each 0.1 X

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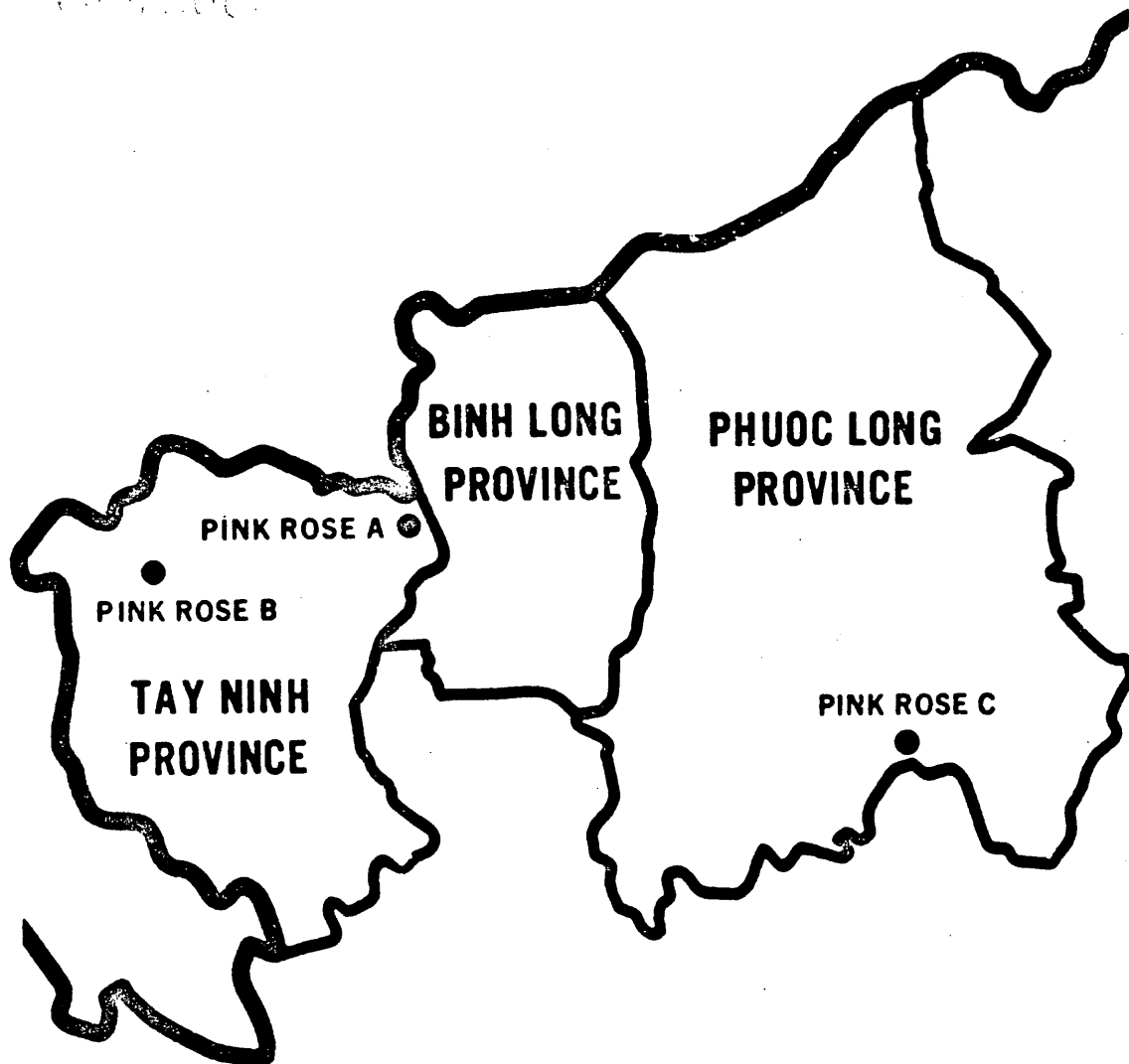


Fig. 7
OPERATION PINK ROSE
January-April 1967

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Fig. 8A

PINK ROSE TARGET AREA A

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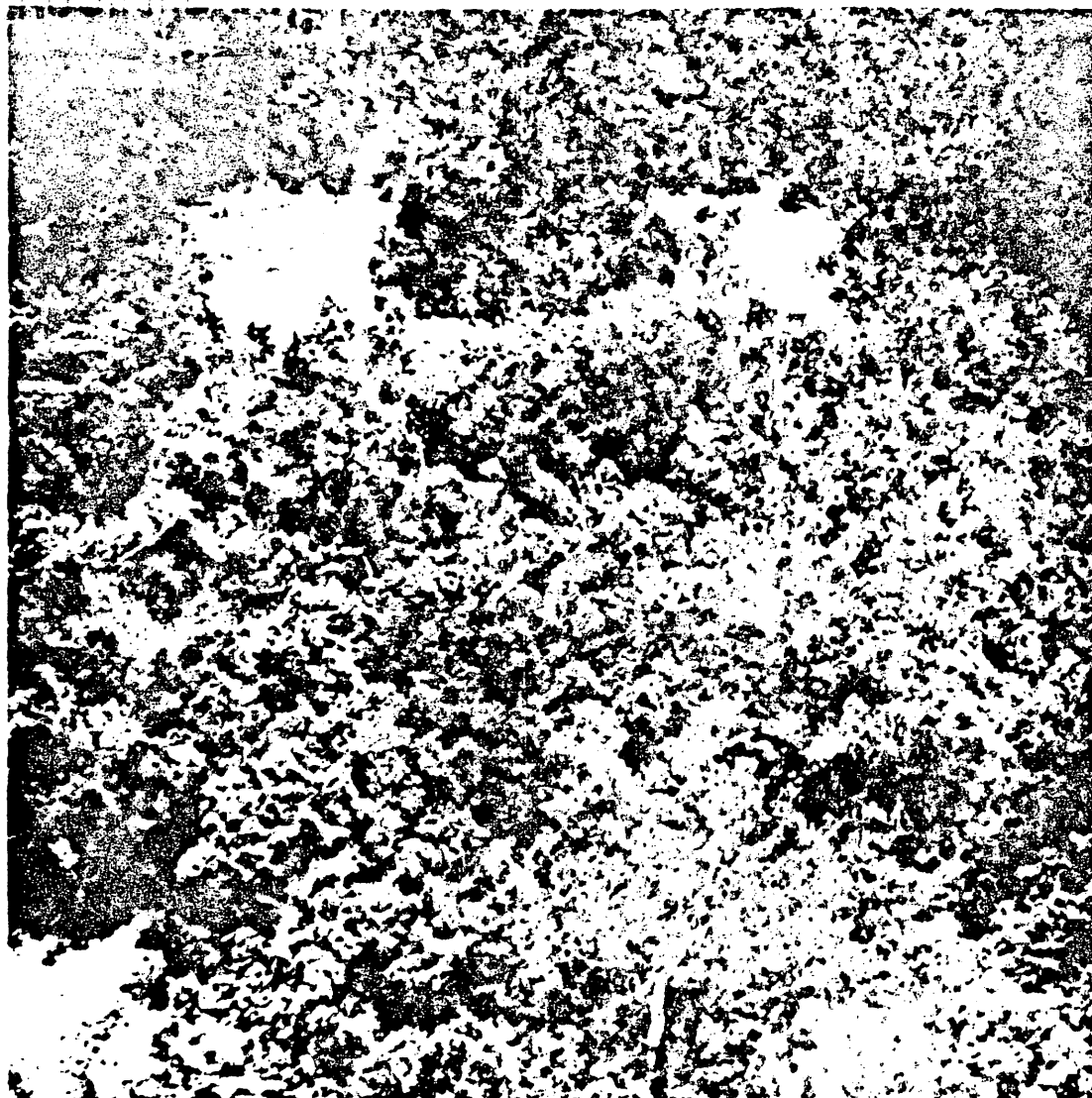


Fig 8B

AREA A FUEL:
DOUBLE CANOPY WITH CLEARINGS

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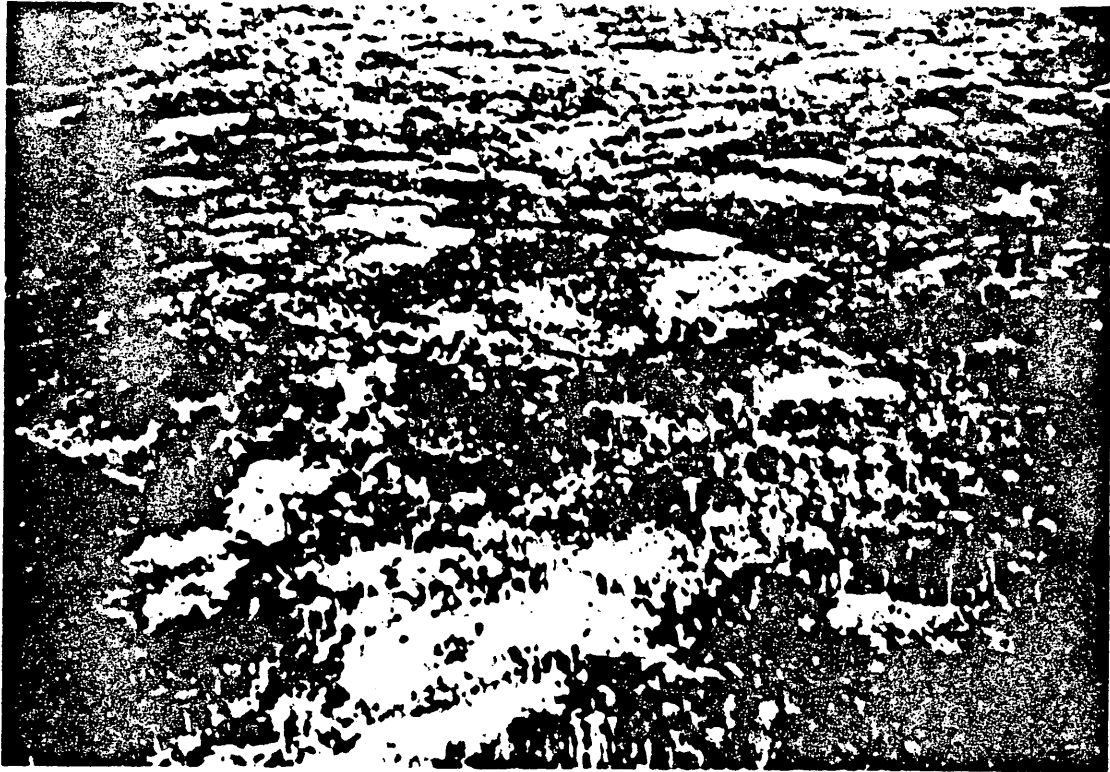


Fig. 9A

PINK ROSE TARGET AREA B

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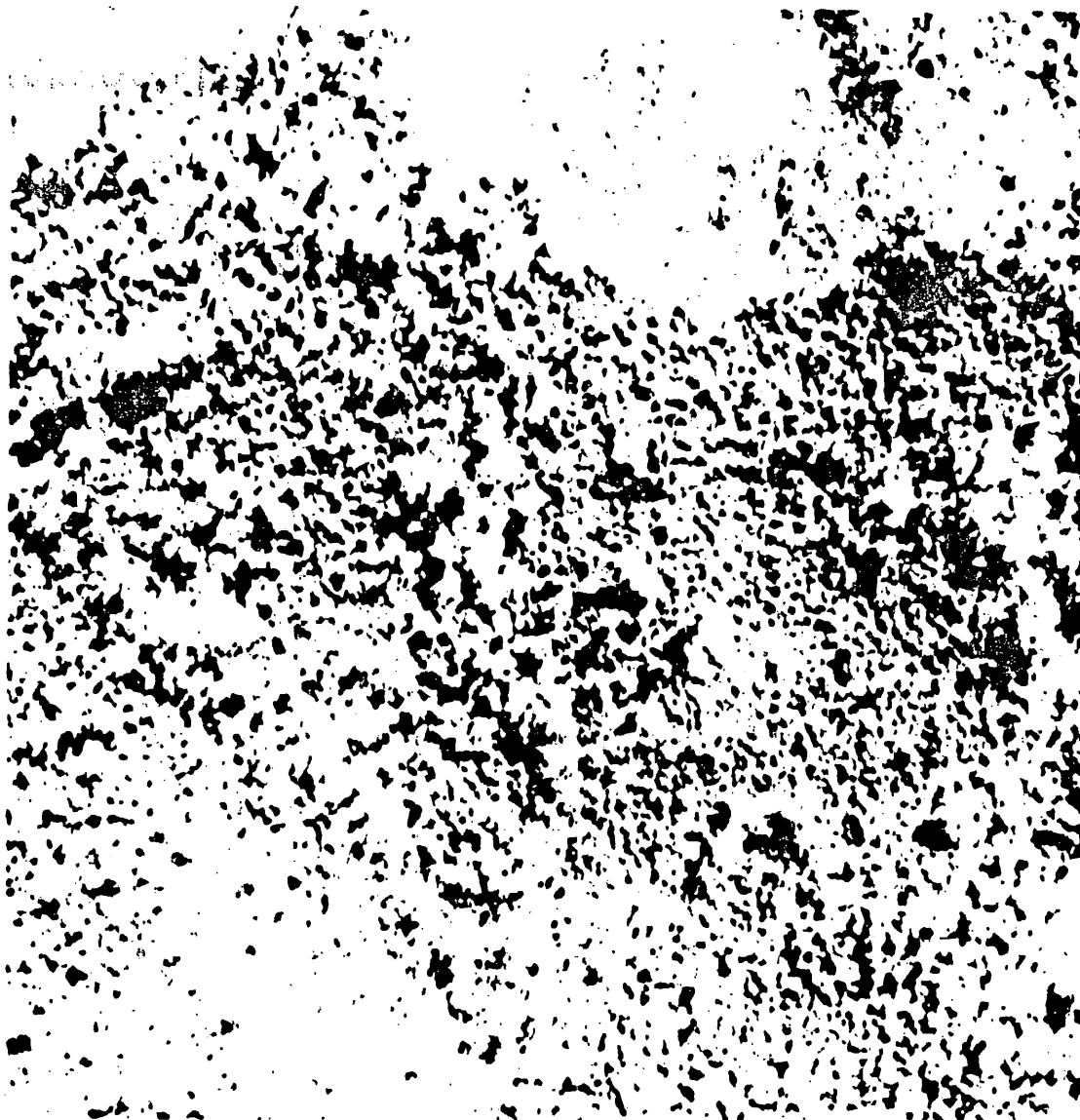


Fig. 9B

AREA B FUEL: PATCHY SECOND GROWTH

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Fig. 10A

PINK ROSE TARGET AREA C

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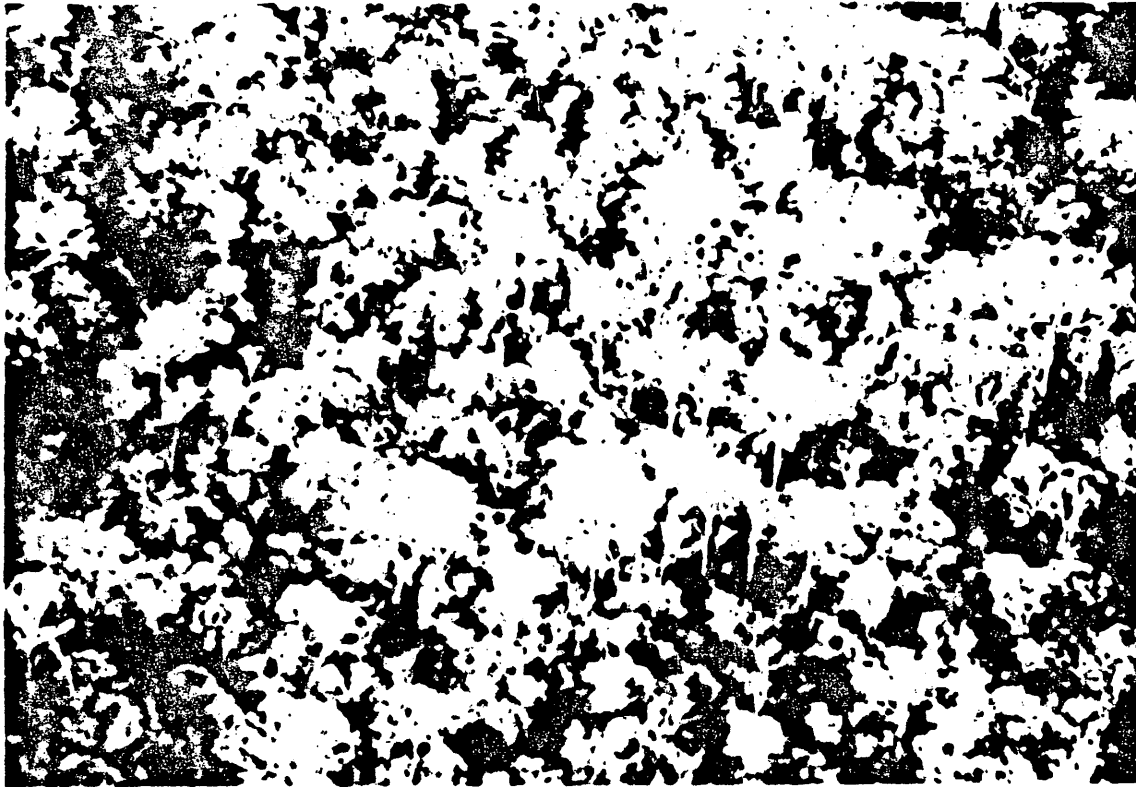


Fig. 10B

AREA C FUELS: HEAVY TRIPLE CANOPY

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of each swath length across one of the test areas. For each aircraft sortie, only 400 gallons were considered as delivered within the area. Thus, the data for the first treatment (see Table 1) may show slightly less than the herbicide rate actually applied.

The second spray treatment was done as a special job with all the spray material applied within the 7 Km. -square areas. Width of swath was reduced and spray discharge was adjusted so that each sortie covered 3 swaths across an area -- a total of 21 Kms. per sortie.

The third spray was applied in a similar manner on one half of each area.

The initial spraying of Area A was completed on 5 December, with most of the acreage sprayed during the last half of November. Area B was sprayed over a 3-month period ending 19 December. Area C was sprayed mainly in November, ending 27 November.

The second spraying was done on all three areas about one month later, between December 16 and 29.

The third spray was applied 5 January on one area and between 16 and 21 January on the other two areas.

The initial spraying on each area was done with either Orange ^{1/} or White, ^{2/} depending on the chemical supply available when each mission was flown. After 15 November, all of the spray on Area A was Orange and much of Area C was sprayed with Orange, but White and Orange were used in about equal amounts on Area B. All of the second spray on Areas A and C was Orange, and all on Area B was White. Blue ^{3/} was used in the third spray on half of each area.

1/ Orange

- 50% n-butyl ester of 2,4-dichlorophenoxyacetic acid
- 50% n-butyl ester of 2,4,5-trichlorophenoxyacetic acid

2/ White (Tordon 101)

- 30% 4-amino-3,5,6-trichloropicolinic acid as the trisopropanolamine salt.
- 70% 2,4-dichlorophenoxyacetic acid as the trisopropanolamine salt.

3/ Blue (Phytar 160)

- 87% dimethylarsinic acid as sodium cacodylate
- 13% dimethylarsinic acid



Fig. 11

**DEFOLIANT SPRAY OPERATION OVER
PINK ROSE TARGET AREA A.**

Table 1 - Herbicide Treatments on Areas A, B, and C

Treatment	Date	Herbicide	Area		
			A	B	C
gallons applied on area					
First	Sept. 24-29	Unknown		3,600	
	Oct. 7-10	Unknown		3,200	
	Oct. 18-30	White	3,200	1,600	1,600
	Oct. 18-30	Orange		1,600	4,000
	Nov. 1-15	White	5,600	3,600	4,000
	Nov. 1-15	Orange		1,200	10,000
	Nov. 16-27	White	4,400	4,200	
	Nov. 16-27	Orange	12,800	3,000	13,200
	Nov. 16-27	Both		3,200	1,200
	Dec. 5-9	White	1,800	1,600	
	Dec. 11-19	Orange		6,300	
		<u>TOTAL</u>	<u>27,800</u>	<u>33,100</u>	<u>34,000</u>
		<u>Per Acre</u>	<u>2.30</u>	<u>2.73</u>	<u>2.81</u>
Second	Dec. 16	Orange			12,600
	Dec. 26-30	White		28,800	
	Dec. 26-30	Orange	23,400		9,900
		<u>TOTAL</u>	<u>23,400</u>	<u>28,800</u>	<u>22,500</u>
		<u>Per Acre</u>	<u>1.93</u>	<u>2.38</u>	<u>1.86</u>
Third	Jan. 5-7	Blue			10,800
	Jan. 16-18	Blue	14,200		
	Jan. 19-21	Blue		23,700	
		<u>TOTAL</u>	<u>14,200</u>	<u>23,700</u>	<u>10,800</u>
		<u>Per Acre</u>	<u>1.95^{1/}</u>	<u>3.91^{2/}</u>	<u>1.78^{3/}</u>

^{1/} Blue was applied on about 0.6 of the total acreage in Area A, making an average rate of approximately 1.95 lb./a -- on the west side of the area.

^{2/} Blue was applied on the south half of Area B, but much of the first swaths drifted to the south off the area. Actual coverage rate on the area is not known but is much below the 3.91 lbs./a.

^{3/} Blue was applied on the south half of Area C at about 1.78 lbs./a.

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PLANNING AND DELIVERY

The M-35 Incendiary Cluster Bomb was chosen for the PINK ROSE incendiary attacks. This bomb weighs 750 pounds and contains a cluster of 57 M 74A1 bomblets. Each bomblet contains 2.75 pounds of PT 1 incendiary filling. The bomb cluster was fused to open at an altitude of approximately 5000 feet. Plans for ignition of PINK ROSE targets called for a B-52 strike of 30 aircraft, each carrying 42 M-35 Incendiary Cluster Bombs. Using this ignition mode, one B-52 provides approximately one ignition source for each 6200 square feet throughout a pattern 700 feet wide by 21,000 feet long. The total B-52 strike would saturate an area 21,000 feet on a side with 72,000 individual ignition sources. Average spacing between ignition points was calculated to be 85 feet.

PINK ROSE I, AREA C, 18 JANUARY 1967

PINK ROSE Target C, 45 miles northeast of Saigon in War Zone D, was ignited as planned on 18 January 1967. The target box was situated just north of the Dong Nai River. A smaller stream drained the eastern half of the target and a north-south road bisected the area. An abandoned air strip was located on the north edge of Area C. The vegetation was characterized by a dense triple canopy tropical forest. Several swamps and clearings were scattered throughout the target. The topography in the area was flat and the elevation was approximately 150 feet.

On 18 January 1967, atmospheric conditions for burning forest fuels were generally unfavorable. The air was cool, moist and stable; characteristic of periodic lulls in the winter northeast monsoon. All South Vietnam was under the influence of the southern portion of the Siberian High. Low level winds were light and northerly up through the gradient wind level. Southeasterly flow from the 850 mb through the 500 mb levels on January 17th became much more pronounced on the 18th with the development of a strong anticyclone north of the Philippines in the upper levels, through 200 millibars. This relatively strong and deep southeasterly flow was responsible for the advection of considerable moisture at all levels.

Bien Hoa, located about 15 miles southeast of target C, was the nearest weather station to the target area. Figure 14 illustrates the values of several meteorological parameters at 1100 LST for the Bien Hoa station from 15 January through 21 January 1967. Figure 15 shows the diurnal trend on 18 January, the day of the strike.

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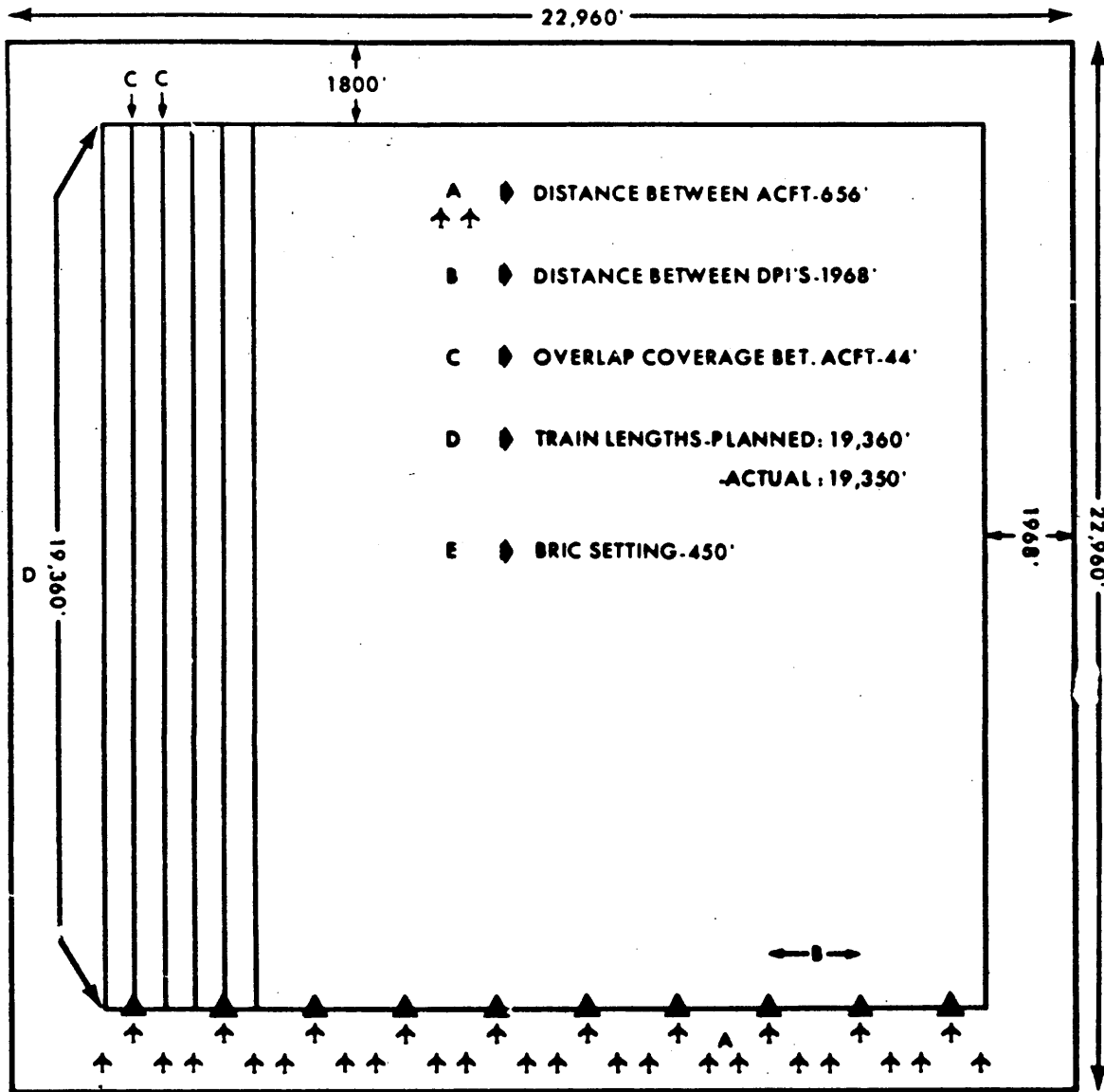


Fig. 12

**INCENDIARY STRIKE PATTERN FOR
OPERATION PINK ROSE**

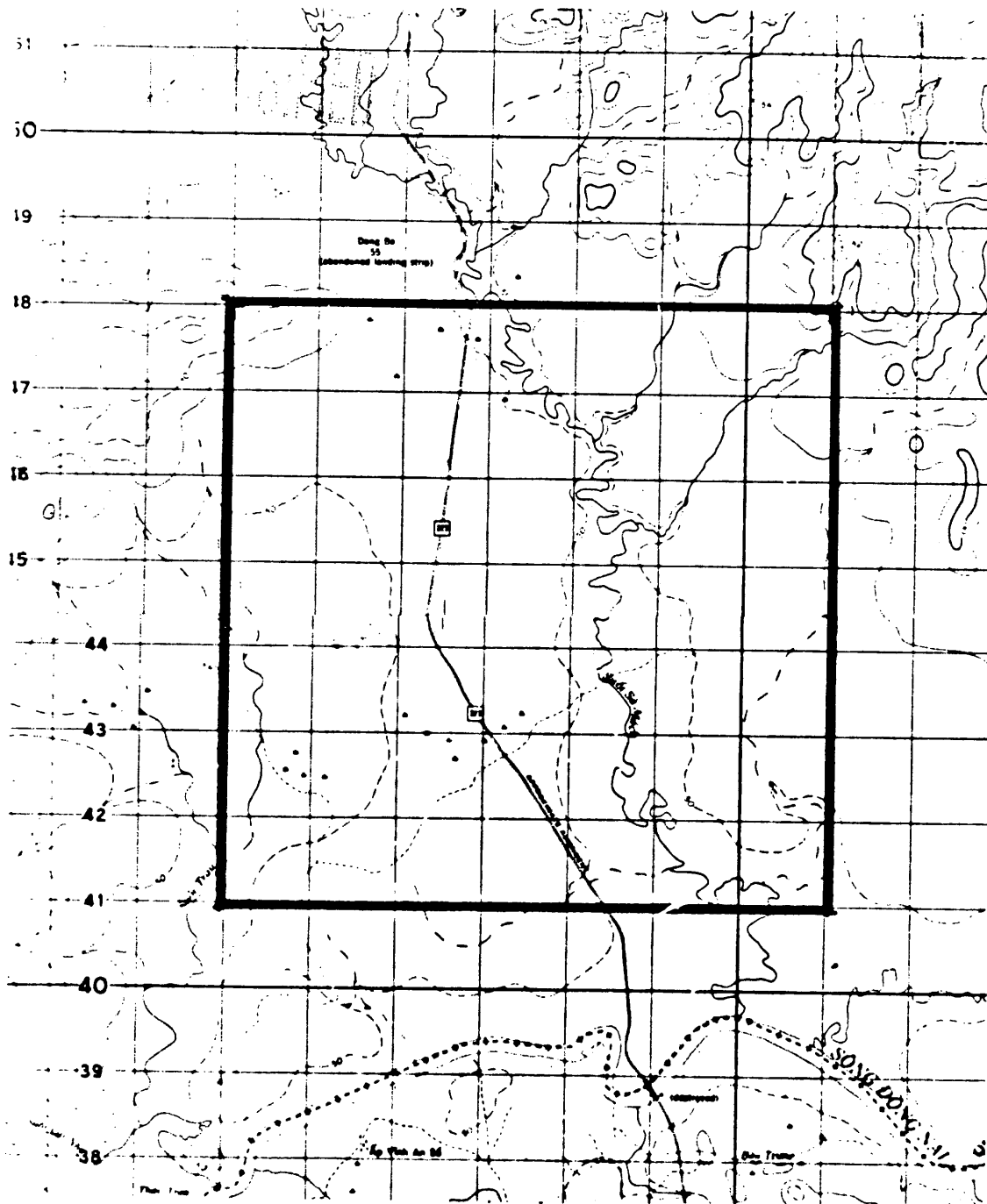


Fig. 13

PINK ROSE TARGET AREA C

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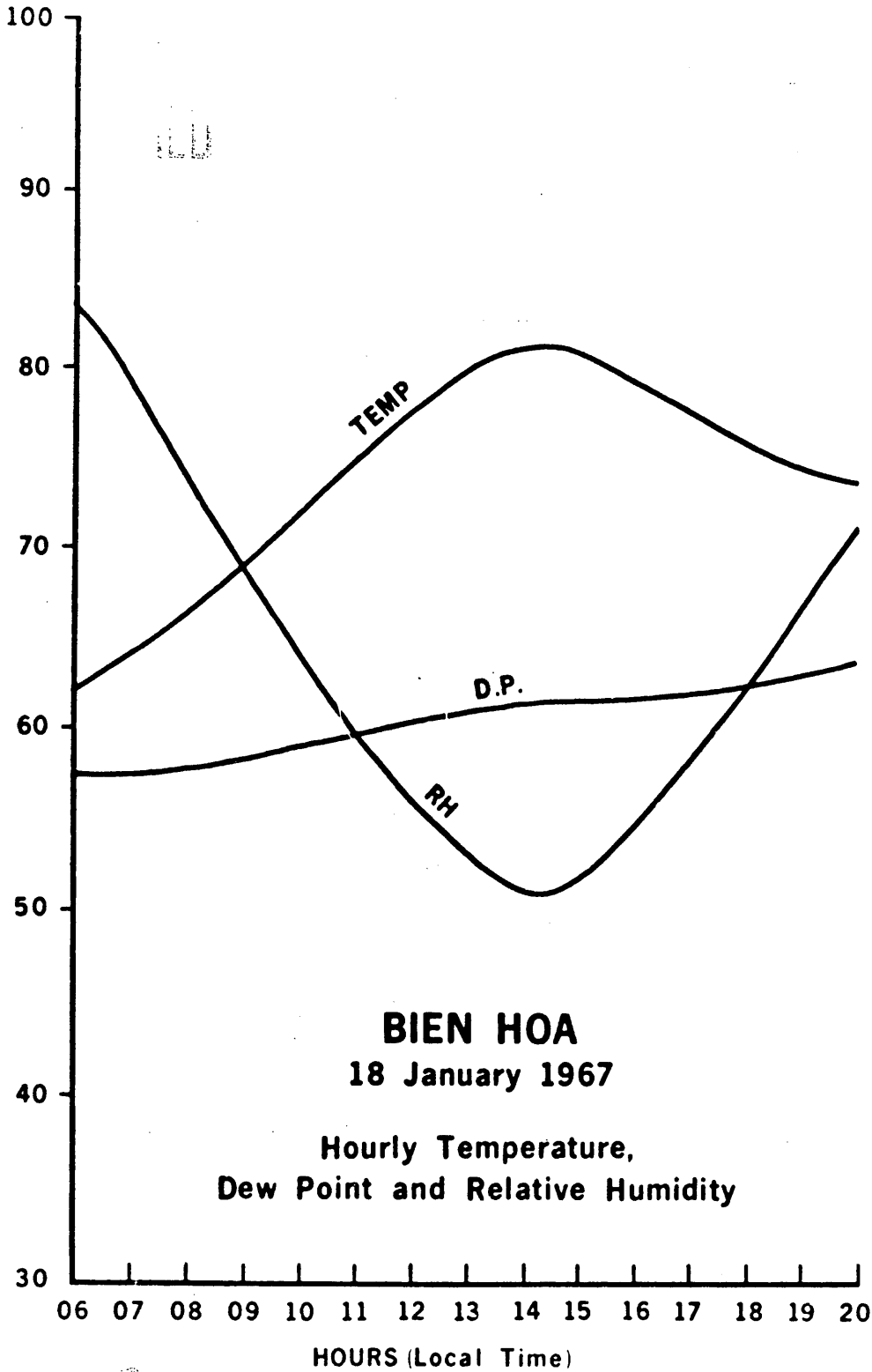
Fig. 14

BIEN HOA 2PM WEATHER

7-31 January, 1967

DATE	TEMP (°F)	RELATIVE HUMIDITY(%)	PRECIP (IN.)	CLOUD COVER(8ths)
7	84	59		6+
8	84	57		6+
9	90	47		1-3
10	88	41		1-3
11	88	50		3-5
12	90	47		6+
13	84	53		3-5
14	83	54		3-5
15	83	54		6+
16	77	50		6+
17	81	47		6+
18	81	51	0.02	6+
19	72	70	0.08	6+
20	81	58	0.08	6+
21	85	51		3-5
22	88	51	0.27	3-5
23	88	59	0.02	3-5
24	84	59		6+
25	86	55		3-5
26	86	51		6+
27	88	52		3-5
28	90	45		1-3
29	92	43		6+
30	84	59		6+
31	88	45		1-3

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BIEN HOA
18 January 1967
Hourly Temperature,
Dew Point and Relative Humidity

Fig. 15

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The nearest station taking upper air soundings was Tay Ninh, some 50 miles to the Northwest of Target C. These soundings show a significant increase in moisture aloft beginning on the 17th and continuing through the 24th. At 1400 on the 18th the sounding shows a deep inversion from 2000 to 4800 feet. The sky was completely overcast in the vicinity of the target area with a layer of clouds at 2500 feet and a second broken layer at 10,000 ft. Virga was prevalent in the vicinity of the target area. The FAC pilot reported light rain on his aircraft at 1427, seventeen minutes after the strike began. The strike began at 1410 and ended at 1448. Ten B-52 passes of three planes per pass effectively delivered all ordnance during the 38 minute strike period. The strips were flown from east to west, starting at the south end of the target box and working north. As judged from post-strike IR imagery, the ordnance drop and ignition pattern were excellent.

As the incendiary strike progressed, the smoke spread in a shallow layer to the southwest under the influence of the surface winds. The low inversion prevented significant convection and kept the smoke trapped below 3000 feet. Aerial observers noted occasional brief surges where small convection columns formed over hot spots and rose to 4000 ft. or higher, but these lasted only a few minutes, and at no time was the column significant enough to be detectable by radar.

Although at least three secondary explosions were documented during the strike, fire spread was negligible except in the northwest corner of the target where fires started in the high grass of the abandoned landing strip and spread for several hundred feet into the adjoining forest.

Fuel removal as calculated from the convective heat release amounted to 550 pounds per acre or less than 2% of the potentially available fuel.

At 0745 on 19 January, an evaluation team moved in by helicopter to assess the effects of the previous day's raid. The only available landing zone was in a swamp in the west central portion of the target area. Although conditions were excellent for observing the pattern and behavior of the ordnance, and the relative effectiveness of the chemical pretreatment, the survey site was too far removed from the northwest corner of fire activity for meaningful observations of fire behavior to be obtainable. The complete post strike evaluation report is shown as Appendix II-A.

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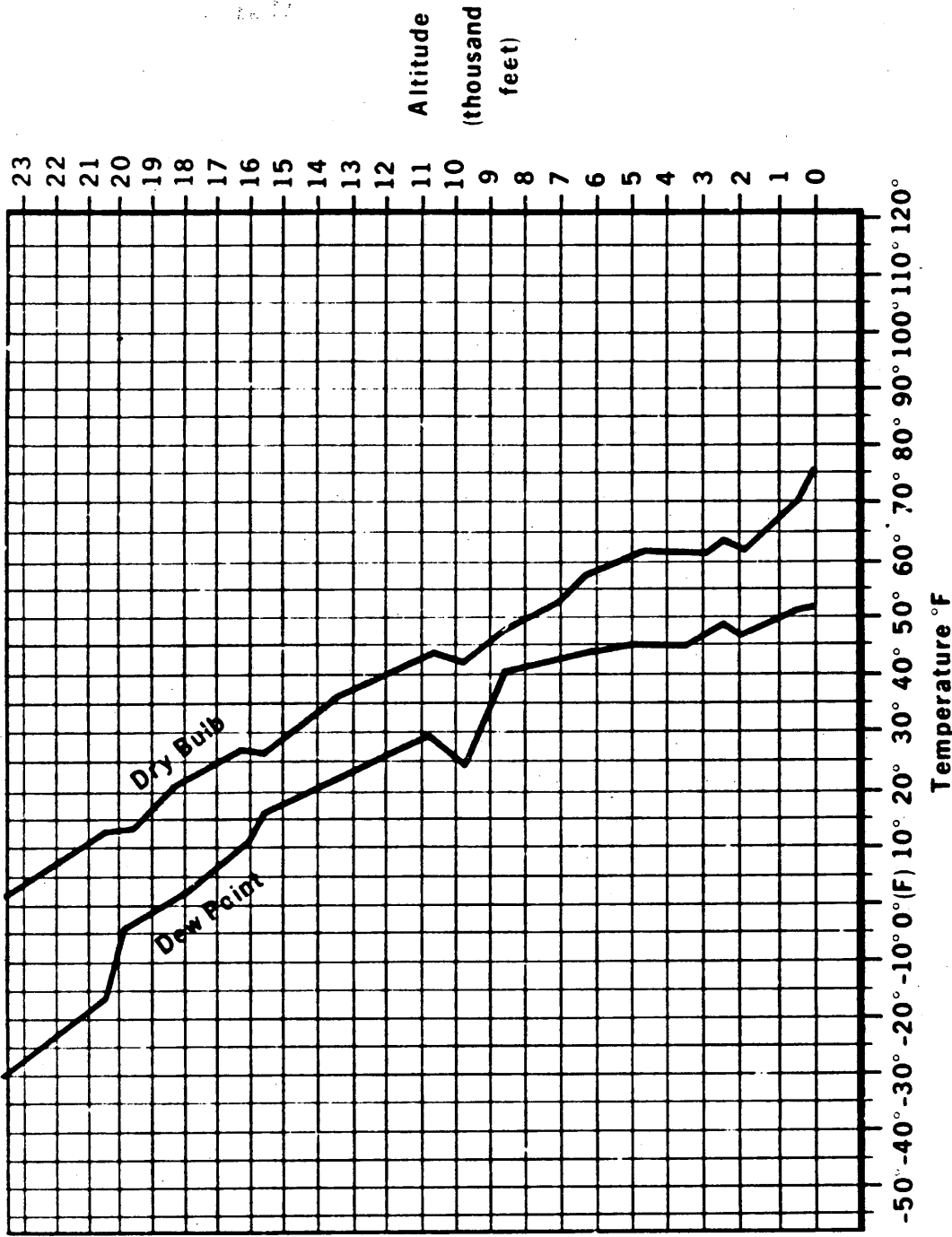


Fig. 16
TAY NINH SOUNDING
18 January 1967 1400 Hours

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Fig. 17

**FIRST STRIKE
PINK ROSE TARGET C**

1410 Hours, 18 Jan., 1967

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Fig. 18

INFRARED IMAGERY OF PINK ROSE TARGET C

1503 Hours 18 January 1967

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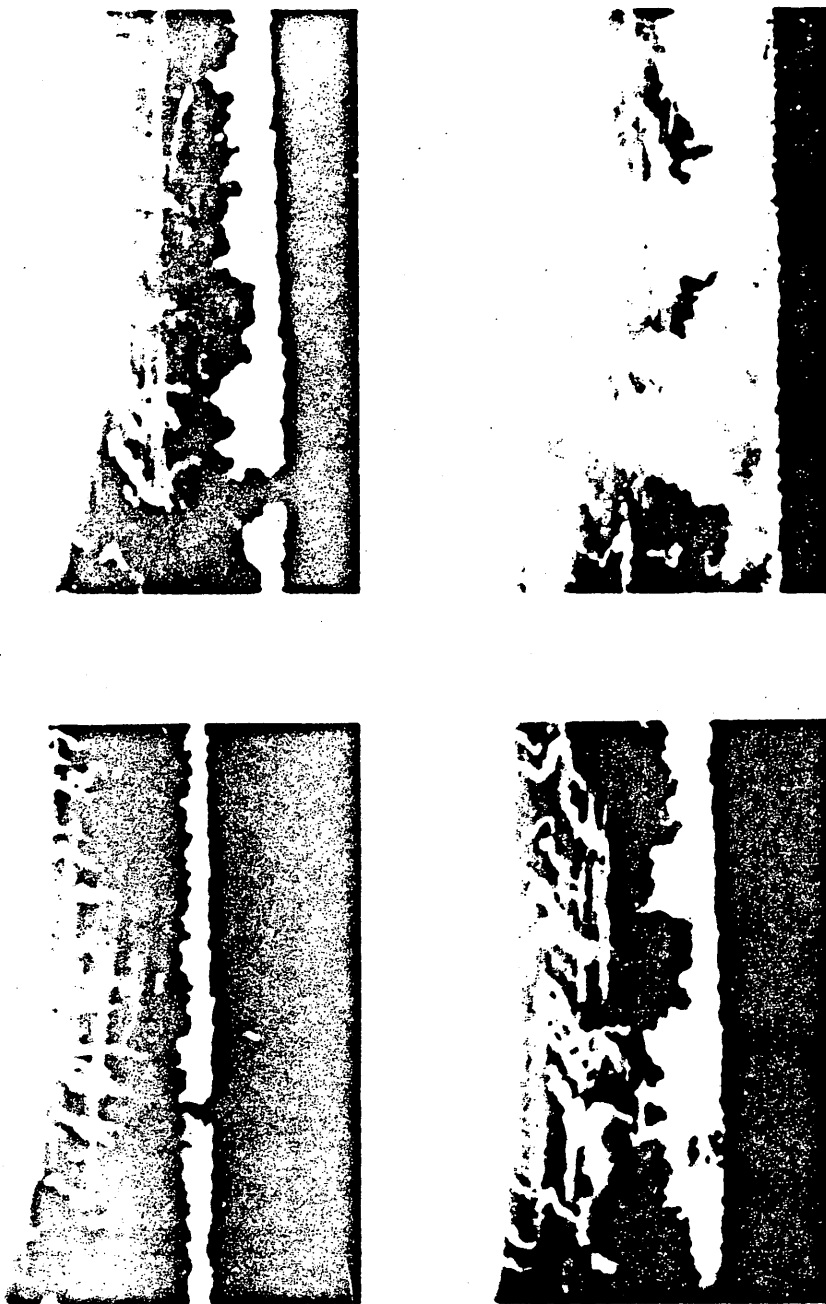


Fig. 19
SECONDARY EXPLOSION DURING FIRST BOMB RUN
PINK ROSE TARGET C
1411-1413 Hours 18 Jan., 1967 (note difference in color and rate of rise of smoke)

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Fig. 20

**FIRE SPREADING FROM ABANDONED LANDING STRIP
PINK ROSE TARGET C**

18 January 1967

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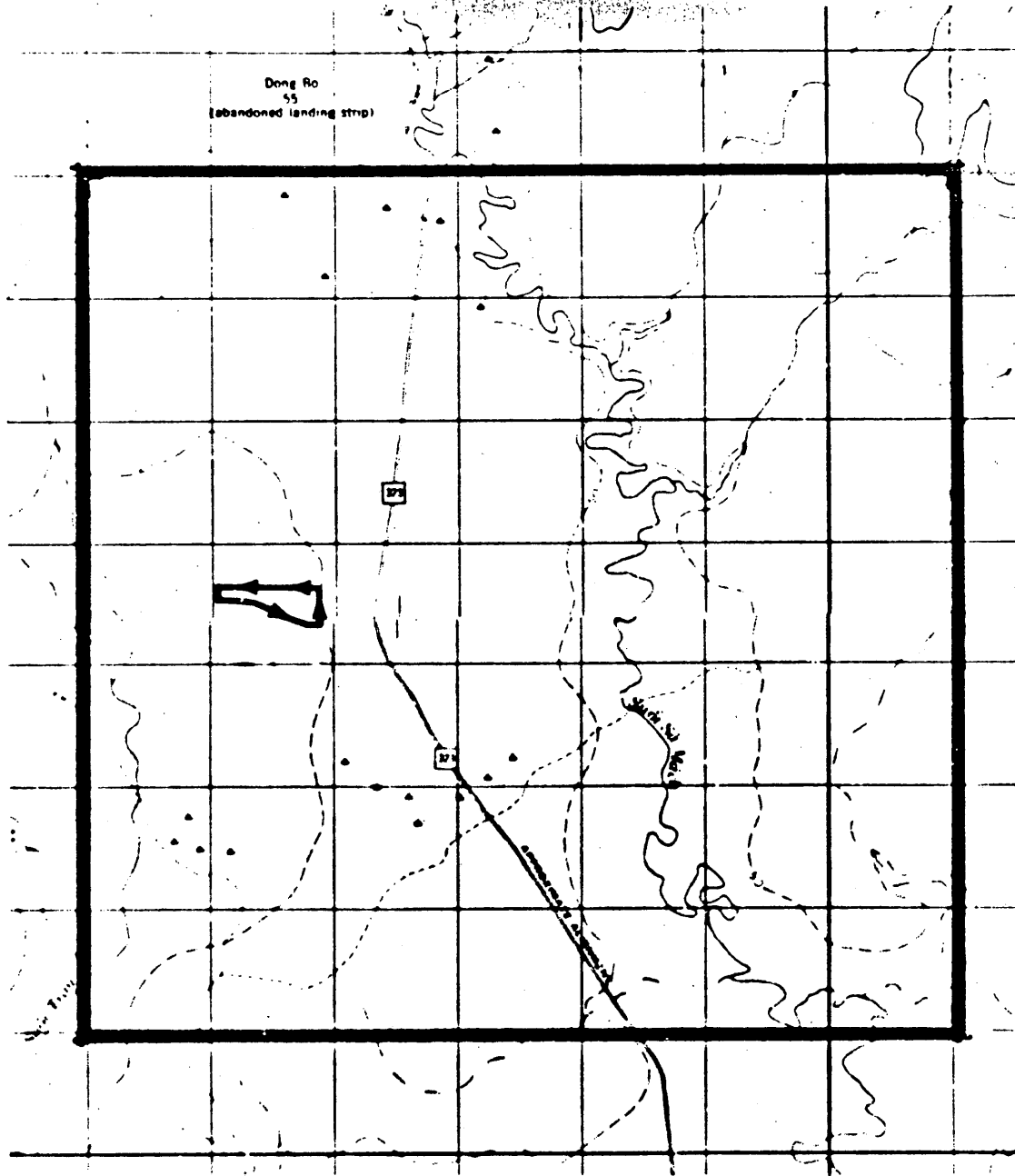


Fig. 21

**ROUTE OF POST STRIKE SURVEY PARTY
PINK ROSE TARGET C**

0745 - 0915 Hours, 19 January 1967

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Fig. 22

**M-74 CASING RECOVERED BY
POST STRIKE SURVEY PARTY**

PINK ROSE II, AREA A, 28 JANUARY 1967

Area A is located about 4 miles south of the Cambodian border and 12 miles southwest of An Loc. Two tributaries of the Saigon River, Rach Trau and Cha Va, drain portions of the target area. The vegetation consisted of a double canopy forest stand with interspersed grass fields and clearings. Bomb craters from a B-52 strike in late 1966 were observed in Area A. The topography was flat and the elevation of the area was approximately 160 feet.

Area A was ignited at 1405 LST on 28 January 1967 under nearly ideal atmospheric conditions. The northeast monsoon flow was well established. No rain had fallen for several days and the dead fuels were well dried after having been exposed to strong solar radiation and relatively warm surface temperatures.

Under the influence of the Siberian High with a flat pressure pattern, South Vietnam and target A were exposed to a well defined northeast monsoon flow from the gradient wind level up to 300 mbs. A strong anticyclone was oriented over the north Indochinese peninsula on 27 and 28 January. The atmosphere was moderately unstable at TOT on the 28th due primarily to surface heating and dry air aloft.

Tay Ninh, located about 25 statute miles southwest of Target A was the nearest regular reporting station in the target vicinity.

Tay Ninh's surface weather for the week of 25-31 January is shown in Figure 24; the diurnal trend for 28 January is shown in Figure 25; and the 1400 sounding is shown in Figure 26. Note that, in contrast to the weather during the strike on area C, weather conditions become more favorable for burning as the strike progresses. Cloud cover was 2/10 or less throughout the raid. Weather during this strike was as nearly ideal for incendiary operations as can be expected in South Vietnam.

The Area A strike used the same ordnance and delivery pattern as the 18 January raid on Area C. The last bomb was dropped at 1443, less than 40 minutes from the start of the strike. Again, delivery was on target and well within programmed time limits.

The initial smoke buildup was quite impressive even though flaming combustion was observed only in the open grass fields and in the timbered margins around openings. Post-strike color photography and aerial reconnaissance flights indicated that the combustion of fuels in the openings was fairly complete. Even such large down fuels as uprooted trees were

... turned to a white ash. This evidence of efficient burning can probably be attributed to the effective drying of fuels exposed to direct solar radiation in clearings and clearing edges.

Secondary explosions within the target area were noted by aerial observers during the incendiary attack. These secondaries were distinguished from the burning of the natural fuels by their accelerated rates of combustion. The FAC pilot on Area A reported 15 secondary explosions during the course of the raid.

The rate of burning in these areas where fuels did support active combustion was considerably greater than on similar sites in Area C. The burning of clearings and edges on Area A was characterized by pronounced convective activity and the production of dense, black smoke. The appearance of this smoke was in marked contrast to the grayish-white background smoke evolved from the low intensity smoldering fires beneath the main forest canopy. Sufficient energy was generated throughout the target box to create indraft winds. Smoke was drawn into the main convection column by these winds from all points on the fire perimeter. The convection column soon developed to a height of 4000 feet and was picked up by the Tan Son Nhut radar within 7 minutes of the initial strike. The maximum height of the convection column (10,000 ft. by radar check) was reached at 1445, just after the strike ended. The fire died out very quickly. By 1457 the column top was down to 8000 feet and convective activity was essentially completed by 1530.

A post strike ground reconnaissance mission was scheduled for 0800 on 29 January. However, intense ground fire from the vicinity of the only possible landing zones precluded direct ground observations. Low level aerial observations indicated that crown removal had been minimal, and that fire activity had been confined to clearings. The complete post strike evaluation report is shown as appendix II-B.

Two photo strips were flown in Area A on 30 January on an east-west flight pattern in the north half of the target. These strips covered approximately 2200 acres, or 18.2 percent of the area. All recognizable burned areas larger than one half acre were mapped. Some areas of litter burn under dense canopy could have been missed. The remaining vegetation cover on the burned areas was compared with the cover on the same areas on the pre-strike black and white photographs. The results are shown as Table 2. The photo comparison conditions were classified as follows:

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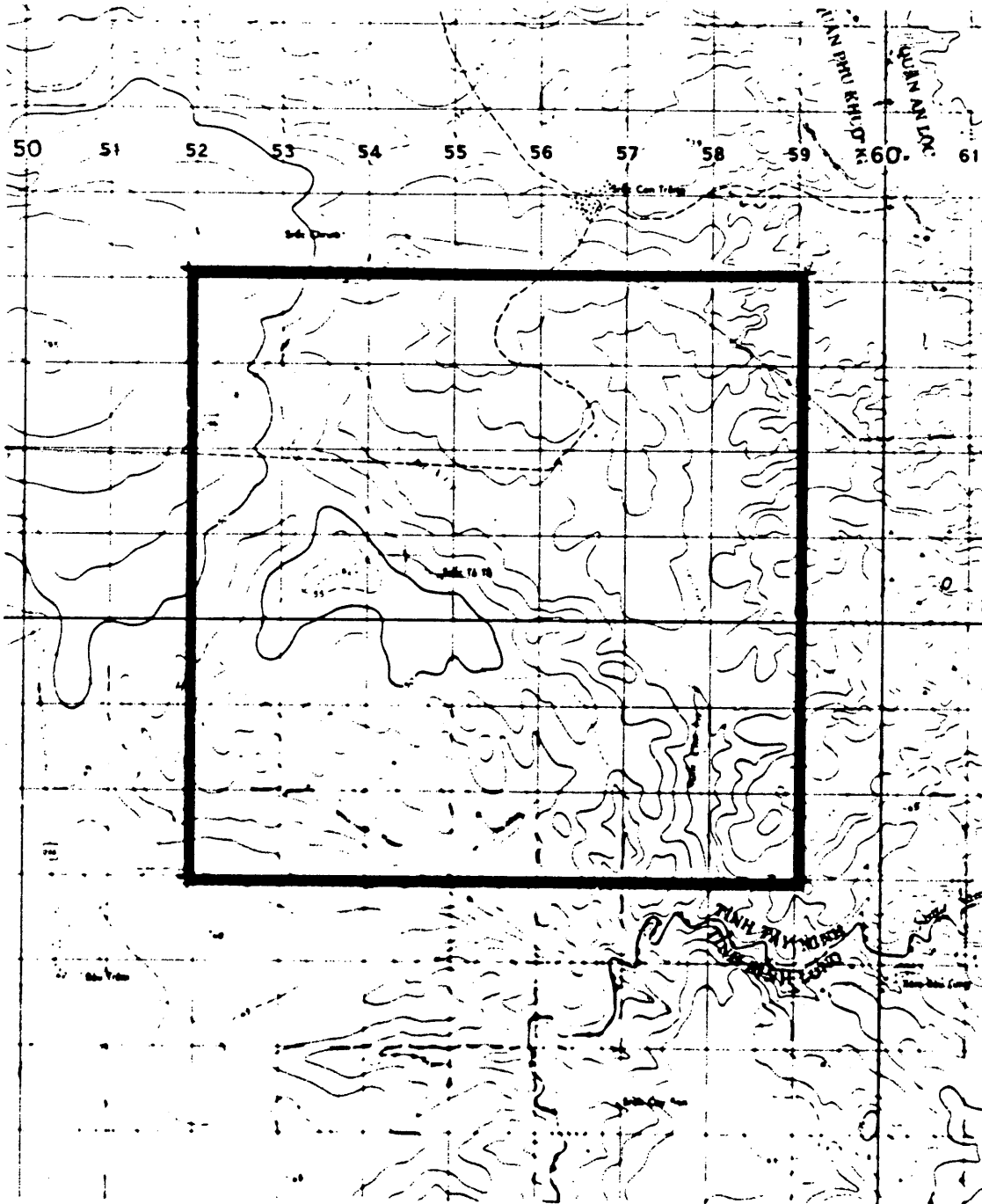


Fig. 23

PINK ROSE TARGET AREA A

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Fig. 24

TAY NINH 2PM WEATHER

7-31 January, 1967

DATE	TEMP (°F)	RELATIVE HUMIDITY(%)	PRECIP (in.)	CLOUD COVER(8ths)
7	88	55		6+
8	87	49		6+
9	90	44		1-3
10	88	47		1-3
11	85	51		3-5
12	84	49		6+
13	86	43		3-5
14	85	42		3-5
15	81	50		6+
16	74	49		6+
17	79	50		6+
18	79	54	T	6+
19	81	58	.01	6+
20	83	51		6+
21	86	49		6+
22	90	48		3-5
23	92	38	.76	6+
24	88	55		6+
25	86	63		1-3
26	90	45		3-5
27	88	59		6+
28	90	40		1-3
29	88	59		3-5
30	90	56		3-5
31	86	59		1-3

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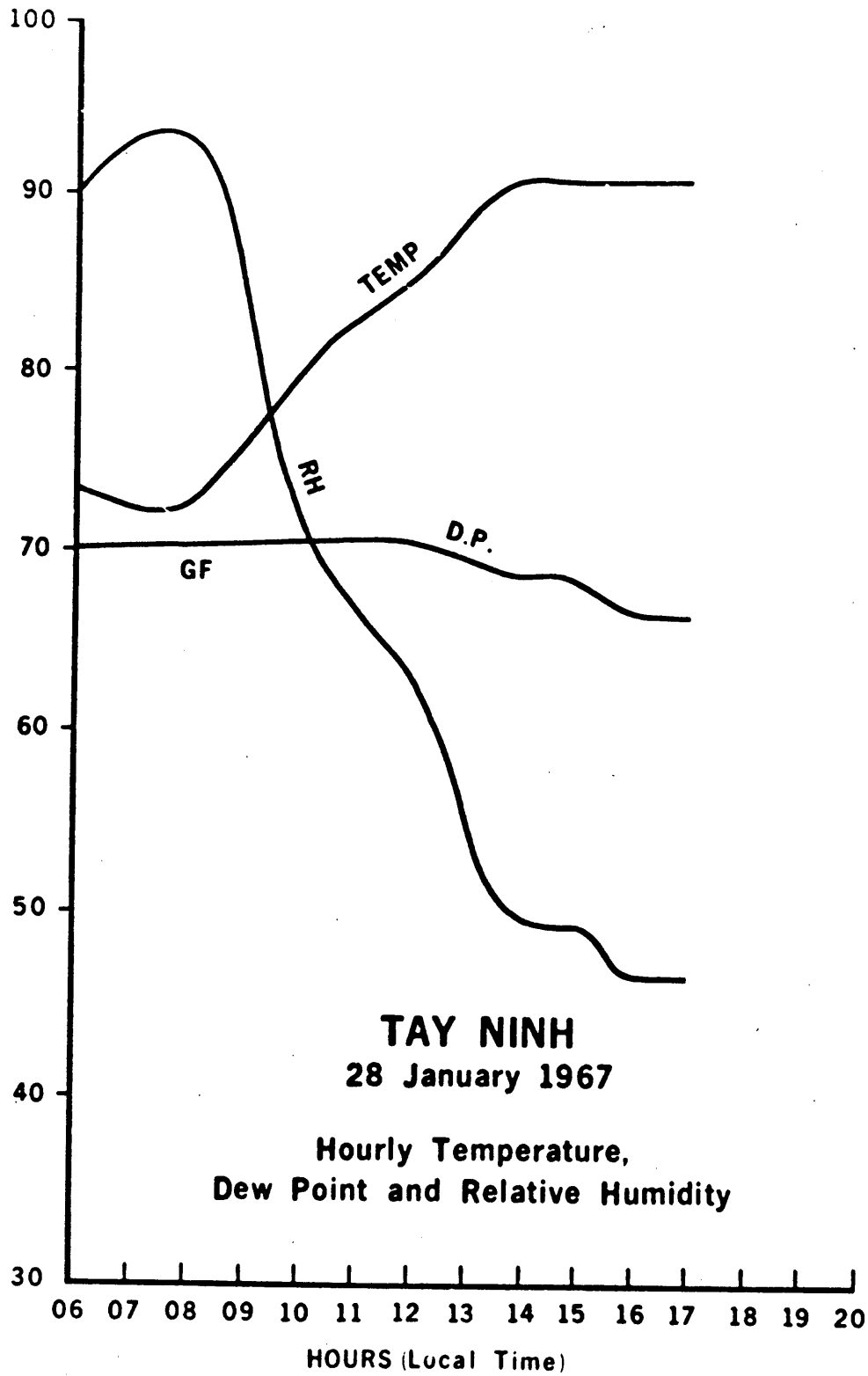


Fig. 25

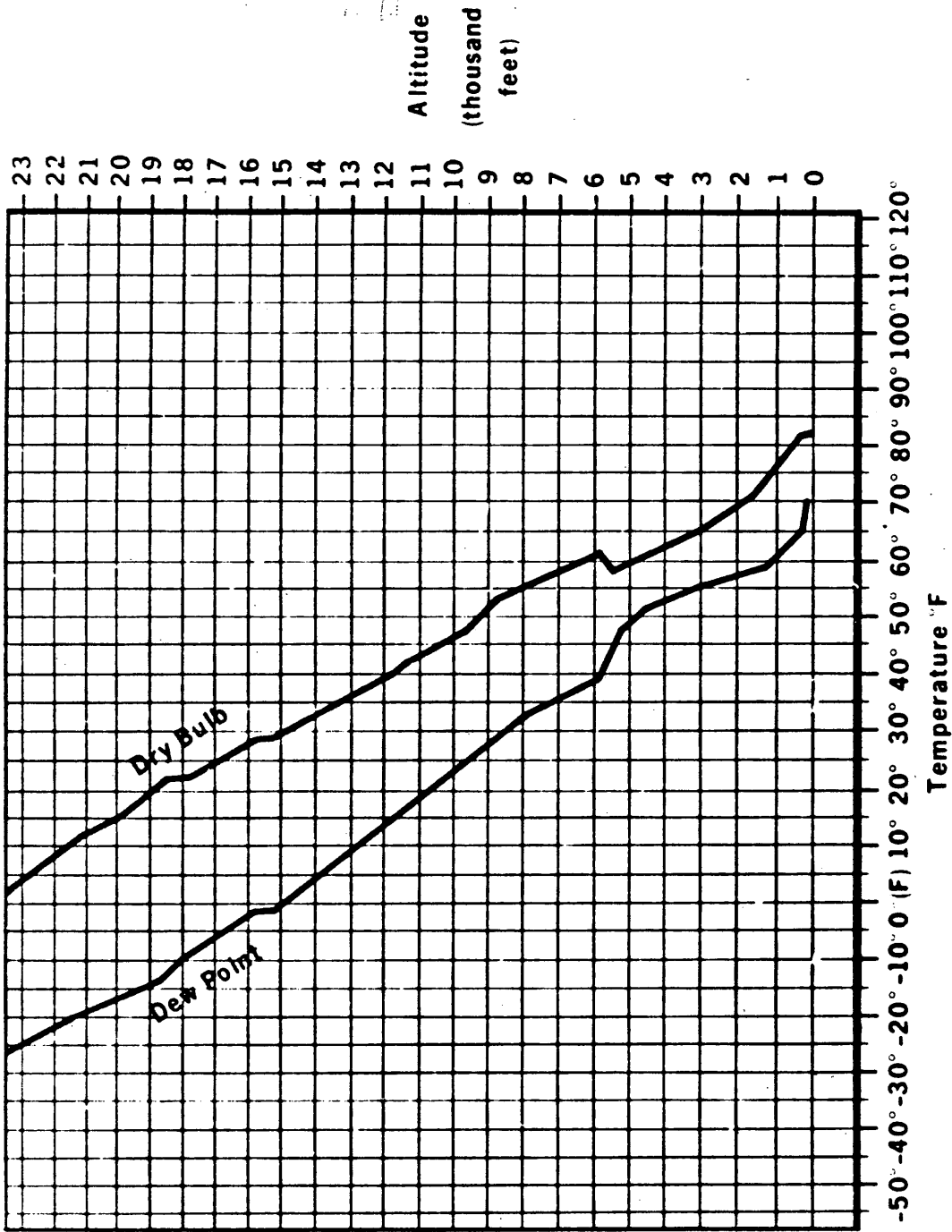


Fig. 26
TAY NINH SOUNDING
28 January 1967 1200 Hours

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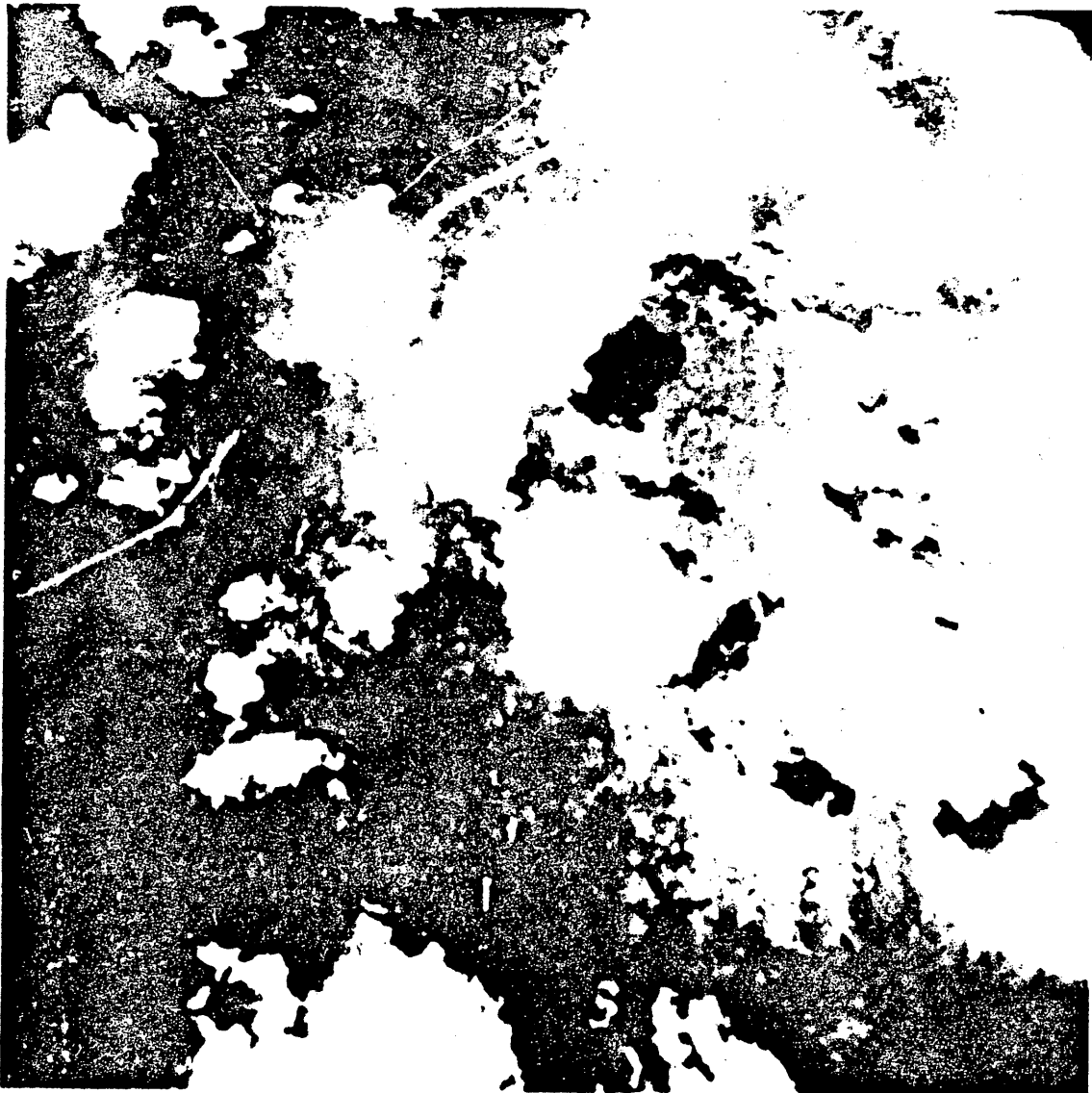


Fig 27A

FIRST STRIKE: PINK ROSE TARGET A

1405 Hours 28 Jan., 1967 (Note light cloud cover)

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Fig. 27B

THIRD STRIKE LINE OVER PINK ROSE TARGET A

1416 Hours 28 Jan., 1967

**(Convection column from first 2 strikes is located
in lower left corner of figure)**

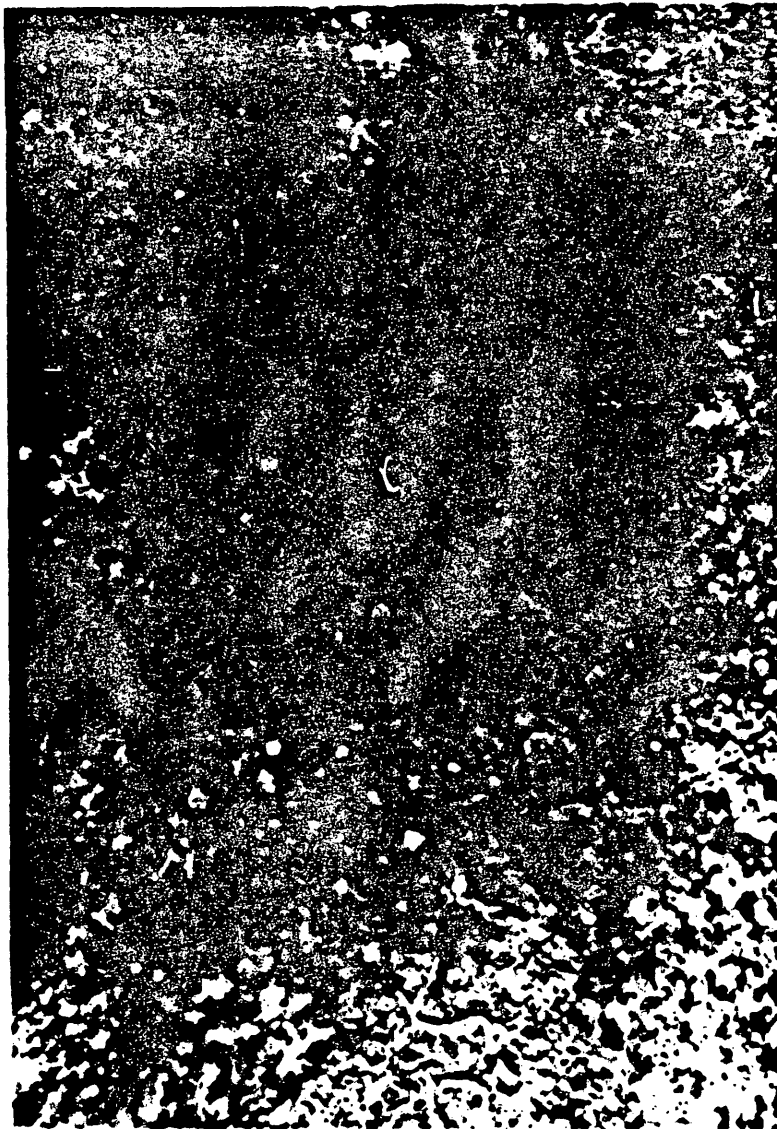


Fig. 28

**FIRES BURNED HOT IN CLEARINGS
(NOTE RESIDUAL WHITE ASH)**

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Pre-Strike Vegetation Type

- | | |
|---|--|
| 1. Nearly complete removal of vegetation. | A. Low, secondary vegetation (under 15 feet high, mainly under 5 feet) having a very open tree canopy. |
| | B. Other secondary vegetation with open to semi-dense forest canopy. |
| 2. Hot ground fire; partial reduction of tree canopy; probably heavy scorching of canopy. | A. Low secondary vegetation, with very open tree canopy. |
| | B. Open to dense forest canopy; but mainly open. |
| 3. Light ground fire; little or no canopy reduction; possible scorching of canopy. | A. Low secondary vegetation, with very open tree canopy. |
| | B. Open, semi-dense, or dense forest canopy. |

Results of the comparison showed that only 7.5 percent of the total area of the post-strike photo sample was altered by fire (See Table 2).

Table 2. Percent of Tropical Forest Modification by Incendiary Attack, Area A, 28 January 1967. (Based on Pre-Strike Black and White and Post-Strike Ektachrome Aerial Photo Coverage of 18.2 Percent of the Total Target)

Aerial Photo Strip	Degree of Burn	Percent of vegetation burned by vegetation type					
		A		B		Total	
		Acres	%	Acres	%	Acres	%
North	1	52.4		3.7		56.1	
South	1	<u>27.6</u>		<u>0</u>		<u>27.6</u>	
Both	1	80.0	3.6	3.7	0.2	83.7	3.8
North	2	5.7		28.6		34.3	
South	2	<u>21.5</u>		<u>4.5</u>		<u>26.0</u>	
Both	2	27.2	1.2	33.1	1.5	60.3	2.7
North	3	6.3		6.9		13.2	
South	3	<u>0</u>		<u>8.2</u>		<u>8.2</u>	
Both	3	6.3	0.3	15.1	0.7	21.4	1.0
Total		113.5	5.1	51.9	2.4	165.4	7.5

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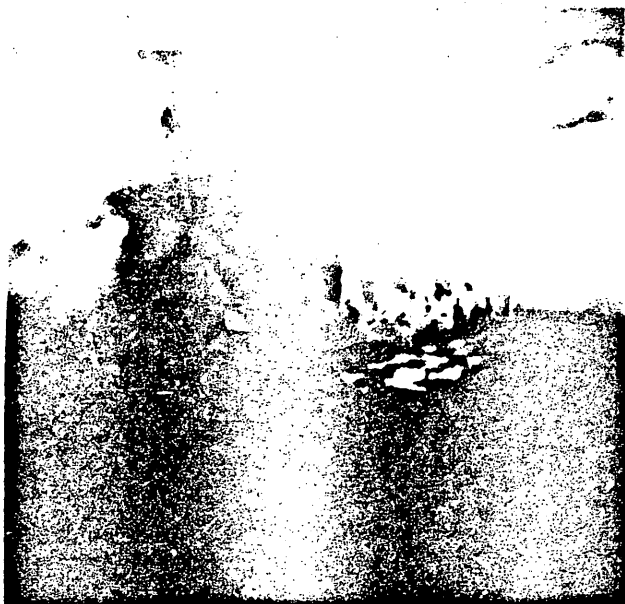


Fig. 29A

1412
Hours

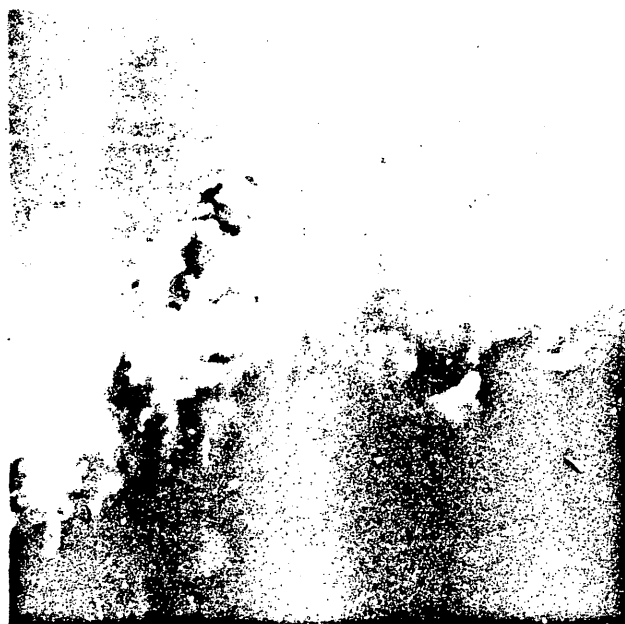


Fig. 29B

1420
Hours

**CONVECTION COLUMN DEVELOPMENT
PINK ROSE TARGET A**

28 January 1967

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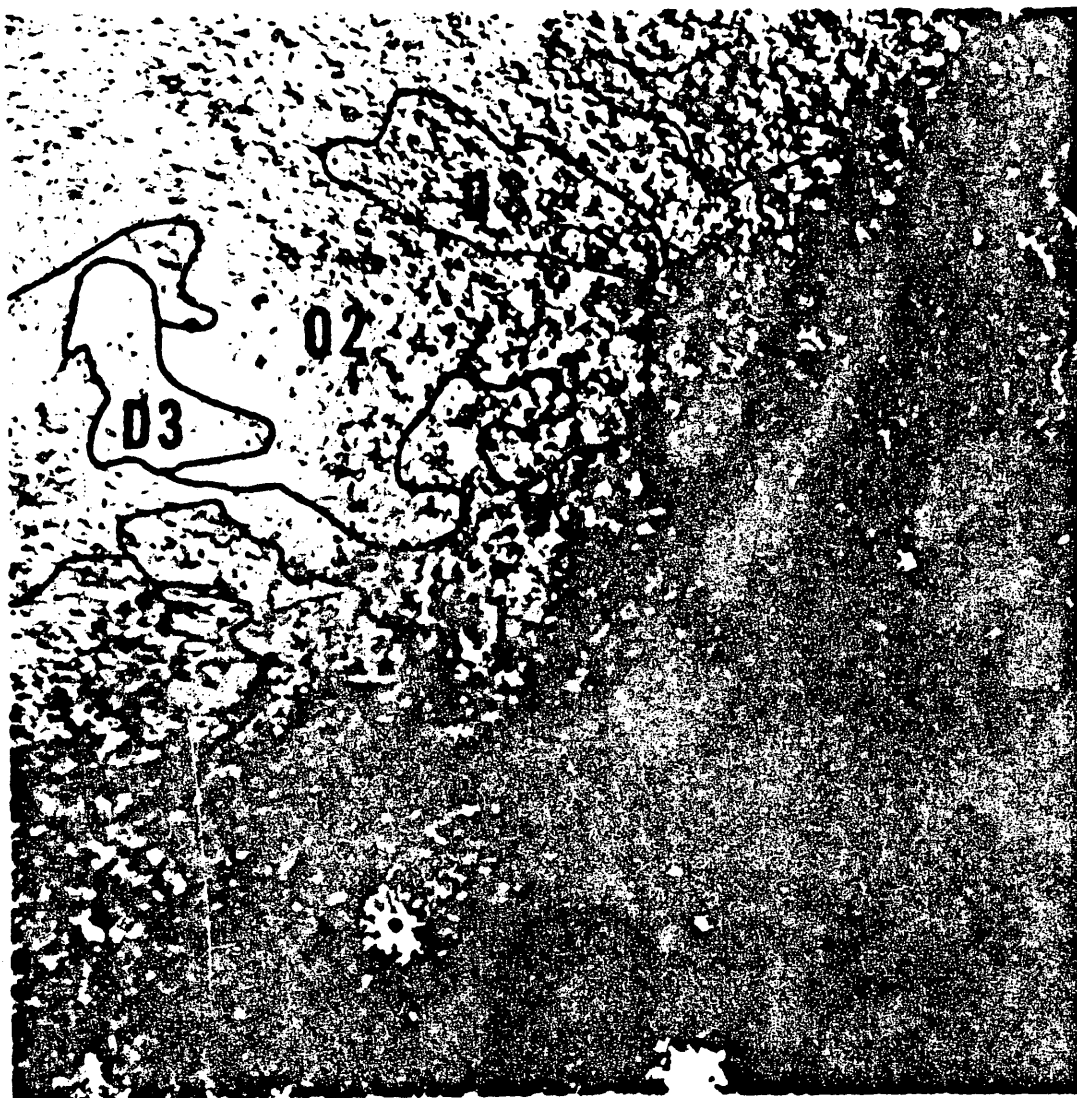


Fig. 30

EXAMPLE OF PHOTOGRAPHIC CLASSIFICATION
OF BURNED AREAS. PINK ROSE TARGET A.

Fuel removal as calculated from measurements of convective activity amounted to 2.5 tons per acre or about 15% of the total available fuel. This figure agrees well with the estimates made during the 29 January observation flights, but is twice that determined from the sample photography.

PINK ROSE III - AREA B, 4 APRIL 1967

Area B is located in War Zone C, about 4 miles from the Cambodian border and 16 miles north-northwest of Tay Ninh. The confluence of two small streams, Ky and May, near the northern center of the target box forms the Ben Da River. National Route 22 between Tay Ninh and the Cambodian border cuts across the southwest corner of the target area. Highway 247 which runs nearly east-west forms the southern boundary of the target. The vegetation on the area was comprised of a fairly dense stand of secondary growth with a patchy mature overstory. Except along the banks of the Ben Da, the target was comparable in species composition and cover density to research site TBNW (described later in this report). The topography was flat and the elevation was approximately 60 feet.

The incendiary raid on Area B began at 1400 LST on 4 April 1967. Weather conditions were less than ideal, but more favorable than those encountered during PINK ROSE I. The week preceding the strike was typical of the transition period between the dry northeast monsoon and the wet southwest monsoon.

A low pressure center over northern Indochina was already apparent from the surface through the 850 millibar level, and accounted for the southwesterly flow over the southern half of South Vietnam. This southwesterly flow was supported by anticyclonic streamline flow from a center located just off the South Vietnamese coast, which at times during the week was located as far east as the Philippines. The two flows caused the development of a convergence zone over the mainland intermittently during the period. Recorded rain fell only on the 3rd of April at Bien Hoa. No other moisture was noted other than fog at many stations in South Vietnam (but not in the target area) on the mornings of 2 and 4 April.

On the morning of the strike, the sky over the target was covered with a double cloud layer; solid stratus at 3500 feet and broken altostratus at 7000 feet. By 1300 the altostratus had dissipated and local thermal convection had broken the stratus to form a 7/10 cover of

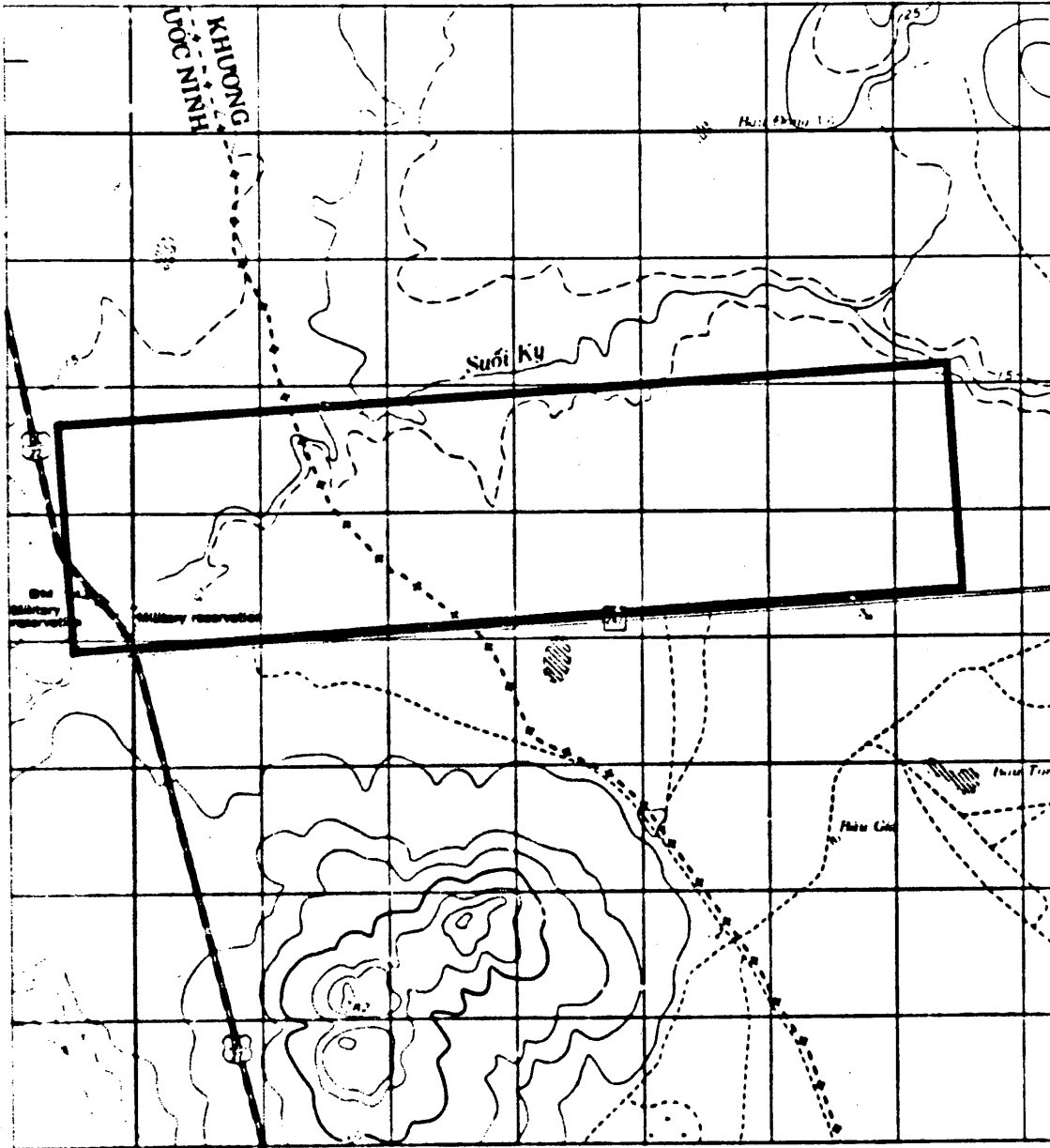


Fig. 31

PINK ROSE TARGET AREA B

stratocumulus with bases at 3500 feet and tops about 4200 feet. This persistent morning overcast would significantly retard dew evaporation, and fuel moistures were undoubtedly higher at TOT than would be expected considering only temperature and relative humidity. Tay Ninh's surface weather for 1-5 April is shown in Figure 32.

The Tay Ninh upper air sounding station is only 10 miles south of the target. The noon sounding showed that conditions were considerably more unstable than on the previous two strikes. The level of free convection was only 8200 feet and the surface free convective temperature was 99°F, only six degrees above ambient at TOT.

For this strike, the B-52 force was reduced to fifteen aircraft, and the target box was compressed to 2300 acres to provide a nominal incendiary spacing of 52 feet (80 feet was the nominal spacing on the first two strikes). Compressing the target box permitted a strike force redeployment such that all bombs were released within 12 minutes. As in both previous strikes, bombing accuracy was excellent.

Because of the higher fuel moistures and lack of solar radiation, fire buildup was noticeably slower than that on the 18 January raid on Area A. For the first 20 minutes practically nothing burned except the incendiaries. Fires did eventually spread, however, and by 1445 the convection column had broken through the cloud layer and topped out at 5000 feet. Rates of spread were determined from sequential infrared imagery. During the maximum buildup period (1425 to 1445 hours) the rate of fire spread in clearings ranged from 2.4 to 4.7 linear feet per minute, about what one would predict for hardwood forest types in the U.S. under similar circumstances. From 1445 to 1515 hours, spread was drastically reduced as the initially ignited spots burned out to leave thin rings of burning litter. As in previous strikes, fires then died out quickly and were confined to a few scattered areas by 1530.

In the ensuing hour, an extremely interesting and rarely documented phenomenon occurred. Although all major fire activity had ceased, the accumulated heat finally pushed surface temperatures above the free convective level. A towering cumulus developed over the target and reached an elevation of 43,000 to 50,000 feet, ^{1/}and more than 1/2 inch of rain fell on the

^{1/}The lower estimate is taken from the Tay Ninh sounding, the upper estimate from aircraft observations. Unfortunately no radar observations were obtained.

DATE	TEMP (°F)	RELATIVE HUMIDITY(%)	PRECIP (IN.)	CLOUD COVER(8ths)
1	95	42	0	1-3
2	99	37	0	1-3
3	97	42	0	1-3
4	93	51	0	6+
5	93	51	0	3-5

TAY NINH 2PM WEATHER

1-5 April, 1967

Fig. 32

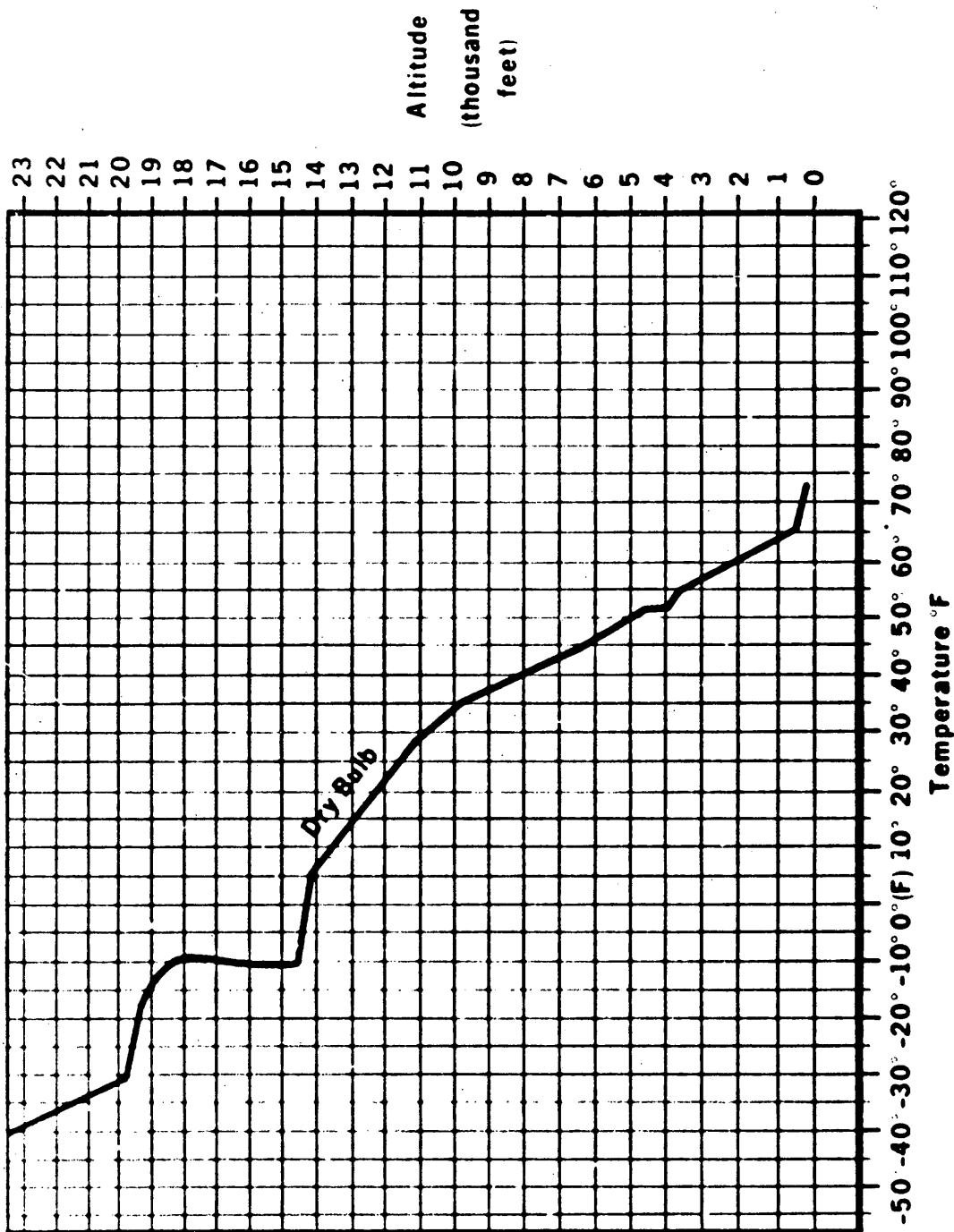


Fig. 33

TAY NINH SOUNDING

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Fig. 34

INITIAL FIRE BUILD UP ON PINK ROSE TARGET B

1415 Hours 4 April, 1967

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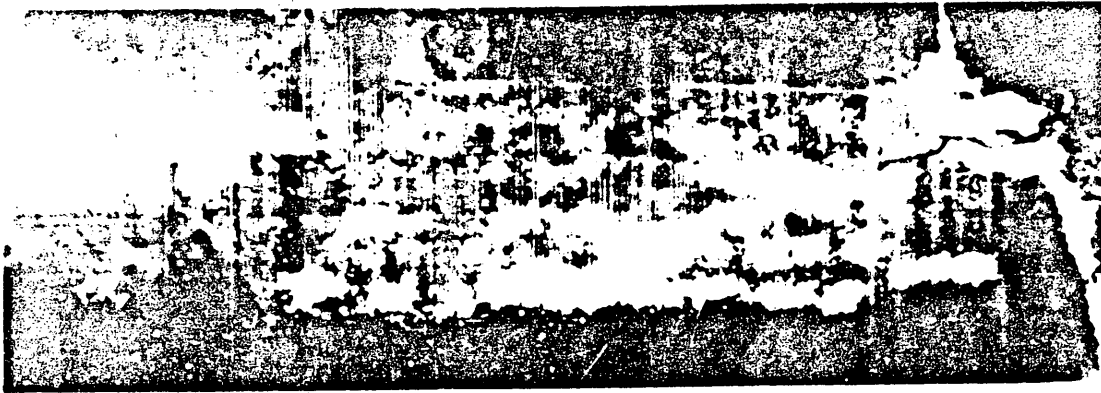
Fig. 35

SOUTHWEST CORNER OF PINK ROSE TARGET B

1440 Hours 4 April, 1967

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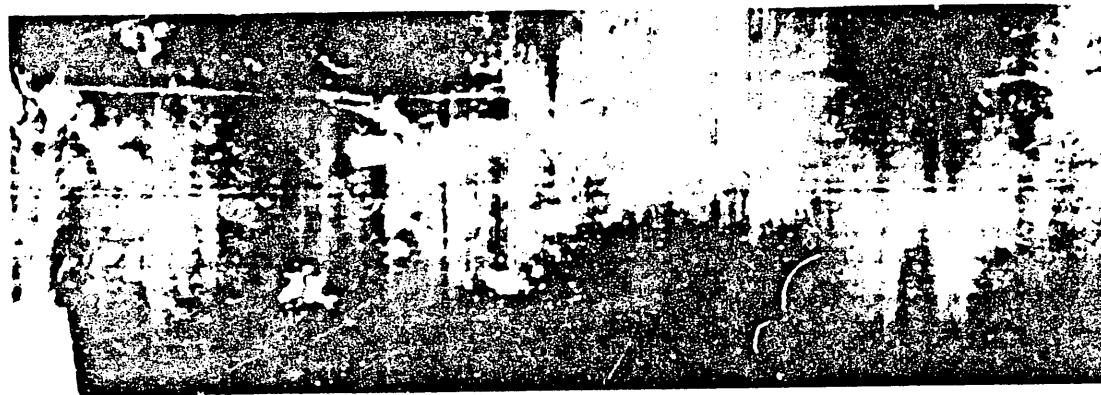
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A. 1420 Hours



B. 1440 Hours



C. 1515 Hours

Fig. 36

INFRARED IMAGERY OF PINK ROSE TARGET B

4 April 1967

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target area before the damage assessment party entered the next morning. Neither towering cumulus nor rain were reported from any other stations within 125 miles of the target area.

Although this event qualifies as a true "firestorm," it should be emphasized that this fire-induced rainstorm in no way affected the course of the fire nor the damage produced, since the fire was essentially over before rain fell.

Ground reconnaissance on 5 April showed that the results, like the weather, were intermediate between those of the first two PINK ROSE tests. Dead logs and snags burned well. Fire had spread for appreciable distances in the surface litter. Clearings burned, and some trees at the edges of clearings were burned. But fire did not spread into the forest crowns and the effective increase in vertical visibility was negligible. Because of the "firestorm" it was not possible to use convection column sounding data to compute fuel removal.

Stem and twig samples taken from defoliated trees and vines showed that the maximum depth of char was 0.17 inches. These samples were collected immediately adjacent to locations where downed logs and snags up to 9 inches in diameter had completely burned through. This is taken as additional evidence that chemical defoliants are not acting as effective desiccants.

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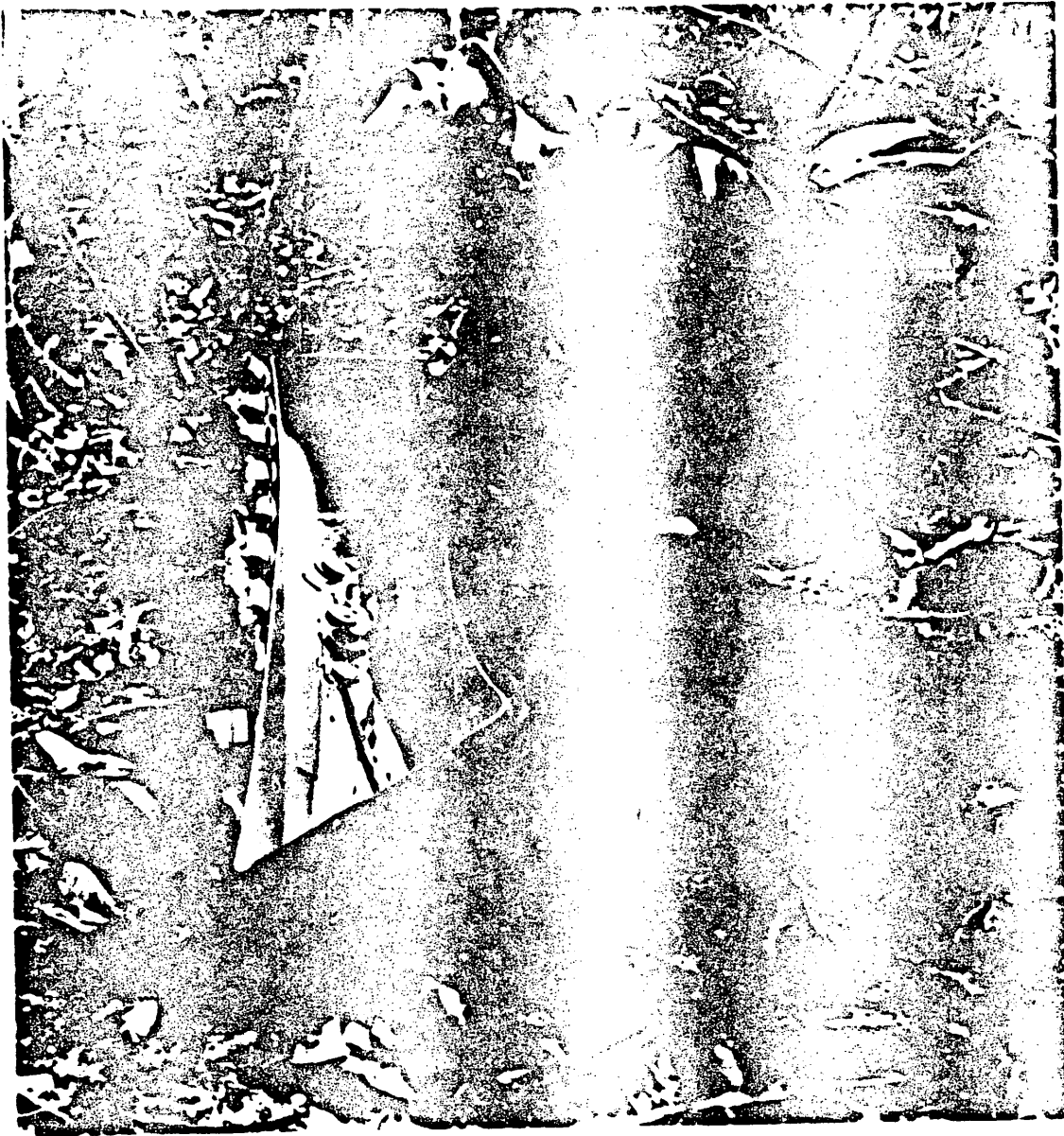


Fig. 37

**FIRE INDUCED RAIN FOUND IN M-35 CANISTER
PINK ROSE TARGET B**

5 April 1967

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DEAD LOGS BURNED TO ASHES



Fig. 38



Fig. 39

ALTHOUGH GROUND LITTER BURNED,
THE FOREST DID NOT.

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RESEARCH SUPPORT

Between 9 January 1967 and 1 March 1967, a 5-man fire research team was detailed to the ARPA Research and Development Field Unit in Vietnam in support of Operation PINK ROSE. The team consisted of an infrared reconnaissance expert, a fire weather meteorologist, a fuels specialist, a fire behavior specialist, and an herbicide specialist. The team assisted in the interpretation of weather data, provided advisory services as requested by the Project Officer, collected data to document the effects of the incendiary attacks, and investigated the flammability properties of tropical forest fuels on a defoliated area near Trai Bi Special Forces Camp south of Area B.

Trai Bi is located 5-1/2 kilometers south of PINK ROSE Area B. Fuel sampling was conducted during January and February 1967. One sampling area (Trai Bi North-TBN) was located 2-1/2 kilometers north of Trai Bi on the east side of National Route 22. The other area (Trai Bi Northwest-TBNW) was located approximately 1 kilometer northwest of Trai Bi. Both areas received a single spray treatment. TBN was sprayed with Orange in September and TBNW was sprayed with Orange in November or December. Data from ranchhand spray crews indicated two missed spray strips in the TBNW area.

The vegetation at Trai Bi was quite comparable to the forest stands observed during flights over area B. The general vicinity was characterized by vegetation that was somewhat sparse in comparison with most Vietnamese fuels. This was in contrast to the more optimum fuel distribution in Area A and the dense triple canopy forest in Area C.

The vegetation at the TBN site was essentially a single canopy stand with scattered overstory trees. The predominant canopy contained saplings and small trees from 12 to 30 feet in height. The overstory trees were 50 to 60 feet high. A stem tally on a 1-milacre plot at TBN produced a total of 38 stems from 6 inches to 20 feet tall. The largest stem diameters recorded on this plot were one of 3/4 inch and one of 1-3/4 inches. About 90 percent of the stems at TBN showed definite treatment effects. Of this 90 percent of stems with treatment effects, approximately 80 percent of the stems were completely defoliated and 20 percent retained dead attached leaves. The remaining 10 percent of the total stand had green attached leaves. The forest floor litter of dead hardwood leaves was essentially continuous, but the fuel loading (weight/acre) of the litter was fairly low. There was practically no vertical continuity of fine,

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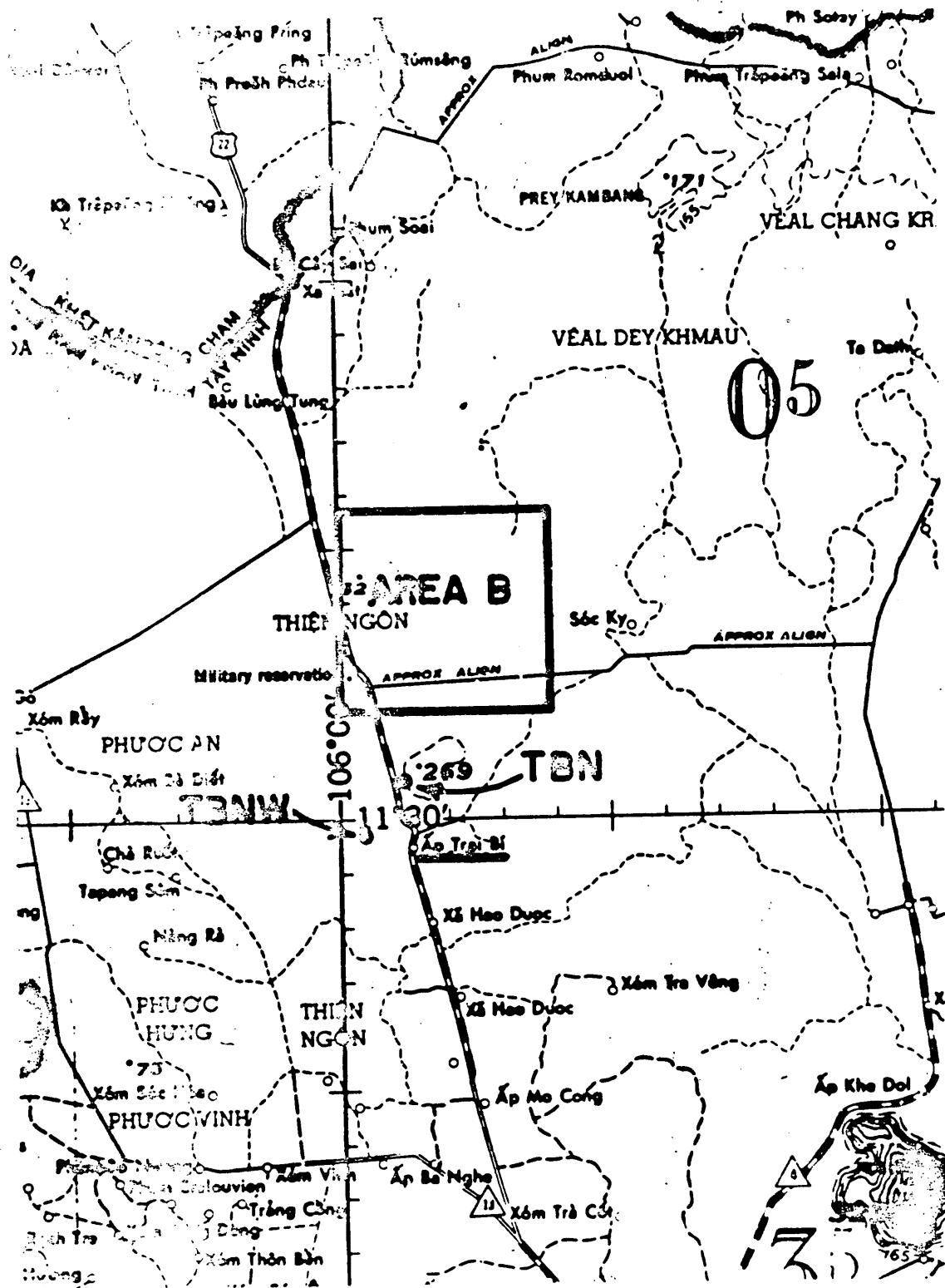


Fig. 40

AP TRAI BI RESEARCH SITE

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Fig. 41

GROUND COVER AT TBN SITE
(Compare with DUC CO fuels in Fig. 5)

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Fig. 42

DEFOLIATED CANOPY AT TBN SITE

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dead fuel within this forest stand. The above vegetation description is characteristic of the entire stand from the woodline north for 1600 feet to the TBN sampling site.

The vegetation at TBNW differed from TBN by having a more pronounced overstory. The trees at the TBNW site did not approach a closed overstory canopy, but there were definitely more mature trees per acre. There were sufficient overstory trees to classify the stand as being double canopied. An active logging operation was working within the TBNW site throughout the field sampling program. The understory was from 12 to 30 feet tall and the overstory was 70-120 feet tall. The contrast between treated and untreated spray strips was readily apparent at TBNW. Approximately 70 to 90 percent of the stems in the treated areas were completely defoliated. In the untreated strips both the understory and overstory canopies retained what appeared to be a normal complement of green leaves. The hardwood leaf litter layer was usually continuous at TBNW, but there was little evidence of vertical continuity of fine, dead material.

FUEL MOISTURE

The moisture content of fuels was determined for samples collected at TBN and TBNW (See Table 3). The moisture content of hardwood leaves and grass was measured by xylene distillation and by oven drying at 103°C for stems and twigs less than 1/2 inch in diameter. All moisture contents are expressed on a dry weight basis. The moisture content of less than 1/2 inch stemwood was consistently high on the treated study areas. The moisture content of the stems was well correlated with the condition of the inner bark layer (i.e., phloem, cortex, and cambium). All trees with a green inner bark, even though completely defoliated, had moisture contents in excess of 100 percent (indicating a viable moisture translocation system).

The cambium inspection of many stems showed that the large majority of treated stems retained a green inner bark layer and thus were at adverse moisture levels in terms of combustion. At moisture contents above 100 percent it is impractical to consider these stems as available fuel under Vietnamese weather conditions. A few treated stems revealed a reddish-brown to brown inner bark which may have been indicative of a species susceptibility to the chemical treatment. Only a very limited number of stems were killed by the chemicals currently being used in Vietnam based on the examination of the inner bark tissue at the sampling sites.

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Table 3. Moisture Content of Fine Fuels and 1/2-Inch Stemwood at Trai Bi, Vietnam, 1967

Date	Area	Fuel Type	1st		2nd		Average	Remarks
			Replicate	Moisture	Replicate	Moisture		
			Percent	Percent	Percent	Percent	Percent	
14 Jan.	TBNW	Ground litter	13	12	12	12	12	Litter composed primarily of species of Dipterocarpaceae, Anonaceae, Guttiferae.
14 Jan.	TBNW	Attached dead leaves	22	13	18			
14 Jan.	TBNW	< 1/2-inch stemwood	129	46				Two different species; 1st replicate Litsea, 2nd replicate unknown.
15 Jan.	TBN	Ground litter	10	10	10			Myrtaceae Family - Barringtonia longipes, Genus and species.
15 Jan.	TBN	Attached dead leaves	11	10	10			
15 Jan.	TBN	< 1/2-inch stemwood	11	11	11			Euphorbiaceae Family - Croton pollanei, Genus and species; no attached leaves; no visible inner bark.
15 Jan.	TBN	< 1/2-inch stemwood	153	163	158			Euphorbiaceae Family - Croton pollanei, Genus and species; attached green leaves and green inner bark present.
16 Jan.	TBNW	Ground litter	12	13	12			Anonaceae Family.
16 Jan.	TBNW	Attached dead leaves	9	10	10			
16 Jan.	TBNW	< 1/2-inch stemwood	120	114	117			Melastomaceae Family - Memecylon, Genus; green inner bark present.
24 Jan.	TBN	Grass	12	13	12			Negrandia madagascariensis, Genus and species.

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Table 3. Moisture Content of Fine Fuels and 1/2-Inch Stemwood at Tral Bi, Vietnam, 1967 (Continued)

Date	Area	Fuel Type	1st		2nd		Average Moisture Content	Remarks
			Moisture Content	Percent	Moisture Content	Percent		
24 Jan.	TBN	Ground litter	12	14	13			
24 Jan.	TBN	<1/2-inch stemwood	126	129	128		This plant had dead attached leaves and green inner bark present.	
25 Jan.	TBNW	Attached dead leaves	12	14	13			
25 Jan.	TBNW	<1/2-inch stemwood	14	14	14		Dead logging slash on the ground.	
5 Feb.	TBN	<1/2-inch stemwood	68	75	72		Brown inner bark.	
5 Feb.	TBN	<1/2-inch stemwood	112	116	114		Green inner bark present.	

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FUEL VOLUME AND ARRANGEMENT

The amount of surface fuel available for combustion was determined by collecting one square foot plots of leaf litter. Three plots were collected at TBN and two plots were collected at TBNW. The plot samples were oven dried at 103°C. and the litter quantity computed in terms of tons per acre of organic matter. The average sampled quantities of litter were 2 tons per acre at TBN and 4-1/2 tons per acre at TBNW.

Although the total unit weight of surface fuels was low, the distribution of the litter was usually continuous over both areas. The continuous distribution of fuel was not maintained in the vertical plane. The vertical orientation of fine dead fuels was limited on the sampling sites and few ladders existed between the surface litter layer and aerial fuels.

FIELD BURNING TESTS

Small test fires were ignited near Trai Bi using white phosphorus and incendiary grenades. Fires were set in concentrations of logging slash at TBNW and in the hardwood litter of chemically treated forest stands at TBN and TBNW. The presence of the logging slash permitted the comparison of fire behavior in a fuel configuration which simulated native slash and burn practices with that of the PINK ROSE fuel orientation.

Litter Test Fire, TBN, 15 January, 1967

The hardwood litter in a treated forest stand was ignited with a white phosphorus grenade. A few ignition points were established, but fire spread was practically non-existent and spot fires were confined to areas of approximately one square foot. Combustion was sustained for only a short period of time within those small spots. The air temperature at 1640 near this burning site was 85°F. and the relative humidity was 49 percent. The moisture content of the ground litter was ten percent.

Slash Test Fire, TBNW, 17 January, 1967

One white phosphorus grenade was thrown into a rather heavy concentration of logging slash consisting of large limbs, branches, and dead leaves. The slash fuels were contained within a perimeter of 114 feet. Flame heights of 10 to 15 feet were observed shortly after ignition. The weather observation at 1435 at the slash fire site indicated an air temperature of 81°F. and a relative humidity of 47.5 percent. The fuel moisture at 1515 was 12 percent

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Fig. 43

LITTER COLLECTION PLOT AT TBN SITE

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Fig. 44

FIRE IN SURFACE LITTER AT TBN SITE

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for leaf litter and 10 percent for dead attached leaves. The relative humidity at 1515 was 50 percent. By 1530 the fire had consumed a large amount of the fuel within the slash concentration. Nothing remained but white ash and charring limb and branch material. The fire did not spread downwind into the sparse leaf litter.

Slash Test Fire, TBNW, 25 January, 1967

At 1355 one incendiary grenade was thrown into a concentration of dead logging slash. Combustion was rapid immediately following ignition, but fire spread was not sustained throughout the fuel bed. The fuel in the center of the slash pile was consumed with practically no spread beyond the point source of ignition. The slash fuel was aerially arranged without much fine surface fuel. The air temperature was 87°F. and the relative humidity was 61 percent at 1407. At 1420 the moisture content of attached dead leaves was 13 percent and the moisture content of small diameter slash branches was 14 percent.

Litter Test Fire, TBNW, 25 January, 1967

At 1515 two incendiary grenades were thrown into a continuous bed of hardwood leaf litter. The litter was ignited but fire spread in the natural fuel was not sustained following the burnout of the grenades. Flame heights were on the order of 4-6 inches and the final size of fire spots was about 12 inches in diameter.

Litter Test Fire, TBN, 5 February, 1967

Hardwood litter beneath the predominantly single canopy stand was ignited at 1205 with a white phosphorus grenade. The fire at the impact point spread slowly and by 1237 had burned an area approximately 25 feet in diameter. At 1240 flames 3-5 inches high were spreading very slowly into unburned hardwood litter. This spot closely resembled some of the ignition points observed in PINK ROSE Target A while flying over the area on February 3. Under the canopy in target area A, the ordnance ignition points were confined to small areas. Sustained combustion of the litter did not occur following ordnance burnout.

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A spot fire also started about 50 feet from the grenade impact point. This spot was characterized by a continuously spreading fire perimeter in all directions. The fire spread slowly and maintained a circular configuration. At 1221 the perimeter of this spot fire was 100 feet. It was apparent by 1223 that the present perimeter would be close to the final fire size. Flaming zones around the perimeter were quite scattered. Backing flames were 6-9 inches high and the flame depth was about 2 inches. The leaves burned to a black ash with the leaf structure well preserved. The black ash readily disintegrated when touched. Some of the residue was in the form of white ash.

The only portion of the area still burning by 1227 was on the northeast and east sides, where flames were backing into a slight wind. By 1240 the fire spot was almost out. There was no vertical continuity of fine, dead fuel in this area and the fire remained a surface fire throughout the burning period.

The weather observation at 1200 on 5 February indicated an air temperature of 86°F. and a relative humidity of 55 percent.

DENDROLOGY

The species composition of the vegetation at TBNW was identified on 7 February by a botanist from the Botanical Garden in Saigon (See Table 4). The identification of vegetation is important in interpreting the response of different species to spray treatment. The identification was stratified by understory and overstory vegetation. There were instances where the same species were defoliated in the overstory but not in the understory. An explanation of this disparity in treatment effects might be attributed to the logging operation in the area. At the time of treatment the overstory may have been more extensive, preventing good understory contact from the single spray flight over TBNW. Or spray drift may have affected overstory trees in the missed strips at TBNW, but not come into contact with understory vegetation. The majority of the overstory trees at TBNW were defoliated. More green leaves remained in the understory at TBNW than were observed at TBN.

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Table 4. Understory and Overstory Vegetation Identified at TBNW

UNDERSTORY

<u>Genus</u>	<u>Species</u>	<u>Family</u>	<u>Remarks</u>
Croton	poilanei		Retained green leaves
Acronychia	laurifolia		
Grewia	paniculata		
Aparosa	filicifolia		Retained some green leaves
Nephelium	chryseum	Sapindaceae	
Ancistrocladus	cochinchinensis	Ancistrocladaceae	
Sindora	cochinchinensis	Leguminaceae	Retained green leaves
Callophylum	retusum	Guttiferae	
Popowia	aberrans	Anonaceae	
Calomus		Palmae	Low, green herbaceous plant
Cinnamomum	zeylanicum	Lauraceae	
Pasania or Lithocarpus		Fagaceae	Retained green leaves

OVERSTORY

<u>Genus</u>	<u>Species</u>	<u>Family</u>	<u>Remarks</u>
Eugenia		Myrtaceae	Retained some green leaves
Parinarium	annamense	Rosaceae	
Dillenia	ovata	Dilleniaceae	
Anisoptera	cochinchinensis		
Sindora	cochinchinensis	Leguminaceae	No leaves in overstory tree
Mangifera	cochinchinensis	Anacardiaceae	
Adina	polycephala	Rubiaceae	
Irvingia	oliveri	Irvingiaceae	Retained green leaves
Dipterocarpus	intricatus	Dipterocarpaceae	
Dipterocarpus	alatus	Dipterocarpaceae	Retained some green leaves
Pasania or Lithocarpus		Fagaceae	No leaves in overstory tree

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LABORATORY FUEL DESCRIPTION

Approximately 35 pounds of hardwood leaf litter were collected near Trai Bi and shipped to the Northern Forest Fire Laboratory for fuel testing purposes. The leaf litter was measured and described in terms of properties which influence fuel flammability (See Table 5). The description of fuel properties will be used in support of subsequent laboratory burning tests.

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Table 5. Fuel Properties of Samples Collected at TBN and TBNW

	<u>TBN</u>	
	<u>English</u>	<u>Metric</u>
Weight/Unit Area <u>1/</u>	1.95 tons/acre	4.37 metric tons/hectare
Heat Content	-----	-----
Ash Content (Leaves)	5.2%	5.2%
Leaf Density	16.8 lb/ft ³	
Leaf Specific Gravity <u>2/</u>		0.255 gm/cc
Compactness of Litter Fuel Bed	65.8 ft ² /ft ³	2.2 cm ² /cm ³
σ <u>3/</u>	1772 ft ² /ft ³	58.1 cm ² /cm ³
	<u>TBNW</u>	
Weight/Unit Area <u>1/</u>	4.50 tons/acre	10.09 metric tons/hectare
Heat Content	8264 Btu/lb	4591 cal/gm
Ash Content (Leaves)	10.4%	10.4%
Leaf Density	17.4 lb/ft ³	
Leaf Specific Gravity <u>2/</u>		0.270 gm/cc
Compactness of Litter Fuel Bed	125.7 ft ² /ft ³	4.1 cm ² /cm ³
σ <u>3/</u>	1675 ft ² /ft ³	55.0 cm ² /cm ³

-
- 1/ Heat content is expressed as the low heat value on an oven dry basis.
 - 2/ Compactness is defined as the surface area of the fuel divided by the void volume of the volume of the fuel bed (ft²/ft³).
 - 3/ σ (Sigma) is defined as the surface area to volume ratio of the fuel, or the surface area of a fuel particle divided by the particle volume. Generally, the higher the value for sigma the greater is the rate of fire spread since more surface area per unit volume is exposed to convective and radiative heating. In contrast to the values for hardwood leaves, the σ value for 1/2-inch sticks is 96 ft²/ft³.

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DISCUSSION

The marginal results of HOT TIP in 1966 were attributed to ineffective desiccation treatment of the vegetation and an inadequate density of ignition points. The absence of overall sustained and active combustion following the incendiary attack was interpreted to result from one or more of the following treatment deficiencies.

1. The vegetation was not drying to low moisture content levels because single pass spray applications were not getting down to treat understory vegetation.
2. The dry season application of chemicals was less effective than spray treatments during the wet season when plants would be more physiologically active.
3. Difficulties in the effective dispersal of chemicals could be caused by the mountainous topography of Chu Pong.
4. The ignition strips had been too widely spaced and this might have prevented the individual fire sets from adequately reinforcing each other.

The PINK ROSE test requirements were planned to minimize all of these treatment deficiencies. The new requirements called for double spraying during the wet season with Orange and White, followed by a desiccant spray application prior to the ignition of targets. Targets were selected in flat topography to provide optimum flying conditions for spray coverage. Ignition density was increased to saturate the targets with individual fire sets.

Despite the modifications of the forest incendiary requirements for Operation PINK ROSE, the three PINK ROSE tests gave conclusive evidence that tropical forest vegetation was not appreciably altered by fire under existing conditions. Fire has been used successfully for centuries in tropical regions by native people employing "slash-and-burn" agricultural techniques. Shifting agriculture burning is characterized by the felling of all, or most, trees on an area and the dry season curing of this fuel just prior to burning. Tropical forests prepared in this way have produced effective fires for clearing purposes.

Prescribing similar clearing practices during wartime is not feasible in insecure areas. During the follow-up stages of the Iron Triangle military operation in Vietnam in 1967, considerable tractor clearing of land was observed. The vegetation was dozed into windrows and

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burned. The results of such clearing appeared effective, but possibilities for widescale application of this technique in areas which remained totally insecure appear questionable. Cost estimates for achieving effective land clearing through aerial bombing with high explosives are extremely high (\$840,000 per square Kilometer).^{1/} Also, such treatment may not satisfactorily prepare an area for subsequent burning since the resulting craters destroy horizontal fuel continuity at the same time that they improved vertical continuity.

In contrast to the optimum fuel arrangement established by slash and burn techniques is the less flammable PINK ROSE fuel model. This model, which developed following the defoliation of standing vegetation, was characterized by:

1. A low surface litter fuel load per unit area.
2. A continuous surface fuel layer in the horizontal plane, but limited vertical continuity of fine, dead fuel; standing defoliated stems usually at excessively high moisture content levels.
3. A minimal level of solar insolation; although the stands are defoliated, the drying of surface fuels is not effectively assisted by solar radiation because of significant shading by branches, limbs and stems.

The high moisture content of the numerous standing small stems combined with the other factors formed a fuel pattern which was incapable of sustaining active combustion following ignition. The low intensity test fires observed near Trai Bi did not generate the energy required to influence even the small stems. Post-strike aerial and ground observations and photo reconnaissance of PINK ROSE targets revealed the same results: ignition point sources burned out rapidly within forest stands with little surface spread and practically no vertical fire spread.

When 1/2-inch stems are at a moisture content of 100 percent there is not sufficient energy produced from the litter fire to ignite these stems. If these stems were at 10 percent moisture content, the litter energy level is theoretically capable of igniting the stems. So the

^{1/} Breit et al. Neutralization of Viet Cong Safe Havens: A Preliminary Study (U). Tech. Paper RAC-TP-191, 1965, 74 pp.

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problem to date in forest incendiary attacks in Vietnam appears to be the inability to effectively desiccate the vegetation. It is evident that current defoliation chemicals, applied in the volumes and concentrations now in operational practice, are not doing the desiccation job. Successful crown removal by fire in Vietnam will not be achieved unless techniques of actual chemical desiccation can be developed.

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APPENDIX I
PINK ROSE Test Plan

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DEPARTMENT OF THE AIR FORCE
HEADQUARTERS SEVENTH AIR FORCE (PACAF)
APO SAN FRANCISCO 96307

26 December 1966

REPLY TO
ATTN OF: PL

SUBJECT: PINK ROSE Test Plan (U)

TO: See Distribution (Pages 100 and 101)

1. (S) This test plan is effective upon receipt and provides for the operational evaluation of a technique to clear forest or jungle growth by fire.
2. (U) The nickname for the 1967 test of this technique is "PINK ROSE."
3. (U) Task organizations will prepare supporting documents containing local procedures and directives as required.
4. (U) Comments and/or recommendations for changes, additions, or deletions to this test plan will be addressed: Headquarters 7th Air Force (PLR), APO 96307.

FOR THE COMMANDER

A. L. HILPERT, Colonel, USAF
Deputy Chief of Staff/Plans

DOWNGRADED AT 3 YEAR INTERVALS;
DECLASSIFIED AFTER 12 YEARS
DOD DIR 52.00.10

PL-66-00783
RDFU Log S-025-67

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**PINK ROSE
TEST PLAN**

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PINK ROSE TEST PLAN

1. References:

- a. Secret MACJ3 memorandum dated 7 Oct 66 to Commander 7AF and JRATA.
- b. Secret COMUSMACV message DTG 050830Z Oct 66 to OSD.
- c. Secret COMUSMACV message DTG 011528Z Jul 66 to CINCPAC.
- d. Secret US Department of Agriculture Forest Service Final Report - Phase I, Forest Fire Research, Volume 1.

2. Purpose:

To determine the techniques and conditions required to destroy large areas of forest or jungle growth by fire.

3. Background:

In September 1965, CINCPAC recommended to the Joint Chiefs of Staff that an immediate requirement be established to develop a capability to destroy by fire large areas of forest and jungle growth in Southeast Asia. This request was approved by the Joint Chiefs of Staff and the Director of Defense Research and Engineering directed the Advanced Research Projects Agency (ARPA) to accomplish the required research tasks. The Forest Service, under contract to ARPA, researched this problem in Vietnam and collected data. A test operation was conducted at Chu Pong mountain (YA 88 02) near Pleiku. Burn of this area was accomplished on 11 March 1966 by B-52 strikes (HOT TIP I & II). The area selected had previously been defoliated and incendiaries were dropped to ignite the area to be burned. It was concluded that although results of HOT TIP were indeterminate, sufficient information did exist to warrant proceeding with project PINK ROSE in three areas selected within War Zones C and D.

4. Technique:

During the period August - December 1966, selected areas will be defoliated twice by C-123 aircraft using orange or white herbicide dispensed from standard dispensers. Selected areas will be resprayed using blue desiccant approximately ten days before ignition. In late January and late February 1967, the selected areas will be bombed by B-52 aircraft using

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M-85 Incendiary Cluster Bombs. The ensuing forest fire is expected to consume the dried vegetation and denude the target sufficiently to deny its use as a safe haven.

5. Objectives:

- a. Validate conclusions reached from previous research on optimum techniques for destruction of forest/jungle areas in Vietnam by fire.
- b. Determine feasibility of employing PINK ROSE techniques as routine operational programs.
- c. Determine supplemental advantages gained by use of burn techniques following defoliation over use of defoliation techniques alone.
- d. Determine magnitude of possible long-range benefits derived from PINK ROSE techniques.

6. Discussion:

a. Selection of Specific Targets for Burn.

(1) War Zone C and D are elements of the 1966-1967 MACV-GVN defoliation program. Three areas have been selected as representative forest/jungle growth for PINK ROSE tests. Each is a square having sides of seven kilometers and each contains approximately 12,000 acres of jungle. These areas also contain known and suspected VC/NVA installations.

(2) A target map is attached as Appendix 1.

b. Selection of date for Target Burn:

(1) Optimum conditions for a forest/jungle burn exist on a hot, dry, relatively cloudless day. Work accomplished during Phase I of Project EMOTE, (Reference 4) indicates that the number of days when forest incendiary operations are possible within the potential target areas is greatest during January and February. These two months have the least rainfall and most nearly meet the optimum requirements. For these reasons, late January has been selected for date of first test burn.

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(2) This same source also indicates that the relative humidity is lowest and the temperature is highest at approximately 1400H. Since these conditions are optimum for good burning, 1400H has been selected as the start time for ignitions.

(3) It is desirable that the target date be flexible for two reasons. First, operational requirements may preempt the use of B-52 strike aircraft for higher priority targets. Second, since weather plays such an important part in successful PINK ROSE operations, it would be highly desirable to have the capability to delay target ignition for one to three days if the weather is unfavorable.

c. Defoliation Program:

(1) Preparation of PINK ROSE targets by aerial herbicide operations will be accomplished to insure proper pre-burn conditions.

(2) Concept of operations will be as follows:

(a) During the period November 1966 - February 1967, continue defoliation of the three target areas. Herbicide operations will be conducted in three phases:

1. Phase I - Initial treatment of each target area. Total target will be treated with three gal/acre of orange herbicide on areas A and C and three gal/acre of white herbicide on area B. Initial application should be completed as quickly as possible. Desired schedule for completion is: Area A - 14 November 1966; Area B - 16 November 1966; and Area C - 18 November 1966. (Note: all areas were completed by 27 November 1966.) Desiccation of the upper canopy as quickly as possible is essential if the treatments are to be effective by the scheduled target strike dates. Orange herbicide is preferred because of quicker action and greater possibility for defoliation of lower canopy through volatilization.

2. Phase II - The three targets selected for burning will be treated with a second herbicide application at a rate of three gal/acre. Targets A and C will be treated with orange and Target B will be treated with white. The following schedule is desired: Area A - 27 Dec 1966, Area B - 28 Dec 1966, and Area C - 26 December 1966.

3. Phase III - During this phase a desiccant, agent blue, (phytar), will be applied to half of each target area to dry dead foliage and other combustible material. Targets

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A and C will receive three gal per acre and Target B will receive 3 gal/acre. The desiccant should be applied on the south half of area B and C and the west half of A approximately ten days ahead of target ignition. It should be applied at right angles to the flight lines used in the initial application on each area. Desired schedule is: Area A - 19-21 January 1967; Area B - 26-28 January 1967; and Area C - 5-7 February 1967.

(b) Schedule and tasks for Herbicide Operations:

1. War Zone C was approved and ordered executed by the Joint General Staff for the period 5 September 1966 - 31 March 1967. War Zone D was approved and ordered executed by the Joint General Staff for the period 16 September 1966 - 31 March 1967.

2. Aircraft and herbicide requirements.

a. The target area of forty-nine square kilometers will require 34 sorties and 34,000 gallons of orange/white herbicide.

b. The first application to three targets will require 102 sorties and 102,000 gallons of orange/white herbicide.

c. The second application to three targets will require 102 sorties and 102,000 gallons of herbicide -- 68,000 orange and 34,000 white.

d. The third application applied to half the target area will require an additional 51 sorties and 42,500 gallons of blue.

e. The total herbicide requirement is 255 sorties and 246,500 gallons of orange/white/blue.

d. Ignition:

(1) The M-35 Incendiary Cluster Bomb has been selected to provide PINK ROSE ignition. This bomb is a standard munition and is available. It weighs 750 pounds and contains a cluster of 57 M74A1 bomblets, each bomblet containing 2.75 pounds of PT1 incendiary filling. The bomb cluster is normally set to open at an altitude of 5000 feet.

(2) In order to effectively ignite one selected target, 1260 M-35 bombs must be dropped (42 for each of 30 aircraft). Since three targets have been selected and prepared, and current planning provides for strikes on all three targets, at least 3780 M-35 bombs must

be available to the 3rd Air Division on Guam. Programming should provide for complete units to include M-35 bombs, M-14 tail fins, two M152/AN-152A1 fuzes per bomb and M23 type B arming wires.

(3) Ignition of each target will be accomplished by a B-52 strike of 30 aircraft. Each aircraft will carry 42 M-35 Incendiary Cluster Bombs. Results of a similar operation last year indicate the need for a greater number of ignition points than were used previously. Reference 4 also specifies that there should be at least one ignition point for each 8000 square feet. Information provided by SAC indicates that one B-52D can provide approximately one ignition for each 6200 square feet throughout a pattern 700 feet wide by 21000 feet long. (Reference Secret message SAC to CINCPAC DTG 061630Z Sep 66.) Proper spacing between individual aircraft and aircraft cells so that each 700 foot swath touches an adjacent one will properly saturate a square 21000 feet on a side or approximately 41 square kilometers. Use of synchronous techniques is desired to reduce the overall span of time between the first aircraft over target and the last. Also, this technique should provide a greater probability of uniformly saturating the target area.

c. Weather:

Since weather conditions so critically affect the burn potential of the target areas, the maximum weather information and advice obtainable must be available to the Project Officer. If a rainfall of 0.2 inches or greater falls in the target area, three drying days will be required. A rainfall of less than 0.2 inches will require one drying day.

f. Documentary Photography:

Project PINK ROSE will probably be the final test of the feasibility of destroying forest/jungle growth by fire. Many agencies, both military and civilian, will be interested in the results. It is, therefore, extremely important that this project be adequately documented. Documentary photography will be required to cover initial planning, defoliation and its effects, strike aircraft support, ignition and post strike effects.

g. Ground Reconnaissance:

(1) The Fifth Special Forces Group will be requested to provide combat team support for four people - A Forest Service Specialist, an ARPA Observer, a MACCOC7 Representative and a photographer. They are to be airlifted into the target area shortly after dawn

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of the day following each incendiary strike (or as soon thereafter as ground and air conditions permit as determined by 5th SFG) and to be airlifted out the same day.

(2) On-site analysis by a qualified Forest Service observer after strike can provide critical answers necessary to logical data analysis not obtainable by any other means. Specific answers required are actual existing species of vegetation, lower canopy conditions, ground fuel type and availability, impact pattern of incendiaries, dud rate determination, effectiveness of ignition, ground cover removal, etc.

(3) It is desirable to obtain samples of ground fuel before strike to determine the true moisture content of existing fuel. Sampling kits and instructions will be provided by the Forest Service for use of Special Forces. If Special Forces personnel are in target area prior to strike, fuel samples should be obtained. A specific mission to fulfill this requirement is not considered necessary. If possible, it would be highly desirable for a Forest Service fuels specialist to obtain samples in or near target B area prior to strike. It may be possible to accomplish this by operating out of the Special Forces camp at Ap Trai Bi (XT 12 70).

4) An on-site evaluation of the tactical effectiveness of the PINK ROSE technique can be provided by accompanying Special Forces personnel. Special Forces personnel associated with the post strike entry party will be interviewed by the Pink Rose Project Officer and their evaluation of effectiveness will be included in the PINK ROSE operational report.

h. U. S. Department of Agriculture, Forest Service:

(1) The Forest Service has had much experience in removing cover by fire and has participated in both Operation SHERWOOD FOREST (1965) and HOT TIP (1966) conducted in Vietnam. For PINK ROSE, the Forest Service will make available to the Project Officer a 3-man team consisting of an infra-red reconnaissance expert (team leader), a fire weather meteorologist and a fuels specialist. This team will arrive in Saigon approximately 9 January 1967. The team will be prepared to conduct laboratory determinations of fuel moisture content, assist in interpretation of weather data, and provide advisory services as requested by the Project Officer.

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(2) A fire behavior specialist will arrive in Saigon on 14 January 1967. He will make evaluations of fire behavior during the operation and on-the-ground technical evaluations of effectiveness after the strike. He will also be available for advisory service as requested by the Project Officer.

(3) An herbicide specialist will be located in Bangkok during January. He will be available for PINK ROSE on Request. Under its contract to ARPA, the Forest Service will be conducting research in Vietnam after the conclusion of PINK ROSE. Forest Service personnel will be available for assistance in compiling or analysing data for inclusion in the operational report as requested by the Project Officer. Forest Service personnel will be returning to CONUS approximately 1 March 1967.

i. Aerial Reconnaissance:

(1) Analysis of target area data furnished by aerial reconnaissance will provide the major input for the technical evaluation of Project PINK ROSE. Requirements can be grouped into three areas - infrared photography, simultaneous dual color photography, and infrared coverage.

(2) The targets will be very hot. Unless precautions are taken during IR readouts, amplifier saturation and DC-level shift will occur obscuring terrain detail on the non-hot areas. Terrain detail is essential for data analysis. Smoke in the area will prevent location of the target center by visual means. Real time viewing of IR signals will be required to locate flight lines. Severe turbulence is expected in the convection column and it should be avoided if possible. Specific requirements follow and will be required for each of the three targets.

(a) Infrared Photography:

1. Area: Complete coverage - a square, 7 km on a side.
2. Filter: Wratten 12 or minus Blue (yellow).
3. Film: IR black and white.
4. Resolution: Three inch ground
5. Overlap: 55 - 65%

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6. Sidelap: 30%

7. Scale: Not less than 5000 feet/frame.

8. Date required: Prestrike - between 1 December 1966 and strike date;
Poststrike - three to five days after strike.

9. Clear sky and high sun are desirable to minimize shadows.

10. Individual 1:8,000 scale mosaics of this coverage are desired as soon as possible after strike.

(b) Color Photography:

1. Area: Sample coverage of each area simultaneously in two colors. Approximately two percent area coverage is required. It should consist of strips flown at right angles to each other. North-South strips should be flown during prestrike photography; East-West strips should be flown during poststrike photography.

2. Film 1: High Speed Ektachrome.

Film 2: CD Color (Camouflage Detection).

3. Filter 1: Haze.

Filter 2: Minus Blue or G.

4. Resolution: 1 inch ground.

5. Overlap: 55 - 70%.

6. Sidelap: None.

7. Date required: Prestrike - three to five days before strike; Poststrike - three to five days after strike.

(c) Infrared:

1. Spectral Region: 8 - 14 microns.

2. Resolution: 2 milliradians.

3. Viewing: Real Time.

4. Recording: 5 inch film and magnetic tape.

5. Scan Angle: 120 degrees.

6. Flight Altitude: 10,000 feet.

7. Time: Start as soon after strike as possible. Runs will be made at five minute intervals for 30 minutes (six runs). Additional runs at 30 minute intervals will be made for the next two hours (4 runs). One run is required the day after the strike, preferably between 1100H and 1400H.

j. Forward Air Controller Support:

(1) Support from Forward Air Controllers in the following locations will be required - Tay Ninh, An Loc and Xuan Loc. Support required will consist of routine direction of 12ACS operations prior to strike, visual observations of target area, and aerial photography in conjunction with normal missions.

(2) Support of 12ACS RANCH HAND operations already is being provided and will not be further affected by PINK ROSE. It is desirable to have reports from Forward Air Controllers on precipitation or lack of it in the target area starting three days before strike date. This report can be called by telephone to the TACC after normal daily flights are completed. The 600th Photo Squadron will provide photographic documentation of Project PINK ROSE. Occasional flights by aerial photographers in Forward Air Controller aircraft are required. These will be conducted in conjunction with normal missions.

k. Psychological operations:

Psychological operations exploitation of B-52 (Arc Light) strikes will continue in accordance with existing instructions to II Field Force V.

l. Data Collection:

(1) Forest Service personnel, from the U. S. Department of Agriculture, will collect technical data and publish technical reports for the PINK ROSE operation.

(2) Support requirements will be obtained through the Seventh Air Force Project Officer.

(3) Data collection will generally be in accordance with the following outline.

(a) Defoliation Program - Obtain maps from the 12th Air Commando Squadron of each area (1/50,000 scale) showing the area sprayed each day by date, the chemical used and the rate of application.

b) Weather - Obtain copies of all data as specified in paragraph 7c(4) of this plan.

(c) Fuels - Obtain:

1. Samples of both treated and untreated leaves and twigs for fuel moisture determination.

2. Samples of ground litter for determination of fuel loading.

3. Herbarium records of species composition of each target area.

(d) Ordnance and Delivery - Obtain:

1. Copy of frag orders for each target.

2. Copy of SAC debriefing information to include time of first and last bomb on each target; number of aircraft and bomb load; and formation type, altitude and air-speed during strike.

3. Depth of penetration of individual incendiaries by soil type supported by B&W photos.

4. Typical ejection pattern of individual incendiaries and extent of variation from the typical pattern (to be determined by analysis of infrared film).

5. Copies of all available photography taken by SAC.

(e) Fire Behavior - Obtain:

1. Rate of fire spread and time of coalescence (to be determined by analysis of infrared film).

2. Rate of rise of convection column by five minute time intervals.

3. Height of column at condensation level.

4. Height of column at icing level.

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5. Diameter of column at base, smoke fallout junction, icing zone and top.
6. Copies of all photography taken during strike.

(f) Fire Effects - Obtain:

1. Increase in vertical visibility (to be obtained from pre and post-strike photography).

2. Increase in horizontal visibility support by B&W photographs.

3. Samples of partially burned fuels for residual energy determination.

4. Depth of char measurements on standing stems.

5. Measurement of stub diameters by height class.

6. Photographic documentation of casualties produced and damage to targets of military interest.

m. Command and Control:

(1) The normal command channels of all participating units will be used to conduct this test.

(2) MACV COC-8 will task the Third Air Division for B-52 support for this mission. Execution of SAC forces will remain with the Strategic Air Command. PINK ROSE requirements will conform with existing Arc Light procedures.

(3) The Seventh Air Force TACC will control all other aircraft participating in this test.

(4) The Project Officer, having evaluated information provided by weather officers, the Seventh Air Force SACLO, Forest Service representative, and FAC reports, will request MACV COC to frag strike units for ignition missions. He will also request the Seventh Air Force TACC Plans Division to frag photo reconnaissance units and documentary photo units. The III DASC will frag FAC units for necessary support missions. The current Operations Division, in coordination with the Project Officer, will issue any necessary instructions to

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recall the B-52 force through MACV COC-8 to Third Air Division. Recall could be from Seventh Air Force if necessary. This instruction to recall would normally only be requested in the event of unfavorable weather which would negate test.

(5) During the execution phase, the Project Officer will closely monitor all conditions affecting desired test results. He will have the authority to cancel a tasked mission at any time that unfavorable conditions preclude optimum test results. Cancellations and subsequent rescheduling of missions will be relayed to participating units through normal control agencies.

7. Support Requirements:

a. MACV will be requested to:

(1) Execute defoliation program within priority as specified in paragraph 6c.

(2) Provide coordination with US Army to obtain support from Fifth Special Forces Group as specified in paragraph 6g.

(3) Provide coordination with SAC/3rd Air Division to assure necessary strike aircraft support. K-17 camera film of strike is requested if conditions permit.

b. Seventh Air Force will:

(1) Provide through the TACC, fragging for the photographic reconnaissance missions and the documentary photographic missions.

(2) Provide through the III DASC, Forward Air Controller Support of defoliation operations.

(3) Provide through the III DASC, Forward Air Controller visual observations in target areas as specified in paragraph 6j.

(4) Provide through the III DASC, observation flights for photographic personnel as specified in paragraph 6j.

c. First Weather Group at Tan Son Nhut will:

(1) Provide a 1st Weather Group coordinator to monitor and coordinate all Air Weather Service meteorological activity in support of this plan (WGO-PL) and furnish PIRAL equipment to Combat Weather Team at Quan Loi to support requirements of this operation.

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(2) Through the Fifth Weather Squadron:

(a) Provide two PIBALS per day, maximum height of 12,000 feet at 0800H and 1400H, from Quan Loi commencing on or about 12 January 1967 and continuing until the day of the final strike, approximately 25 February 1967. The PIBAL data will be furnished to Det 2, 40th Weather Squadron.

(b) Insure that all upper air data received from US Army Meteorological Units at Tay Ninh, Cu Chi, and Phuoc Vinh during the period shown above are encoded and transmitted on the SEA Weather Net.

(3) Through Det 2, 30th Weather Squadron, provide to the ARPA Staff Meteorologist the following data:

(a) Weather observations from III Corps in the vicinity of the target area.

(b) Rawinsonde data (plotting and sounding) from Tay Ninh, Cu Chi, and Phuoc Vinh.

(c) Coded PIBAL information from Quan Loi.

(d) Target Area forecast provided by Det 14, 1st Weather Group.

(e) Radar scope photos beginning five days before each strike, photos to be taken only where echoes appear on scope. On the day of the strike, pictures will be taken at 10-minute intervals beginning at 1300H and continuing until the ARPA representative terminates the requirement.

(f) Other meteorological services and/or data requested by the ARPA Staff Meteorologist and coordinated through 1st Weather Group Project Officer.

(4) Through Det 14, First Weather Group, provide:

(a) At approximately 64, 40, 16 and 10 hours before strike time a 24-hour forecast for the target area. This forecast will contain cloud condition, surface wind in miles per hour, and a specific forecast of rain or no rain. If rain is forecast, the amount of precipitation expected will be included. In addition, a forecast of temperature in degrees F, and relative humidity for 1400H on day of strike will be provided.

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(b) Other meteorological services and/or data requested by the ARPA Staff Meteorologist and coordinated through 1st Weather Group Project Officer.

d. The 600th Photographic Squadron will provide documentary photographic support in accordance with the following:

- (1) Motion picture format - 16mm ECO.
- (2) Still photography format - 120 and 35mm Color, 120 B&W.
- (3) A shooting outline will be followed as agreed to between Project Officer and 600th Photographic Squadron. Basically, this will be a scenario covering initial planning, defoliation of selected areas and its effects, B-52 support, strike of target and post-strike effects.
- (4) Photography will require the following aircraft support:
 - (a) One CH-3C or equivalent for D-day.
 - (b) Two each F-100F's for D-day to photograph release of ordnance.
 - (c) Two O-1F's to photograph target area prior to D-day, on D-day, and 2-3 days after D-day. The flights prior to and after D-day can be made with one aircraft on two separate flights, one for still photography and one for motion picture photography.
 - (d) Two flights with RANCH HAND aircraft.
 - (e) Aircraft to fly photo chase on RANCH HAND aircraft, possibly F-100 or CH-3C.
- (5) The Project Officer will provide photography dates, locations, contacts, and print requirements and distribution.

e. Forest Service, USDA will:

- (1) Provide technical advisory service to OSD/ARPA RDFU-V and Project Officer as specified in paragraph 6h.
- (2) Collect data as specified in paragraph 6i.

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f. OSD/ARPA RDFU-V will:

(1) Provide technical inputs to Project PINK ROSE through Project Officer and provide liaison between Forest Service and OSD/ARPA RDFU-V.

(2) Direct the ARPA Staff Meteorologist to:

(a) Coordinate with task organizations through 1st Weather Group on existing and future weather requirements.

(b) Provide film for scope photography.

g. 460th Tactical Reconnaissance Wing will: Provide reconnaissance requirements as specified in Section 6i.

h. 12th Air Commando Squadron will: Provide herbicide and desiccant treatment of areas as specified in paragraph 6c.

8. Time Schedule:

PINK ROSE Project assigned to AFTU-V	4 Oct 66
Arrival of ARPA/Forest Service Team	1 Nov 66
Selection of three specific target areas	6 Nov 66
Preliminary draft of Test Plan	9 Nov 66
Coordinated Test Plan complete	15 Dec 66
Establish weather watch	12 Jan 67
Blue Spray of target areas	8 Jan, 5 Feb, 10 Feb 67
Ignition of target areas	C-18 Jan; A-25 Jan; B-1 Feb 67
Post-strike analysis	19 Jan, 16 Feb, 23 Feb 67
Operational report	23 Mar 67

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9. Coordination:

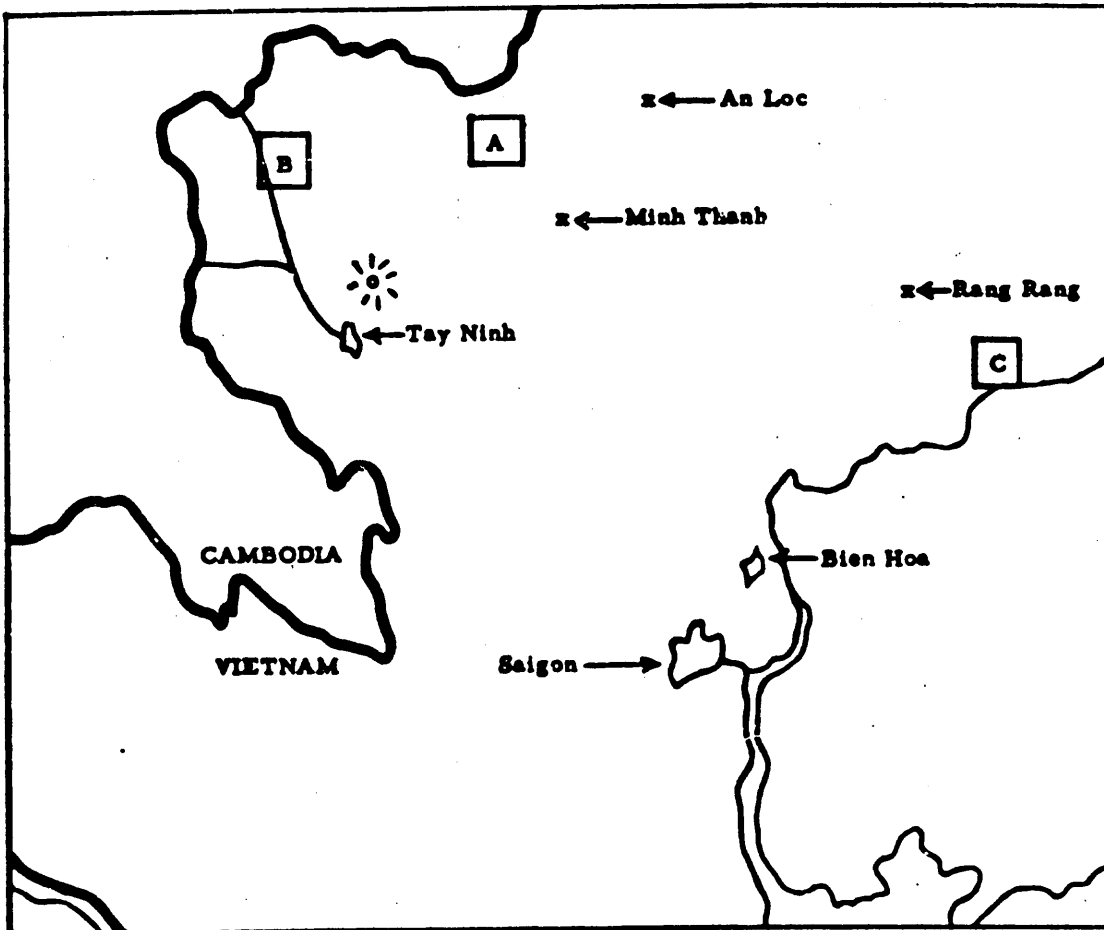
Military Assistance Command, Vietnam

MACJ3	Colonel Gregory, 14 Dec 66
MACJ34	Colonel Brooks, 13 Dec 66
MACSA	Dr. McMillan, Colonel Hammett, 10 Dec 66
MACCOC2	Colonel Stanton, 14 Dec 66
MACCOC7	LtCol Callanan, 14 Dec 66
MACCOC8	Colonel Lemoine, 11 Dec 66
ARPA RDFU-V	Major Rosenthal, 15 Dec 66

Seventh Air Force

TACC	B/Gen Talbott, 15 Dec 66
DOSACLO	Colonel Weyant, 15 Dec 66
1st Weather Group	LtCol Hughes, 12 Dec 66
12th Air Commando Squadron	LtCol Dennis, 15 Dec 66
315th Air Commando Wing	Colonel Blair, 13 Dec 66
460th Tac Recon Wing	Colonel Nelson, 14 Dec 66
600th Photo Squadron	Capt King, 12 Dec 66
U. S. Department of Agriculture	Mr. Chandler, 6 Nov 66

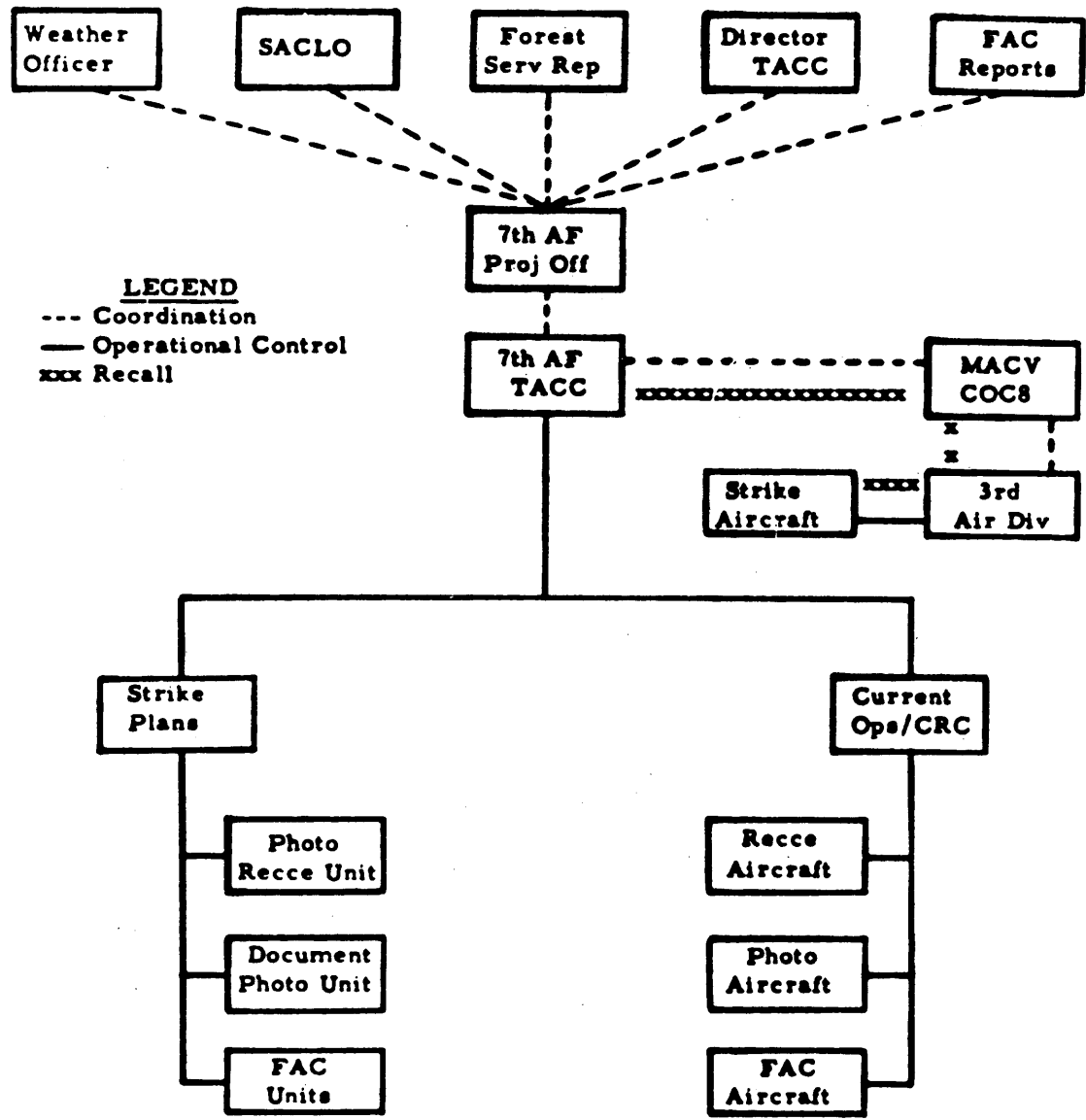
Note: Final Coordination will be with MACV J2, J3 and Director, COC. Seventh Air Force will be with DI, DO and PL.



Target A - XT5277-5284-5984-5977
Target B - XT0975-0982-1682-1675
Target C - YT3441-3448-4143-4141

TARGET MAP

APPENDIX 1



LEGEND
--- Coordination
— Operational Control
xxx Recall

FUNCTIONAL RELATIONSHIPS

APPENDIX 2

APPROVED TEST PLAN DISTRIBUTION LIST

Department of Defense

Director, Advanced Research Projects Agency, Research and
Development Field Unit, Vietnam 10

United States Air Force

AFRDQR 1

AFRDC 1

AFRDQ-A 1

AFRDDE 1

Pacific Command

J-3A12 2

Scientific Advisory Office 2

Pacific Air Forces

DORQ 1

Military Assistance Command, Vietnam

MACJ3 10

Seventh Air Force

DO 5

DI 1

TACC 1

Air Force Advisory Group (ODC) 1

AFSC Liaison Officer (DAFSC) 1

SAC Liaison Officer (DOSACLO) 1

1st Weather Group 3

12th Air Commando Squadron 1

315th Air Commando Wing 1

460th Tactical Reconnaissance Wing 1

600th Photographic Squadron 1

United States Army

Army Concept Team in Vietnam 1
Headquarters, Dept of the Army, ACSFOR CM, Washington, D. C. 1

United States Navy

Navy Research and Development Unit, Vietnam 1

Strategic Air Command

CINCSAC 1
Cmdr, 3rd Air Division 5

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APPENDIX II-A

**Post Strike Evaluation Report PINK ROSE Target Area C
19 January, 1967**

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OPERATION PINK ROSE

Post Strike Evaluation of Target C

From 0745 to 1915 on Thursday, January 19, 1967, a post strike evaluation was made of the effects of the January 18 incendiary raid on Target C. Landing was effected in the east end of the swamp at YT 359443. Light ground fire was experienced on landing and fresh tracks were observed at the margin of the LZ. The evaluation party moved north from the LZ approximately 100-150 yards until reaching the estimated centerline of a bomb run (probably the south plane on run 5). We then moved east along the bomb run centerline for approximately 1 kilometer (to YT 349447), moved south to the margin of the swamp and followed the swamp margin back to the LZ. Observations were made in an area approximately 1 km. long by 1/4 km. wide, or 1/2 of 1% of the entire target area. Special note was made of the ordnance effectiveness, defoliation effectiveness, fuel composition and fire behavior.

ORDNANCE:

Delivery pattern was approximately as predicted. The pattern was planned to give an average spacing of 71.1 ft. between incendiaries within a strip extending 271 ft. on each side of each centerline, and an average spacing of 102.2 ft. in the intervening 158 ft. between adjacent centerline strips. The actual pattern was somewhat tighter than this with average spacings of 50-60 ft. along the centerline and about 120-130 ft. at the extreme edge of the pattern. The distance between adjacent centerlines could not be determined accurately, nor could the relative area receiving heavy and light concentrations. Our impression was that about half the area received heavy (50 ft. spacing) and the other half light (120 ft. spacing) rather than the 2:1 ratio predicted.

The dispersal of incendiary material from the tail of the canister varied from 2 to 20 ft. depending on the angle of penetration of the canister into the ground. No duds were found. However, many (perhaps 20%) bomblets were prematurely activated by contact with tree branches before reaching the ground, and thermite ejecta was found up to 50 ft. from these bomblet casings. Such premature activation would be helpful in spreading fire providing that the liquid material would also reach the ground before burning, etc. Because of the highly fire resistant nature of the ground fuels at the time of the strike, we could not determine whether material other than thermite had come down hot.

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From thermite ejecta found remote from bomblet casings in the swamp where contact with trees was impossible, it was evident that some additional bomblets had also activated prematurely, probably at the time of the main M-30 canister opening. These should be considered as duds since ejected material would burn out in the 5000 ft. free fall after canister opening.

Except in the swamp, bomblets did not bury themselves deeper than 2/3 the length of the casing, even though the ground in the forest was quite moist and soft. In the swamp, bomblets often buried themselves completely. But in all cases where bomblets were located, tail ejection had been sufficiently forceful to eject incendiary material at least a foot or two beyond the impact crater.

In summary, the M-74 munition in the M-35 cluster mode, dropped with a 5000 ft. fuse altitude is an acceptable and effective ordnance for forest ignition.

DEFOLIATION

Measured by color change, the double sprayings one month apart were extraordinarily effective in desiccating heavy triple canopy. The final spray with contact desiccant produces no color change, and since the weather precluded moisture measurements or meaningful fire behavior observations, no evaluation of the effectiveness of contact desiccants on this operation is possible.

The overstory was almost completely killed and about 80% of the leaves had fallen. The middle canopy was 80% dead and had lost 15-25% of its leaves. The 20% of green material remaining in the middle canopy appeared to be a result of species susceptibility rather than spray penetration. The understory was about half dead - half green with clear evidence of both species susceptibility and differential spray penetration. Nearly 80% of the bamboo type species were green, about 1/2 of the low palmetto types appeared dead, and nearly all broad-leaved vines and shrubs were killed.

FUEL COMPOSITION:

Fuels in the surveyed area of Target C were heavy by Vietnamese standards. Total available fuels were estimated at 35-40 tons per acre. The understory vegetation averaged about 15 ft. in height and consisted of a mixture of palmetto types, bamboo types, broadleaved vines and tree seedlings. The middle canopy averaged 30-50 ft. in height and consisted almost

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entirely of broadleaved tree species, mostly suppressed or shade tolerant types with large, thick leaves. The upper canopy was 80-120 ft. high. Since most of the upper canopy was defoliated, species identification was difficult. Judging from the leaf litter on the ground, the predominant species had small, thin leaves similar to ash or poplar.

The litter layer averaged 3/4 inch to 1-1/2 inches in depth. About 2/3 of the litter appeared to have come from the defoliated upper canopy. Horizontal distribution of litter was uniform. There were no barriers to fire spread with the exception of puddles of standing water in areas of poorest drainage.

Vertical continuity was also good. Although the vines and suppressed seedlings alone did not have sufficient fine fuels to carry fire into the middle story crowns, about 1/4 of the forested area had sufficient additional fuel in dead brush and bamboo types to initiate crowning in the middle canopy.

FIRE BEHAVIOR:

Essentially nil. Free burning spread outside the immediate vicinity of incendiary sets was confined to open grassy areas of good drainage such as the Dong Bo abandoned landing strip, and the road banks on highway 323. In the area surveyed by the evaluation team, it was a rare fire that spread more than 2 feet from the parent ignition source, and many spread only a few inches. The only fires still burning on Thursday morning were in dead stumps, snags, and limb crotches where dry wood had been sheltered from the rain. In no observed instance was aerial vegetation ignited by fire in ground fuels. Fires in standing trees had evidently started from direct contact with incendiary material.

These observations indicate that litter fuels were at or above their fiber saturation moisture content at the time of the strike (1410-1450 Jan. 18). Either rain had fallen in the morning of the 18th, or drying conditions were insufficient to remove the water absorbed from dew or ground fog during the night.

In summary, Target C was just too wet to burn on the afternoon of Jan. 18.

Craig Chandler
U. S. Forest Service

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APPENDIX II-B

**Post Strike Evaluation Report PINK ROSE Target Area A
29 January, 1967**

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OPERATION PINK ROSE

Post Strike Evaluation of Target A

From 1030 to 1230 on Sunday, January 29, 1967, a post strike evaluation was made of the effects of the Jan. 28 incendiary raid on Target A. Landing could not be effected in either of the two potential LZ sites due to intense ground fire and the lead pilots estimate that both sites were booby-trapped. Consequently, evaluation was limited to low level aerial sweeps over the target. No information was obtainable on ordnance effectiveness, but special note was made of defoliation effectiveness, fuel composition, and fire behavior.

DEFOLIATION:

Measured by color change, about 70% of the forested area had been completely killed by double spraying. Ten percent of the area had up to 25% green leaves mixed with the brown, and 20% of the area had from 25-50% green leaves. The "greener" areas were all in locations with double canopy, and were concentrated in fairly large blocks of 2-5000 acres. Not all double canopy showed green; in fact, most double canopy appeared completely dead at all levels. Riparian sites with palm type understories seemed exceptionally susceptible to chemical treatment.

In summary, desiccation efforts on Target A were effective, so far as could be determined from aerial inspection.

FUEL COMPOSITION:

Fuels in Target A were slightly lighter than the average for Vietnam. Estimated weights of potentially available fuel were 4-5 tons per acre in the grassy clearings, 10-15 tons per acre in single canopy sites, and 20-25 tons per acre in double canopy sites. (It should be noted that aerial estimates of fuel weight are not too reliable.)

Species composition could not be determined from the air, except for the fact that palm type understories were confined to streambank and marshy sites. Overstory composition was probably different between single and double canopy sites, since trees on single canopy sites had lost virtually all of their leaves, while upper story trees on double canopy sites retained appreciable foliage, probably more than half.

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Vertical continuity could not be readily determined, but appeared to be adequate to support crown fires in most double canopy sites. Crown fires could not be expected in single canopy sites because of the excessive loss of crown foliage.

In summary, at least one third of the area had sufficient fuel, brown and arranged so that, from close aerial inspection, it should have supported crown fires.

FIRE BEHAVIOR:

Only in the grassy clearings did fires spread well. Flame heights in the clearings reached 10-15 feet. Chemical treatment had no apparent effect on these clearing fires which burned identically to "farmer" burns of similar clearings in untreated areas under similar weather conditions.

Many downed logs and snags burned fast, hot, and completely, leaving residues of white ash (a sign of good environmental conditions). Even the trunks of some trees uprooted by the December, 1966 B-52 strike burned to white ash, showing a higher rate of drying in heavy fuels than anticipated.

Under single canopy, fires spread in ground litter for about 15 feet on each side of the incendiary set before dying out. Under double canopy, ground litter fires spread only about 6 feet on either side of the parent ignition source.

Approximately 75% of the area in clearings burned over, while only about 9-12% of the ground area under single canopy and about 3-5% of the ground area under double canopy burned. The extent to which these fires removed underbrush could not be determined from the air. Crown canopy removal was definitely negligible.

The incendiary strike on Target A can be considered as a definitive test of the operational feasibility of removing crown cover by fire in Vietnamese forests. The target was selected as being better than average in vertical continuity. The area was double sprayed with herbicides with visually satisfactory results. The weather was as nearly optimum for burning as can be reasonably expected in Vietnam. Incendiary spacing was adequate to produce reinforcing fires. But even under this favorable combination of circumstances, it was impossible to reduce the overall fuel moisture content sufficiently to produce a crown fire.

Craig Chandler
U. S. Forest Service

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APPENDIX III

Memorandum: Dr. W. G. McMillan to Gen. W. C. Westmoreland
12 February, 1967

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**HEADQUARTERS
UNITED STATES MILITARY ASSISTANCE COMMAND, VIETNAM
APO San Francisco 96222
Office of the Science Advisor**

MACSA

**TO: General W. C. Westmoreland, COMUSMACV
FROM: W. G. McMillan, MACSA
RE: PINK ROSE Incendiary Tests**

		<u>CONTENT</u>			
<u>Section</u>	<u>Page</u>	<u>Section</u>	<u>Page</u>		
1. Purpose	110	5. Outstanding Technical Questions	116		
2. Background	110	6. Ancillary Military Effects	117		
3. Principal Technical Results	112	7. Conclusions and Recommendations	118		
4. Theoretical Orientation	114				

* * * *

1. Purpose

This note constitutes a preliminary and informal summary of the results of the two PINK ROSE tests so far conducted under ARPA Project EMOTE, and discusses the advisability of continuing with the projected third and final test. Although the opinions expressed here are mine, I have had the benefit of extensive conversations with Colonel C. E. Hammett (MACSA), Lt. Colonel K. A. Davidson (7° AF), Major H. M. Rosenthal (ARPA-RDFU-V), and Messrs. C. Chandler and Hirsch (US Forest Service).

2. Background

As shown in Table 1 below, there have been altogether four attempts to produce large-scale fires in the jungle areas of South Vietnam.

TABLE 1. INCENDIARY OPERATIONS IN SOUTH VIETNAM

Test	Date	Location			Area (km ²)	#A/C	Ordnance			
		Province	Target	Coords			Diesel Oil (Metric T)	Napalm (Metric T)	#M-35 Clusters	
SHERWOOD FOREST	31. III. 65	Tay Ninh	Boi Loi Woods	XT5035	154	29 A1E 24 C123	8 B57	96	2.0	64
HOT TIP	11. III. 66	Pleiku	Chu Pong Mountain	YA8900	14	13 B52	-	-	0.25	255
PINK ROSE I	18. I. 67	Long Khanh	War Zone D (Target C)	YT3744	49	30 B52	-	-	-	1260
PINK ROSE II	28. I. 67	Tay Ninh	War Zone C (Target A)	XT5580	49	30 B52	-	-	-	1260

PINK ROSE III	20. II-67?	Tay Ninh	War Zone C (Target B)	XT1178	vi	30 B52	-	-	-	1260

Based on the information gained from SHERWOOD FOREST and HOT TIP, an attempt was made to design the PINK ROSE series to optimize defoliation and choice of weather conditions. Accordingly, three areas (Targets A, B & C) 7x7 km were defoliated during fall 1966. Targets C and A were struck in January, with each of 30 B-52's dropping 42 M-35 incendiary cluster bombs fuzed to scatter their 57 M-74 incendiaries at ~1km altitude. Each M-74 incendiary consists of a nose-fuzed thermite stick surrounded by a cylinder containing 1.25kg of PT1 jellied hydrocarbon which is ejected rearward into a band perhaps 0.5m wide and ~3m long, depending on angle of incidence. With the seeding density of incendiaries used, a regular distribution on a square lattice would have yielded a spacing of 26m between ignition points.

Meteorological conditions for the tests are given in Table 2.

TABLE 2. METEOROLOGICAL TEST CONDITIONS

<u>Test</u>	<u>Time</u>	<u># Days Since Rain</u>	<u>Temp (°F)</u>	<u>RH (%)</u>	<u>WIND (kt)</u>	<u>CLOUD Cover</u>
SHERWOOD FOREST	1600	0	74	72	2	10/10
HOT TIP	1400	9	94	45	10	2/10
PINK ROSE I	1400	15	84	65	0	0/10 (w. mist)
PINK ROSE II	1400	5	92	52	0	2/10

3. Principal Technical Results

The results of the four tests are summarized in Table 3.

TABLE 3. INCENDIARY TEST RESULTS

<u>Test</u>	<u>Smoke</u>	<u>Cloud Rise (km)</u>	<u>IR</u>	<u>Post Recce</u>	<u>Guesstimated % Burned</u>			<u>Expls/ Fires</u>
					<u>Grassland</u>	<u>Forest Floor</u>	<u>Crown</u>	
SHERWOOD FOREST	dense	2.5	--	aerial	5	<1	<1	>5
HOT TIP	v dense	6.5	--	aerial	DNA	30	17	?
PINK ROSE I	dense	1.5	good	ground	50	2	0	>3
PINK ROSE II	v dense	3.0	poor	aerial	75	10	<1	>15

From the meteorological conditions alone -- particularly the number of contiguous prior days without rain -- it is clear in retrospect that only HOT TIP and PINK ROSE II had even a remote chance of producing extensive burning. In fact, ground follow-up the day after PINK ROSE I found the ground actually muddy in some places. Messrs Chandler and Hirsch of the US Forest Service attribute the relative excellence of HOT TIP, especially the crown fire, primarily to the mountainous terrain. That forest fires burn more fiercely on uphill slopes is presumably due to a combination of better heat transfer ahead of the fire, favorable winds, and greater dryness resulting from good drainage.

In the absence of adequate ground post-reconnaissance, several indirect factors must be used to arrive at an estimate of the extent of burn. The height of cloud rise, coupled with information on the local temperature structure of the atmosphere provides an estimate of the total heat liberated. Aerial photography is useful in estimating the extent of grassland and crown fires, but does not yield information on the understory burn when the canopy is unaffected.

The intent of the IR measurements is to determine the spreading rate of the understory fires and to follow the persistence of hot spots, both of which yield information on the fuel condition and fire intensity. Unfortunately the only successful IR measurements were those on PINK ROSE I, for which there was very slight (~15cm) spreading about the ignition points.

It is virtually impossible to convert visual observations on the smoke into anything quantitative. While some fuels give smokes having characteristic colors, the color of wood smoke apparently depends to a considerable extent upon both particle size and moisture content.

The Forest Service representatives have provided the estimates given in Table 4 for vegetation amounts in the several types of South Vietnam jungles.

TABLE 4. TYPICAL FUEL DISTRIBUTIONS IN SOUTH VIETNAM JUNGLES

<u>Jungle type</u>	<u>Understory Fuels (Below 3m)</u>					
	<u>Grass & Leaf Litter</u>		<u>Leaves</u>		<u>Twigs < 1cm Dia.</u>	
	<u>Dry Wt*</u>	<u>@% Water</u>	<u>Dry Wt*</u>	<u>@% Water</u>	<u>Dry Wt*</u>	<u>@% Water</u>
Grassland	10-12	@ 8-11	-----DNA-----			
Single Canopy	7	@ 9-12	4.5 0.5	@ 8-11 @120-150	5 15	@ 40-50 @120-150
Double Canopy	10	@10-13	10 2	@ 9-12 @120-150	6 20	@ 40-50 @120-150
Triple Canopy	15	@12-15	15 15	@ 11-14 @120-150	8 22	@ 40-50 @120-150

*Metric tons per hectare (1 hectare = 0.01 km² = 2.47 acre)

4. Theoretical Orientation

In order to estimate the conditions required for effective jungle burning and to assess whether our test conditions are anywhere close to these, we here examine the various sources and sinks of heat energy for the burning process. A convenient unit of energy in which to express the various heat quantities is the Solar Minute (SM), i. e., the radiant energy received from the sun per minute per unit area (at the equatorial zenith). The magnitude of the SM unit is 0.8×10^{16} erg per hectare, or 0.2 tons HE equivalent per hectare.

Since the energy liberated by burning (dry) wood to completion is approximately 4 times that from the explosion of an equivalent weight of HE, we may express the amount of heat released Q per hectare in terms of the dry weight W (tons/hectare) of fuel burned as*

$$Q = 20 W \text{ (SM)}. \tag{1}$$

If the fuel contains water in weight-fraction f , the heat investment Q_v necessary to vaporize the water would be

$$Q_v = 3.0 Wf \text{ (SM)}. \tag{2}$$

Since the wood won't burn at the boiling point of water (100°C) we must invest enough additional heat Q_p to bring the fuel to the ignition point, which I estimate to be 300°C . This additional heat investment is

$$Q_p = 1.0 W \text{ (SM)}. \tag{3}$$

Finally we need to include the heat of combustion q (per hectare) of the incendiary ordnance itself.

Combining the heat generated by the burning vegetation and ordnance fuel, and assigning a heat transfer efficiency η for the process of drying out and bringing the vegetation ahead of the fire to the ignition point, the excess heat is simply

$$\text{excess heat} = \left[\eta (20 + q/W) - (3.0f + 1.0) \right] W. \tag{4}$$

* Parenthetically, one might well ask why a forest fire has so much more destructive effect than say 20 W minutes of sunshine. The reason is that the heat fueling the fire at the burning front is greatly concentrated in both space and time, leading to a temperature high enough to propagate.

A large positive excess heat should lead to good burning, while a small or negative excess will give very little area burned outside that actually splattered by the ordnance fuel.

For the 72,000 M-74 incendiaries in the 49 km² of PINK ROSE I or II, the heat contribution q of the ordnance is readily calculated to be

$$q = 0.9 \text{ (SM)}. \quad (5)$$

Since to represent a significant burn W must be greater than ~ 1 (metric ton/hectare), q/W is negligibly small in comparison with the additive 20 in Eq. (4).

The heat transfer efficiency η is very hard to estimate, since it depends sensitively upon the geometry of the fuel (e. g., logs lying in contact with tinder are more easily ignited). However, we may turn the question around by estimating what value of the heat transfer efficiency would be necessary to give zero excess heat, and see if that value appears feasible of achievement. Setting the excess heat in the above equation equal to zero and solving for the efficiency, we obtain

$$\eta = (3.0f + 1.0)/20 = 0.15f + 0.05. \quad (6)$$

Thus, for a moisture content $f = 0.1$ (i. e., 10%), $\eta \sim 7\%$; while for $f = 1.0$ $\eta \sim 20\%$.

We know from the existence of forest fires in western US that the efficiencies $\sim 5-10\%$ predicted by Eq. (6) to be required for burning dry dense vegetation containing only 10-20% moisture are indeed achievable. Even greater efficiencies are possible on mountain slopes under favorable meteorological and geometrical conditions. But the likelihood of achieving anything approaching the necessary 20% or greater efficiency in the flat, moist jungles of South Vietnam seems very small.

It should be emphasized that the above calculation is for orientation purposes only, and glosses over such important points as the fuel distribution, the variable moisture content, the poor contact of the understory fuels with the standing trees and canopy, and the critical question of the rate of the burning process as opposed to the thermodynamic admissibility, which is all this calculation addresses.

5. Outstanding Technical Questions

With the possible availability of one last test of the PINK ROSE series, we may ask what technical questions remain unanswered and what test parameters might be altered to make operational effectiveness more likely.

a) Meteorology - Several days, perhaps preferably even two weeks, of dry hot weather should precede the test. In III CTZ the weather for late February or early March is probably as good for this purpose as we are likely to get.

b) Time of Day - In examining whether 1400 hours is the best delivery time we considered the possibility that the late-afternoon beginning of the nocturnal inversion might enhance the fire by holding the heat closer to the ground. However, prevailing opinion, based upon the observation that forest fires subside appreciably at night, is that any such inversion enhancement would be more than compensated by the greater moisture absorbed as the afternoon temperature declines.

c) Ordnance Density - While it is clear from the calculation of the previous section that a tremendous increase in ordnance density would be required to make any substantial contribution to the overall heat liberated, an increase of the density of ignition points might cause the ignited areas to run together and, through the mutual reinforcement resulting from the quicker burn, promote more efficient heat-transfer and drying of the overstory fuels.

d) Ordnance Delivery Sequence - The observation that smoking wood fires can, under certain conditions, be made to burst into flames by application of a match to the smoke leads to the question whether it might prove effective to withhold some of the incendiaries, dropping them into the smoking regions perhaps 20 minutes after the first seeding. Our consensus is that this probably wouldn't cause any reduction in total burn, and might increase it.

e) Effect of Terrain - While there is little doubt that SHERWOOD FOREST and PINK ROSE I were not even close to being marginally successful, the firing of Target B under weather conditions similar to those of HOT TIP would permit a comparison of flatland vs mountain jungle burning.

In summary, while there are some technical questions that the firing of Target B might help answer, it cannot be argued at this stage that these answers are likely to hold any

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promise for the development of an operationally effective method of jungle burning in South Vietnam. Against this pessimistic view we might note, however, that these operations have been quite successful in burning elephant grass and even in burning a substantial portion of the jungle in the mountainous Chu Pong HOT TIP test.

6. Ancillary Military Effects

In our disappointment over not being able to produce on call a spectacular jungle firestorm there is danger of overlooking the not inconsiderable military effects (cf. Table 3) which these incendiary raids have produced, effects which may rival those of the average B-52 bombing attack. The most significant military factors appear to be the following.

a) **Secondaries** - If several hot, dry days have preceded the strike, the jungle floor leaf litter and understory fuels should be dry enough to cause appreciable spread of fires from the ignition points. Under these circumstances it appears likely that inflammable surface structures and materiel would be ignited and damaged if not destroyed. Indeed, numerous secondaries have been observed. While such materiel is also vulnerable to GP bombs, we note that the area covered in PINK ROSE I or II, 49 km^2 , is per aircraft ~ 5 times that of the standard B-52 strike.

b) **Smoke** - While the smoke generated, even in the poor PINK ROSE I event, appeared very dense, experienced forest firefighters believe that trained personnel would have no difficulty surviving. Untrained personnel, on the other hand, might panic and be overcome or even burned. It is not known whether the hostile rifle fire encountered by the post-reconnaissance helicopter party on attempting to land in the PINK ROSE II LZ came from survivors or from outside enemy reconnaissance units.

c) **Psychological** - There may be a psychological factor in adding incendiaries to all the other weapons systems the enemy has to suffer. He might well ask himself: "Good grief! What next?" The psychological effect would, of course, be greater if some of the enemy were actually killed or injured, which stresses the importance of trying to get some feedback from captives or Chieu Hoi's who may have experienced or witnessed these events. One rumor we haven't been able to pin down has it that some 200 VC were killed by fire on Chu Pong Mountain, representing about 10% of the total enemy strength believed to be located there--roughly the same percentage as the area burned.

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7. Conclusions and Recommendations

a) We foresee no real prospect of deriving a practical method of achieving jungle burning of military consequence in South Vietnam, at least in the humid flatlands.

b) In the drier, higher plateaus and mountains, jungle burning might be made effective under ideal weather conditions which, however, would seriously restrict the season and operational flexibility.

c) Even in the flatlands the elephant grasslands have been demonstrated to burn efficiently.

d) The favorable combination of high, dry and defoliated mountainous terrain in the western DMZ and panhandle might make it worthwhile to consider burning as an aid in impeding infiltration and in clearing for better observation.

e) We have examined the possibility of substituting for Target B in PINK ROSE III some other area of military importance that is both mountainous and already defoliated, but have found no such area in South Vietnam for which there is likelihood of suitably hot and dry weather in the next few months.

With respect to the advisability of firing PINK ROSE III in the Target B area,

i) While there are some interesting technical data (e. g., the extent of burn, size of twigs burned, rate of spread, etc.) which PINK ROSE III would help nail down, we cannot argue that these data are critical to our understanding.

ii) Nevertheless, upon adding to the desired technical data the not inconsiderable potential ancillary military effects, I am moved to recommend proceeding with PINK ROSE III, provided this does not interfere seriously with other demands for the B-52 resources.

iii) Assuming that the decision is reached to stage PINK ROSE III, I concur in the recommendation of the 7^o AF to reduce the area to one-third of the originally planned 7x7 km target, without reducing the number of aircraft, in order to increase the density of ignition points.

iv) I concur also in the firing date of 20 February nominated by combined ARPA/7^o AF PINK ROSE Planning Group, subject, of course, to continuing fair weather.

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v) Finally, it is essential to have detailed post-ground reconnaissance if we are to obtain the technical data desired.

W. G. McMillan

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APPENDIX IV

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-----FULL TRANSLATION-----

14-00000-67

EASTERN NAM BO LIBERATION ARMY
CÁ BIÊN BÀ RIA AND BIÊN HÒA PROVINCE UNIT No. 30/TB

CIRCULAR

On 17 and 28 January 1967, the enemy B52 bombers dropped incendiary bombs in the vicinity of war zone D to set fire to the forests in Suối Bang area.

This type of bomb was contained in boxes of 32 each. The bomb, itself resembles the container of a 57mm recoilless rifle shell. When dropped, the boxes opened and released the bombs. Some pierced the soil as deep as 30cm, some lay sideways on the surface of the ground. The bombs exploded and set fire to the forest. The phosphorous burned for about 60 seconds, igniting tree leaves, especially dry tree leaves, because prior to the bombing the enemy sprayed defoliants on the target areas.

At first the bombs produced white smoke which turned black after the forests caught fire. Some small bombs did not explode until five minutes after they came into contact with the ground.

These bombs will cause insignificant casualties but some burns and damage to equipment (if precautionary measures are not taken).

Precautionary Measures

- The area around trenches must be clear of dry tree leaves for 1 to 2 meters (uncovered trenches must be camouflaged with green tree branches).

- Trenches must be provided with covers. In the trenches there must be cans of loose dirt, sand or ash to put out the fire (if the fire spreads into the trenches) or cloth mats, gunny sacks, etc... may be used (better when soaked in water) to cover the entrances of the trenches.

- Documents, equipment, food and other items must be properly kept in trenches provided with covers.

Upon receipt of this circular various addressees will expeditiously disseminate it to take precautionary measures in time to foil the enemy attempt and preserve our forces.

True copy No.

/S/

9 March 1967

Distribution:

14 Village, agencies, units, District Party
Committee Security Section and District Unit.

For the Province Unit
Headquarters Chief of Staff,
/S/ HÃ VĂN THUẬN

19 March 1967

For the District Unit Headquarters clerk.

NG MINH HOÀNG.

-----END OF TRANSLATION-----

KIN

(Document captured 27 March 1967, 15 km. NE of Vung Tau.)

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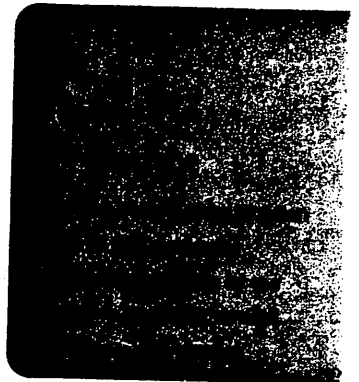
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CLIMATOLOGICAL AND METEOROLOGICAL ANALYSIS

FOR

OPERATION PINK ROSE (U)

by

CLYDE A. O'DELL
ESSA Weather Bureau

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JAN 12 1982

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Remote Area Conflict
ARPA Order No. 818

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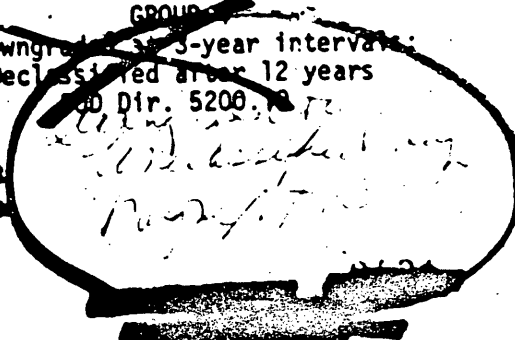
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CLIMATOLOGICAL AND METEOROLOGICAL ANALYSIS

FOR

OPERATION PINK ROSE (U)

by

**CLYDE A. O'DELL
ESSA Weather Bureau**

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Sponsored by

Advanced Research Projects Agency

Remote Area Conflict

ARPA Order No. 818

*Transmitted to
by Douglas/T...*

**1968 Pacific Southwest Forest and Range Experiment Station
P. O. Box 5007, Riverside, California 92507
Forest Service - U. S. Department of Agriculture**

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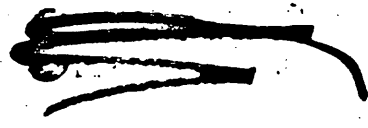
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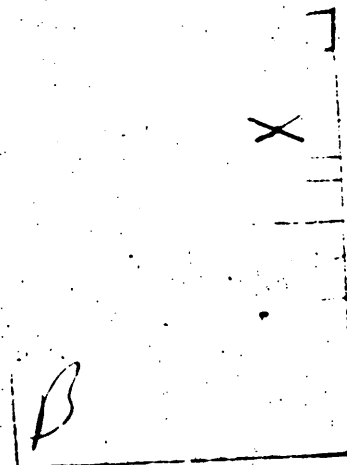
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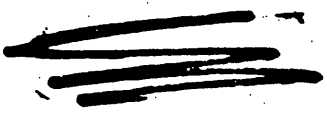


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ACKNOWLEDGMENT

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SUMMARY

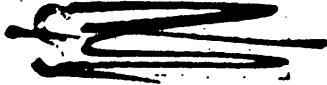
This report is limited essentially to an analysis of climatological and meteorological data related to Operation Pink Rose, conducted in early 1967.

A great deal of information is readily available on the general climate of Southeast Asia, particularly the southwest monsoon season and the synoptic causes of it. We were more interested in the dry-season (October-April) climate commonly referred to as the northeast monsoon. Little information on this subject is available in analyzed form although a great deal of raw meteorological data are becoming available primarily due to the increased political activity in the area.

The Siberian High dominates the Southeast Asian climate. The seasonal north-south movement of the Intertropical Convergence Zone (ICZ) controls large scale flow regimes. Together, the Siberian High and the ICZ are responsible for the wet and dry seasons and their intermediate transition periods. The southwest monsoon season is much too wet to conduct burning experiments in nearly all of Southeast Asia. The dry season is interrupted often with convectively produced shower activity, but at times limited burning operations may be conducted.

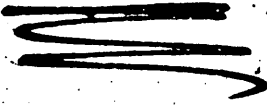
Tables of statistical probabilities (see Appendix 4) have been calculated to aid in planning burning operations. In two attempts to arrive at meaningful probabilities we have succeeded in bracketing what we feel are important parameters in conducting burning operations.

The factors most critical to successful burning are the condition and arrangement of fuel and the environment within which it must burn.



Sufficient drying after specified amounts of rain will produce burnable fuels. The proper environment is one in which air temperatures are high and relative humidities are low. The atmospheric lapse rate should be unstable such that a fire-produced convection column can readily form to heights of 30,000 feet or more. Such an atmosphere is difficult but not impossible to come by in Southeast Asia, specifically South Vietnam. Perhaps, equally difficult is fuel conditioning in an environment not particularly suited to drying. It has long been recognized that wind is a major factor in evaporation and drying. Dense tropical growth may have sufficient wind velocities over the canopy to adequately dry crown fuels, but flow is light near the ground and low-growth fuels and, subsequently, drying is poor even though temperatures are quite warm.

Meteorological aspects of three burning experiments are discussed in some detail. The first experiment was a failure due primarily to poor fuel conditioning. The second and third experiments were moderately successful.



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THE SYNOPTIC CLIMATOLOGY OF SOUTHEAST ASIA

The climate of Southeast Asia is dominated by the semi-permanent Siberian High and controlled by the seasonal migration of the Inter-tropical Convergence Zone (ICZ). Two primary flow systems in the lower troposphere, the southwest monsoon and the northeast monsoon, together with the transition periods between them are responsible for a wet season and a dry season.

NORTHEAST AND SOUTHWEST MONSOON

The fundamental cause of the Indo-Asiatic monsoon wind system is differential heating (or cooling) of land areas, as compared with surrounding ocean regions. In winter, with the deficit of solar radiation in northern latitudes, the land surfaces and the overlying air become colder than the sea surface temperatures over the surrounding Pacific and Indian Oceans. This tropospheric temperature difference aids in the formation of the large, cold semi-permanent Siberian high pressure area which covers all of the Asian mainland. The clockwise low-level flow of air around this high pressure area results in a general north-east wind regime (northeast monsoon) over Southeast Asia.

During the summer period the Asian continent is warmer than the surrounding oceans. The resultant temperature difference aids in forming a large, semi-permanent low pressure area over northern Southeast Asia and south of the Tibetan Plateau. The counter-clockwise circulation around this low pressure system results in southwest winds over much of Southeast Asia. These winds are known as the southwest monsoon.

The transition from the southwest monsoon to the northeast monsoon takes place, at the earliest, around the latter part of September. Unfortunately, onset dates of the northeast monsoon have not been

established for individual years. -

The northeast monsoon period (October-April) is generally characterized by long rainless periods interspersed with relatively short rainy periods. For example, during January and February the majority of weather stations in Southeast Asia have only, on the average, 1-5 days with rain above a trace. However, the topography of the area has an important effect on the spatial rainfall patterns with certain local coastal areas receiving significant amounts of rainfall during the normally dry period.

During winter, surges of the monsoon alternate with lulls. Surges of the northeast monsoon are associated with deepening cyclones within the strongly frontogenetic China and Japan seas. Cyclogenesis accelerates the northerly flow west of the cyclone center and causes a "surge". As the cyclone passes away to the east, the monsoon gradually weakens until the next depression develops. A monsoon surge reaches the tropics as an east-northeast wind and, as the colder air moves across the much warmer seas, convection clouds rapidly form. Precipitation may result, especially along exposed coastal regions of Southeast Asia (e.g., north-central coast of Vietnam).

Lulls between surges occur when the continental anticyclone, or a cell which splits off from it, moves eastward. Winds south of the high pressure center veer, convection clouds over the warm seas decrease and cooling along the coast may produce stratiform clouds. Little change occurs in short lulls but when they are prolonged, high pressure over China may break down altogether and a ridge from the Pacific anticyclone extends across the area and onto the mainland. These conditions may eventually lead to the development of "crachin" along the northern coastal regions of Vietnam.



SUB-TROPICAL JET STREAM

During the transitional period between the southwest monsoon and northeast monsoon a significant change occurs in the upper-level flow over south China and southeast Asia. Perhaps, the most significant feature is the establishment of the sub-tropical jet stream along the southern edge of the Himalayas. Its onset is abrupt, first becoming evident over northwest India in late September or early October, and then advancing downstream at about 3 deg. longitude per day. Once the jet stream is established south of the Himalayas its position remains almost stationary throughout the dry season (Yeh 1950).

Over the southeast Asia region, subsidence is both more intense and confined than over North America. Widespread subsidence occurs south of the jet stream over northwest India. However, over northeast India and southeast Asia, north of 15N, juxtaposition of jet-stream and convergent upper-level (300-200 mb) southwesterlies of equatorial origin seem to result in much more vigorous subsidence downstream. The excess of air at high levels, which can escape neither north nor south, subsides downstream in a zone, which has rather rigid latitudinal limitation. It has been suggested that the cool-season aridity of Burma, Thailand, and Indo-China results from compensating subsidence and low-level divergence beneath upper convergence. (Ramage 1952).

TERMINATION OF THE DRY PERIOD

A pronounced warming trend over the mainland of southeast Asia and southern China begins in March, April and continues into May. During this time screen temperatures may reach extreme values varying from 100 to 114°F. A general increase in rainfall is also observed.

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The northward advance of the monsoon westerlies (southwest monsoon) begins with this warming trend but the principal advance over southeast Asia occurs in conjunction with tropical cyclogenesis in the Bay of Bengal. The mean calendar date of the onset of the southwest monsoon has been established around 17 May with an approximate range of 33 days.

The onset of the southwest monsoon ushers in the summer period of disturbed weather in which thunderstorms and squall-lines become more frequent over the south Asia regions. An inspection of daily single-station rainfall amounts for stations in Burma, Thailand, and the windward side of Vietnam show general increases in the frequency and amount of rainfall.

During the period of the onset of the southwest monsoon another abrupt change occurs in the large-scale circulation features. The sub-tropical jet stream south of the Himalayas weakens and eventually disappears, the polar westerlies shift northward in conjunction with the sub-tropical ridge and eventually the upper-level winds (300-200 mb) shift to easterly directions over all of southeast Asia.

SYNOPTIC SCALE WEATHER SYSTEMS WITHIN THE COOL SEASON

1. Crachin

The "crachin" of the coastal regions of northern Indo-China and south China is a humid period of fogs and drizzle or light rain which sets in at about the time of the normal annual temperature minimum, generally toward the end of January, and interrupts the dry season. The crachin may persist into mid-April, gradually merging with the rains of the rainy season proper. Though there may be prolonged precipitation, the amounts recorded are small.

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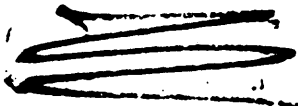
It has been suggested that crachin may develop in two ways: (1) as the result of mixing of two nearly saturated air masses along a frontal surface, and (2) by surface cooling of a warm moist air mass. The latter is almost always the cause of the worst and most persistent crachin.

The trend in monsoon surges and lulls is toward an increasing number of easterly surges, increasingly long lulls between surges and more persistent crachin, as the dry season advances. Turbulence, topography, diurnal heating, and dew point/sea temperature difference, all play important parts in determining when and where crachin will develop and what form it will take. The interrelation of these factors along the coast may be extremely complex.

Since the vigorous crachin usually occurs in the cooler trough region west of the surface high, it is associated with local winds veering with height. Surges of the northeast monsoon may be important crachin modifiers. However, from February onward even moderate surges may not dissipate crachin for the air behind the front can still be undergoing surface cooling along the coast.

2. Tropical Trough

"Tropical trough" is a name given to an upper-level disturbance which appears around mid-January over southern India at and above 30,000 feet. The trough, moving eastward, sharply interrupts the prevailing upper tropospheric southwesterlies. The lower troposphere is little affected until the trough reaches the Andamans but from there on it intensifies and colder air moves in from the north.




Once over Thailand or Indo-China, a tropical trough may remain stationary for a week or more. The reason for this may lie in the long-wave pattern of the low latitude polar westerlies.

The first sign of the eventual dissipation of the tropical trough comes with reappearance of the upper southwesterlies over southern India. Spreading northeast, they reestablish with the low-latitude polar westerlies, creating the normal pattern of high-level convergence in the region of the tropical trough. The trough weakens or dissipates in situ, although it may sometimes move eastward if the low-latitude portion of an Asia Minor trough has already started to move eastward. The sub-tropical ridge moves north to its usual latitude, and weather returns to normal winter conditions.

The "tropical trough" occurs from three to six times in a cool season, but has not been observed to develop much before mid-January. From there on, it is increasingly common, being the major rain producer for the dry belt during March and April. The monthly variation in occurrence probably results from increasingly frequent breakdown in the upper southerlies to the south and west of India as the season advances. The reason for this is not known.

3. West China Trough

In winter the major Far Eastern long wave mid-latitude westerly trough lies along about 125°E . Surface cyclones usually develop east of this longitude. However, a few times (rarely more than four) every cool season the trough along 125°E dissipates or moves rapidly eastward. A warm ridge extends westward from the Pacific anticyclone bringing fine weather to China



and sea fog to the China coast. The Siberian anti-cyclone retreats northward and westward over south China with dew point and temperature rises, and pressure falls. At this state, a trough in the westerlies moving east from India will intensify over west China. This results in the region of surface cyclogenesis being displaced about 20 degrees westward.

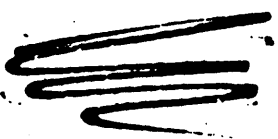
Occasionally, a west China trough situation lasts from ten to twenty days. However, when the trough finally moves eastward to its normal position the continental anticyclone is restored to its usual position. Toward the end of April this situation ceases to be of significance.

The west China trough situation is usually favorable for "crachin" development but further research is necessary to establish the effect of this situation on the weather of southeast Asia.

4. Tropical Cyclones and Easterly Waves

In most parts of the world, during winter, the sub-tropical ridge slopes equatorward with height and usually reaches to within 10 to 12 degrees latitude of the equator in the high troposphere. Over southeast Asia and the Philippines, however, the ridge axis above 700 mb is almost vertical and is found between 15 and 17°N.

South of the ridge, in the region of deep easterly flow, disturbances typical of summer continue to be observed. Tropical storms or typhoons may persist there for several days, usually dissipating when a strong northeast monsoon surge feeds cold, dry surface air into the circulation.



Waves in the easterlies are not uncommon. They propagate slowly westward, with low-level divergence and fine weather ahead, and low-level convergence and precipitation behind.

Tropical cyclones develop in the southeast Asia waters (China Sea and Bay of Bengal) any time of the year but are more frequent during the transition periods (September-November; April-May) and during the southwest monsoon (May-September).

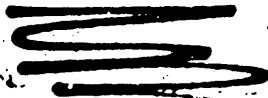
The rainfall in Indo-China and Thailand during the fall transition period (September-November) is due primarily to tropical cyclones moving from the sea to the land. During this period, especially south of 30°N , the situation is one of ebb and flow between the northeast monsoon and typhoons; the latter dominate at first, but by January only feeble storms or weak easterly waves penetrate west of 125°E .

Easterly waves are relatively more common than tropical cyclones in mid-winter, but they seldom produce rain in the region of extremely shallow low-level easterlies north of the sub-tropical ridge aloft.

Occasionally, the superposition of a wave in the easterlies on a trough in the polar westerlies may result in mutual intensification and general rainy conditions. However, the frequency of this type of situation is unknown.

Tropical cyclogenesis in the Bay of Bengal and to a lesser extent in the China Sea precedes or coincides with the onset of the southwest monsoon.

A large number of tropical cyclones that develop in the Bay of Bengal during May often track to the northern sections of the Bay or into Burma. These storms with a northward track are often accompanied with deepening monsoon westerlies in their right-hand sectors. It is these westerlies



which usher in the southwest monsoon over southeast Asia and terminate the prolonged winter dry period.

MESOSCALE WEATHER SYSTEMS

The predominate mesoscale weather system is the thunderstorm or squall line. During the dry season conventional surface heating aided by orographic influences provide the possible trigger mechanism for such storms. However, certain synoptic disturbances which augment the low-level convergence, e.g., "tropical trough", easterly waves or tropical cyclones may increase thunderstorm or squall-line development.

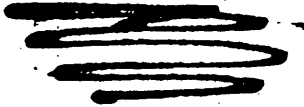
Generally speaking, good observational data for mesoscale weather systems are lacking for southeast Asia.

LOCAL EFFECTS

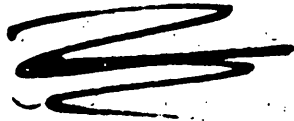
Many of the local effects on meteorological elements are produced by topography. Meteorological observations are usually lacking in the mountainous regions. Therefore, it is not too surprising to find little written on the subject except perhaps in the broad-scale sense.

Examination of mean monthly rainfall charts for southeast Asia indicate in general terms the influence of the topography. During the southwest monsoon, rain shadow regions can be observed in the Irrawaddy Basin of Burma, the central Valley in Thailand, and to a certain extent on the leeward side of the Chaine des Cardamomes in Cambodia.

Geographic enhancement of rainfall can be observed on the windward sides of the Arakan Yoma and Bilauk Taung in Burma, Trengganu Highlands of Malaya, Chaine des Cardamomes of Cambodia and Chaine Annamitique in Vietnam and Laos.



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During the winter or cool season, rainfall is augmented along the Chaine Annamitique in Vietnam due to the forced ascent of the northeast monsoon. This also occurs along the extreme southern peninsula in Thailand and the Malay peninsula.

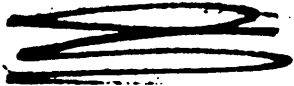
Foehn winds have been noted to occur in certain regions of Indo-China. During certain synoptic situations a warm, dry wind descends from the Western Highlands of Laos causing very uncomfortable conditions along the north-central coast of Vietnam and possibly in regions of Laos and Thailand. Strong foehn conditions may also be observed on the leeside of the Chaine Annamitique in Vietnam during strong surges in the northeast monsoon.

Along coastal areas land and sea breezes should be expected. However, little information is available on this subject for southeast Asia.

FIRE WEATHER PROBABILITY IN SOUTHEAST ASIA

ASSUMPTIONS AND LIMITATIONS OF THE DATA

Fire Weather Probabilities.--Several stations in southeast Asia for which data in "N-Summary" form were available were used as a basis for computing the probability of target readiness for Project Emote operations (Appendix 4). The format illustrated in Table 1 is similar to that used in an earlier report (Forest Fire Research Final Report, Phase 1, Volume 2) with some significant changes. First, the basis for the input data has been changed in light of the new requirements for accumulating drying days. After a light rain (≤ 0.2 inch), 1 drying day must occur before target readiness is achieved. After a heavy rain ($> .2$ inch), 3 drying days



ENCLOSURE

INPUT DATA 0.015 0.031 0.105 0.437 0.412

PROBABILITY THAT AT LEAST ONE SITE BECOMES READY IF ALL SITES RECEIVE A HEAVY RAIN THE DAY BEFORE THE WEATHER MATCH BEGINS

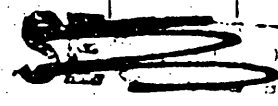
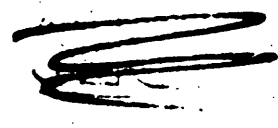
DAYS SINCE WEATHER MATCH BEGAN	NUMBER OF SITES INCLUDED IN WEATHER MATCH									
	1	2	3	4	5	6	7	8	9	10
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.070	0.135	0.195	0.252	0.304	0.353	0.398	0.440	0.479	0.516
4	0.386	0.623	0.768	0.858	0.913	0.946	0.967	0.980	0.988	0.992
5	0.684	0.900	0.968	0.990	0.997	0.999	1.000	1.000	1.000	1.000
6	0.850	0.978	0.997	0.999	1.000	1.000	1.000	1.000	1.000	1.000
7	0.926	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	0.961	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
9	0.978	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	0.988	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
12	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
13	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
14	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

PROBABILITY THAT AT LEAST ONE SITE BECOMES READY IF ALL SITES RECEIVE A LIGHT RAIN THE DAY BEFORE THE WEATHER MATCH BEGINS

DAYS SINCE WEATHER MATCH BEGAN	NUMBER OF SITES INCLUDED IN WEATHER MATCH									
	1	2	3	4	5	6	7	8	9	10
1	0.412	0.654	0.797	0.880	0.930	0.959	0.976	0.986	0.992	0.995
2	0.839	0.974	0.976	0.999	1.000	1.000	1.000	1.000	1.000	1.000
3	0.942	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
4	0.967	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	0.978	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6	0.987	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
7	0.993	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
9	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
12	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
13	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
14	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

PROBABILITY THAT A RANDOMLY CHOSEN SITE IS READY = 0.000

TABLE 1. FORMAT OF STATISTICAL TABLES OF PROBABILITY OF TARGET READINESS.



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must be accumulated. A drying day is defined as one in which fuel-moisture content will decrease, finally down to equilibrium level. Specifications for a drying day are:

1. No rain has fallen in the preceding 24 hours.
2. Minimum relative humidity drops below 70 percent.
3. Afternoon cloud cover is less than 3/8.

A second difference is that column XX in Fig. 12 of the Phase 1, Volume 2 report has been expanded (see Table 1) to include more than one site after a heavy rain.

There are five input probabilities for each station for each month. Referring again to Table 1, note these probabilities are as follows:

$0.015 = P_H$ = probability of a heavy rain within a day

$0.031 = P_L$ = probability of a light rain within a day

$0.105 = P_a$ = probability of an overcast day

$0.437 = P_b$ = probability of a half-overcast day

$0.412 = P_c$ = probability of a clear day.

P_H and P_L were determined from "N-Summary #3" data which are precipitation amounts grouped in classes and mean number of days/class on a monthly basis. For our purposes > 0.004 inch was defined as a rainy day and this data together with the class $> .39$ inch and $> .99$ inch were plotted on semi-log paper and an interpolated value for $> .2$ inch was determined from the graph. This value was the number of heavy rain days. This value subtracted from the total rain days ($> .004$) gave the number of light rain days. Then

$$P_H = \frac{\text{number of heavy rain days}}{\text{number of cases}}$$

$$P_L = \frac{\text{number of light rain days}}{\text{number of cases}}$$

The cloud cover probabilities were determined from "N-Summary 17" for the local time nearest 1400 LST. N-Summary 17 (mean number of days with indicated total and low cloud amounts) groups data by cloud cover classes as 0 - 1/8, 0 - 2/8 ($\leq .25$), 3/8 - 5/8 ($.25 < N < .75$), and 6/8 - 8/8 ($\geq .75$). The interval 0 - 2/8 is defined for our purposes as being clear, 3/8 - 5/8 as being 50 percent cloud cover, and the 6/8 - 8/8 interval as being 100 percent cloud cover. Then

$$P_a = \text{overcast} = \frac{\text{number of days 6/8 - 8/8 cover}}{\text{number of cases}}$$

$$P_b = \text{50 percent cover} = \frac{\text{number of days 3/8 - 5/8 cover}}{\text{number of cases}}$$

$$P_c = \text{clear} = \frac{\text{number of days 0 - 2/8 cover}}{\text{number of cases}}$$

It is realized that these approximations for cloud cover and interpolated rain values leave something to be desired. But it is not unreasonable to assume that for a first approximation, considering the type of data which are available, that the statistics can have meaning in a general sense if used intelligently.

COMPUTATIONS OF FIRE WEATHER PROBABILITIES

1. Single sites

Given:

$$P_H, P_L, P_a, P_b, P_c$$

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Assuming that:

- a. Present weather is independent of past weather.
- b. No drying occurs on rainy or overcast days (zero "drying days").
- c. A half-overcast day is equivalent to one-half "drying day".
- d. A clear day is equivalent to one "drying day".
- e. A fire will burn if 3 or more "drying days" have accumulated since the last heavy rain > 0.2 inch provided that 1 or more "drying days" have accumulated since the last light rain.

What is the probability that at least one "burning day" will occur within an N day weather watch, ($N = 1, 2, \dots, 15$), if

- A. When the weather watch is instituted, 2 "drying days" have accumulated since the last heavy rain?
- B. When the weather watch is instituted, no "drying days" have accumulated since the last heavy rain?

We recognize that a given site on any given day may require 0, 1, 2, 3 "drying days" before being in a suitable condition for burning. Thus a site may be described as being in one of the following states:

<u>State Number</u>	<u>Drying Days Needed</u>	<u>Days Since Heavy Rain</u>	<u>Days Since Light Rain</u>
1	3	0	-
2	$2 \frac{1}{2}$	$\frac{1}{2}$	-
3	2	1	-
4	$1 \frac{1}{2}$	$1 \frac{1}{2}$	-
5	1	2	0
6	$\frac{1}{2}$	$2 \frac{1}{2}$	$\frac{1}{2}$
7	0	3	1
"	"	"	"

The desired probabilities for questions A and B above are then:

- A. The probability that a site now in state 5 arrives in state 7 in no more than N steps.
- B. The probability that a site now in state 1 arrives in state 7 in no more than N steps.

We have assumed that present weather is independent of past weather, which of course it is not. However, the degree of dependence is unknown. As a first approximation we have assumed dependence of present weather on past weather to be small and have formulated the problem as a Markov Chain; that is, the process of drying may be described as a random or stochastic process which moves from state i to state j with probability q'_{ij} where the q'_{ij} depend only on the present state of the process.

The matrix Q' of single step transition probabilities q'_{ij} , in terms of the P_j described earlier are given in Table 2. The probabilities we require for questions A and B can easily be derived from these single step

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TABLE 2 - MATRIX Q' OF SINGLE STEP TRANSITION PROBABILITIES

	Q'							
	1	2	3	4	5	6	7	8
1	HLa	b	c					
2	H	La	b	c				
3	H		La	b	c			
4	H			La	b	c		
5	H				La	b	c	
6	H				L	a	b	c
7	H				L		a	b
8	H				L			a

Where $HLa = P_H + P_L = P_a$;

$H = P_H$;

$La = P_L + P_a$;

$a = P_a$;

$b = P_b$;

$c = P_c$; and

$L = P_L$

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probabilities. We form the matrix Q (see Table 3) from Q' by making state 7 an absorbing state and computing the N step transition matrix $Q^{(N)}$ by raising Q to the N -th power. The desired probability for question A is then $q_{5,7}^{(N)}$ and, for question B, $q_{1,7}^{(N)}$. Both occur in the right most column vector of the matrix. Hence, instead of $Q^{(N)}$ we may compute $Q^{(N-1)}q$ where q is the seventh column of Q . The computations were performed from right to left as:

$$Q(Q(Q(\dots(Qq\dots))))$$

Each multiplication was then a matrix by a column vector; no multiplication of Q by itself was necessary.

2. Multiple Sites

Find the probability that at least one of M sites ($M = 1, 2, \dots, 10$) will experience at least one "burning day" within an N day weather watch ($N = 1, 2, \dots, 15$) if, when the weather watch is instituted, 2 "drying days" have accumulated at each site since the last heavy rain, and also under the assumption that no drying days have accumulated since the last heavy rain.

These probabilities were calculated from the formula:

$$P_{M,N} = 1 - (1 - P_N)^M$$

Where

$P_{M,N}$ = desired probability for M sites and an N day watch.

P_N = single site probability from 1, $(q_{5,7}^{(N)})$ or $(q_{1,7}^{(N)})$

The basic assumption here is that the weather at one site is independent of the weather at any other site, which of course it isn't. This obvious error will be minimized during the drier months when rainfall is essentially of the shower type from air mass rather than frontal systems. Individual rain showers tend to be random in their occurrence

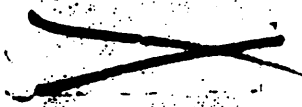


TABLE 3 - MATRIX Q OF N STEP TRANSITION PROBABILITIES

	Q						
	1	2	3	4	5	6	7
1	HLa	b	c				
2	H	La	b	c			
3	H		La	b	c		
4	H			La	b	c	
5	H				La	b	c
6	H				L	a	bc
7	"				"	"	1

Where $HLa = P_H + P_L + P_a$;

$H = P_H$;

$La = P_L + P_a$;

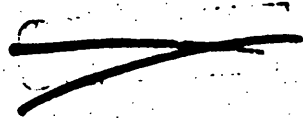
$L = P_L$;

$a = P_a$;

$b = P_b$;

$c = P_c$;

$bc = P_b + P_c$



and in this sense the argument for site independence is presented.

3. Unconditional Probabilities

What is the probability that a random day is a burning day?

For the solution to this problem, we return to the matrix Q' of section 1. The desired probability, U , is the probability that the process is found to be in state 7 or a higher state on a random day.

If the u_i are the probabilities from the stationary distribution of the chain then

$$U = \sum_{i=7}^{\infty} u_i = 1 - \sum_{i=1}^6 u_i$$

The stationary probabilities satisfy the system of equations.

$$u Q' = u$$

where u is a row vector with elements u_i and Q' is the extension of Q .

A stepwise solution of the system for the first ten u_i was obtained

with the following formulae:

$$u_1 = P_H / (1 - P_a - P_L)$$

$$u_2 = u_1 P_b / (1 - P_a - P_L)$$

$$u_i = (P_c u_{i-2} + P_b u_{i-1}) / (1 - P_a - P_L)$$

where $i = 3, 4$

$$u_5 = [P_c u_3 + P_b u_4 + P_L (1 - \sum_{i=1}^4 u_i)] / (1 - P_a)$$

$$u_6 = (P_c u_4 + P_b u_5) / (1 - P_a)$$

4. Days that Burning Operations are Possible.

How many days are burning operations possible at any location in any month?

The number of days equals the unconditional probability, u , times the number of days in the month in question.

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ANALYSIS OF NUMBER OF DAYS THAT BURNING IS POSSIBLE

In Phase 1 of Project EMOTE, restrictions on amounts of rain and number of drying days were recognized to be too severe. In an effort to remedy this we have gone too far the other way in establishing a heavy rain as $> .2$ inch /day and reducing the number of drying days to 1 after a light rain and 3 after a heavy rain. A comparison of map analyses of the two sets of conditions readily bear this out. We have the advantage now of at least knowing the limits within which we can operate. They are as follows:

- a. After a heavy rain ($> .2$ inch) 3 drying days are not enough and 5 drying days are too many.
- b. After a light rain ($\leq .2$ inch) 1 drying day is not enough and 2 drying days are too many.

These limits would apply generally to the dryer months - November through March. It is recognized that only in isolated areas could a successful operation be conducted in the rainy season. For convenience in comparison, two maps for the same month appear on each page (see Figures 1-12). The map on the right illustrates too liberal restrictions on burning operations while the one on the left illustrates too conservative restrictions. The liberal analysis (right chart) appears to be quite sensitive to the prevailing monsoon flow, certainly much more so than the conservative analysis. One can readily see the effects of prevailing southwest flow moving northward from Malaysia beginning in March and continuing through November while the effect of northeast flow can be seen from October through February. September and October, as well as February and March, are transition months. The interior of the

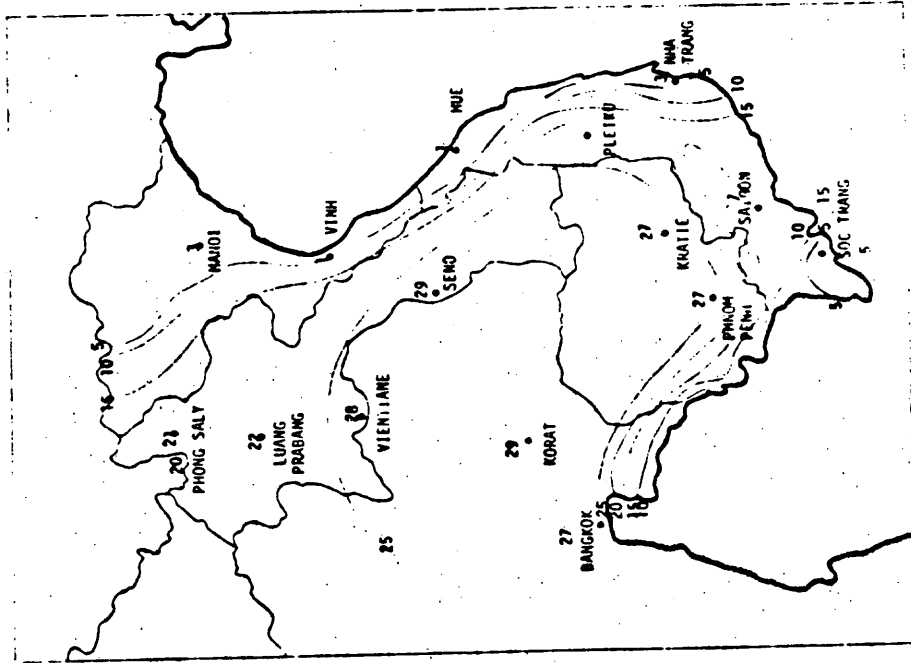
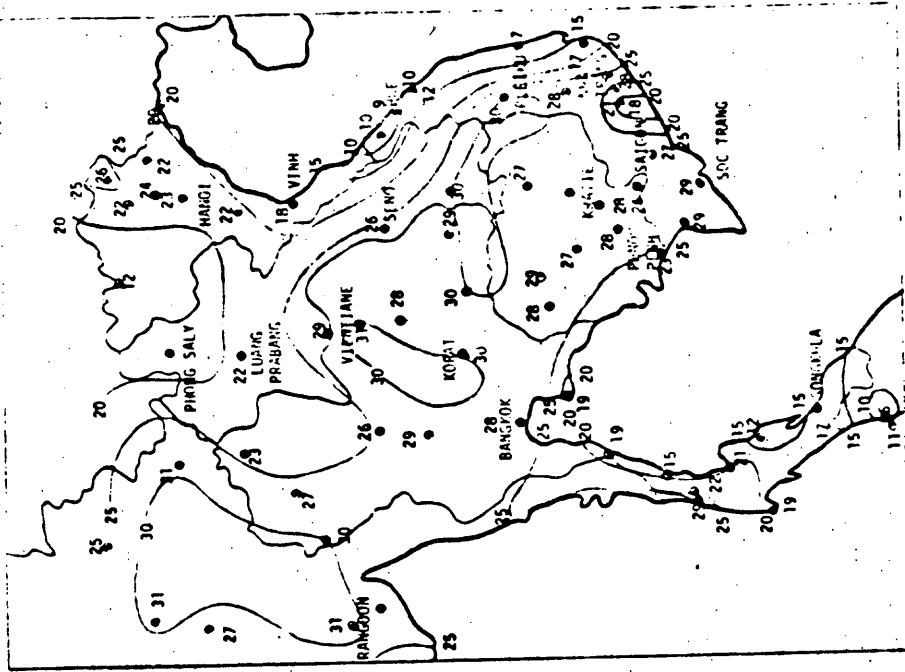


Figure 1.--Number of days that burning is possible in January given:

- (a) Five or more "drying days" have accumulated since the last heavy rain provided that 2 or more "drying days" have accumulated since the last light rain.
- (b) Three or more "drying days" have accumulated since the last heavy rain provided that 1 or more "drying days" have accumulated since the last light rain.

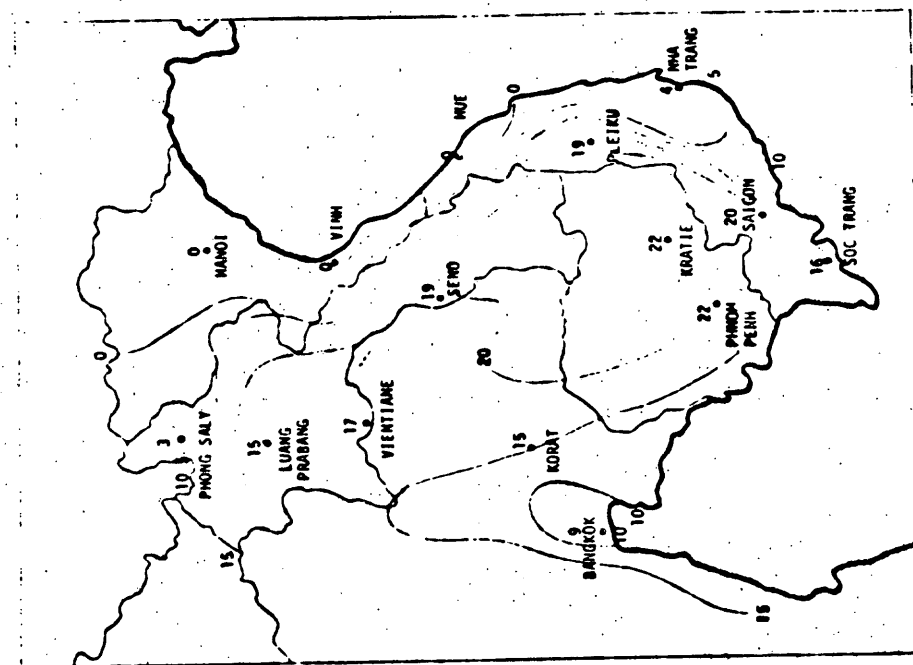
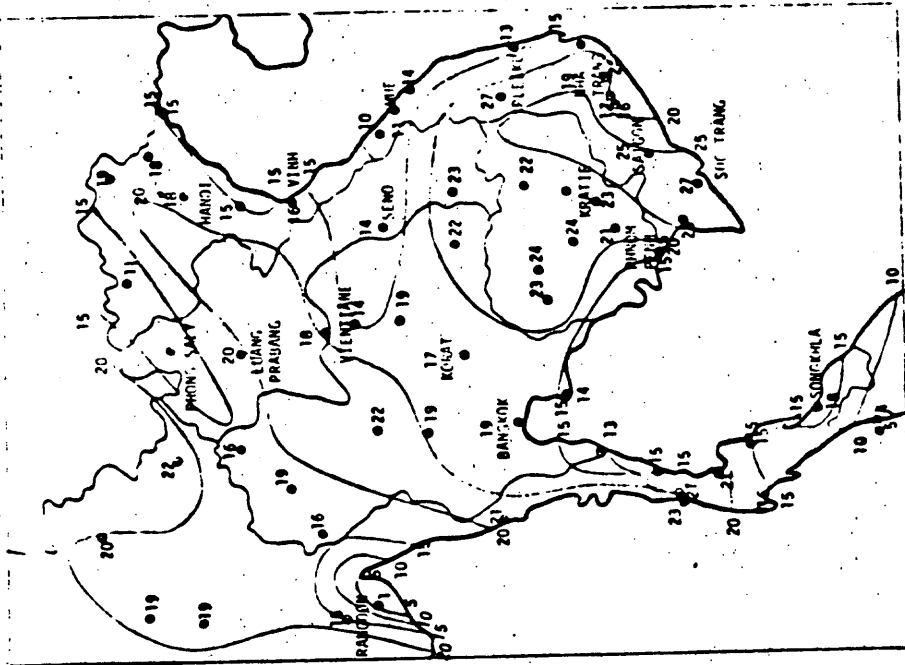


Figure 2.--Number of days that burning is possible in February given:

- (a) Five or more "drying days" have accumulated since the last heavy rain provided that 2 or more "drying days" have accumulated since the last light rain.
- (b) Three or more "drying days" have accumulated since the last heavy rain provided that 1 or more "drying days" have accumulated since the last light rain.

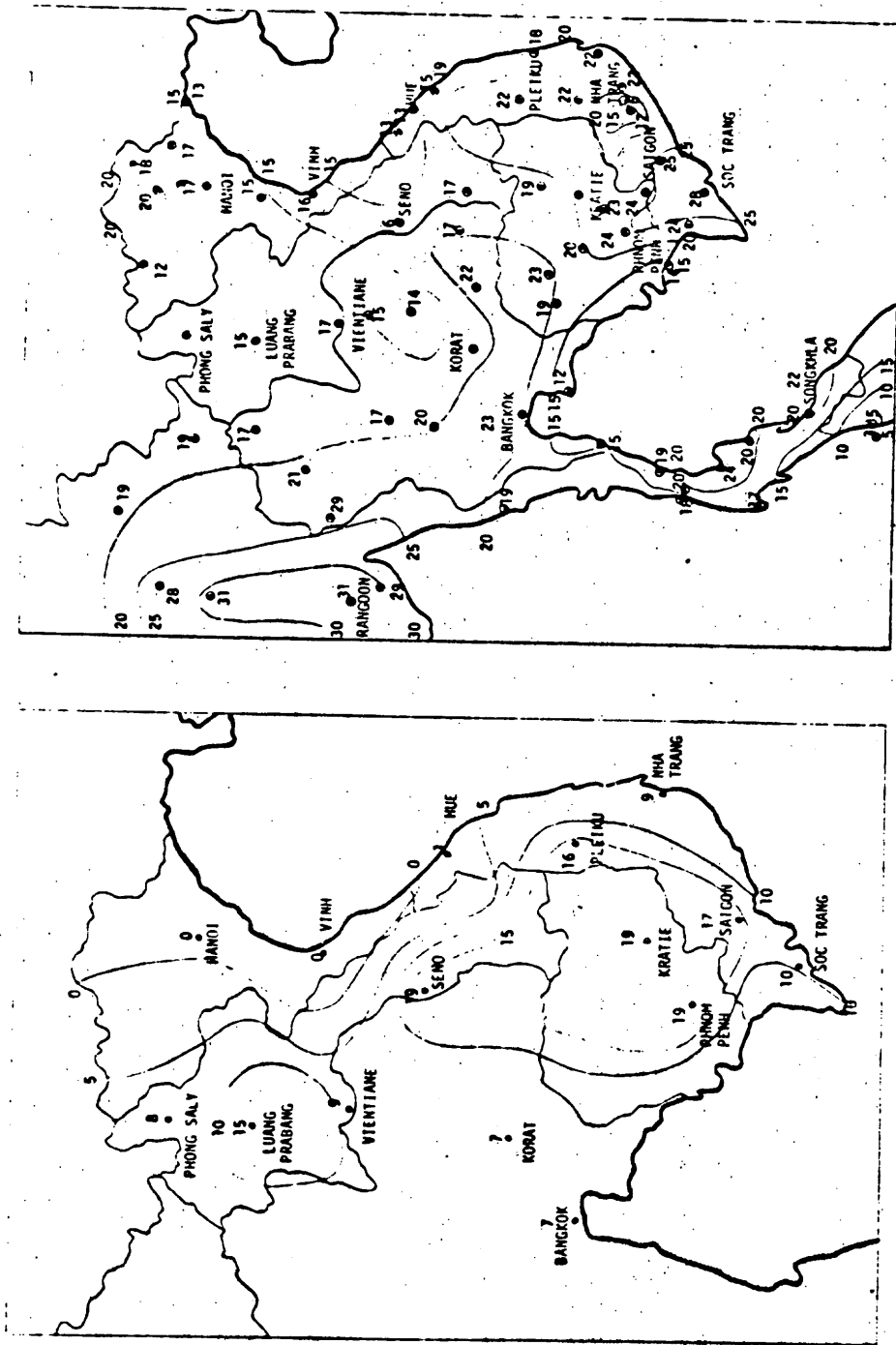


Figure 3.--Number of days that burning is possible in March given:

- (a) Five or more "drying days" have accumulated since the last heavy rain provided that 2 or more "drying days" have accumulated since the last light rain.
- (b) Three or more "drying days" have accumulated since the last heavy rain provided that 1 or more "drying days" have accumulated since the last light rain.

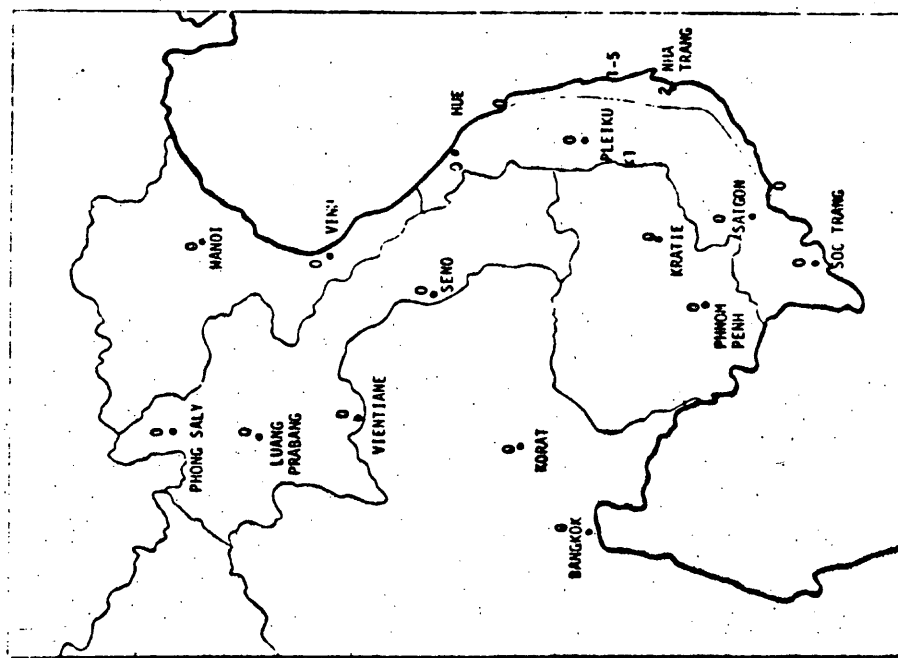
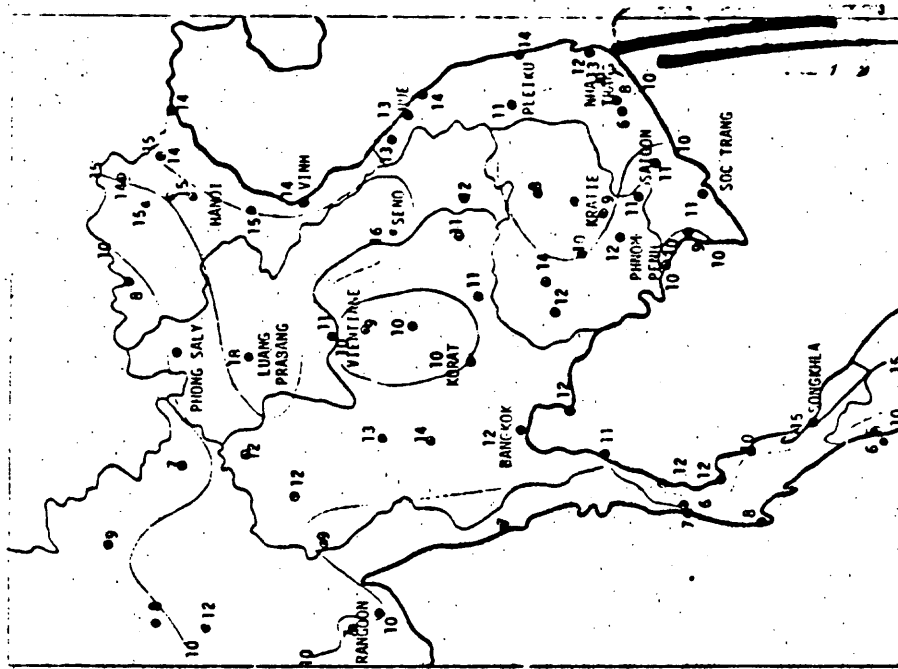
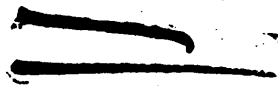


Figure 5.--Number of days that burning is possible in May given:

- (a) Five or more "drying days" have accumulated since the last heavy rain provided that 2 or more "drying days" have accumulated since the last light rain.
- (b) Three or more "drying days" have accumulated since the last heavy rain provided that 1 or more "drying days" have accumulated since the last light rain.

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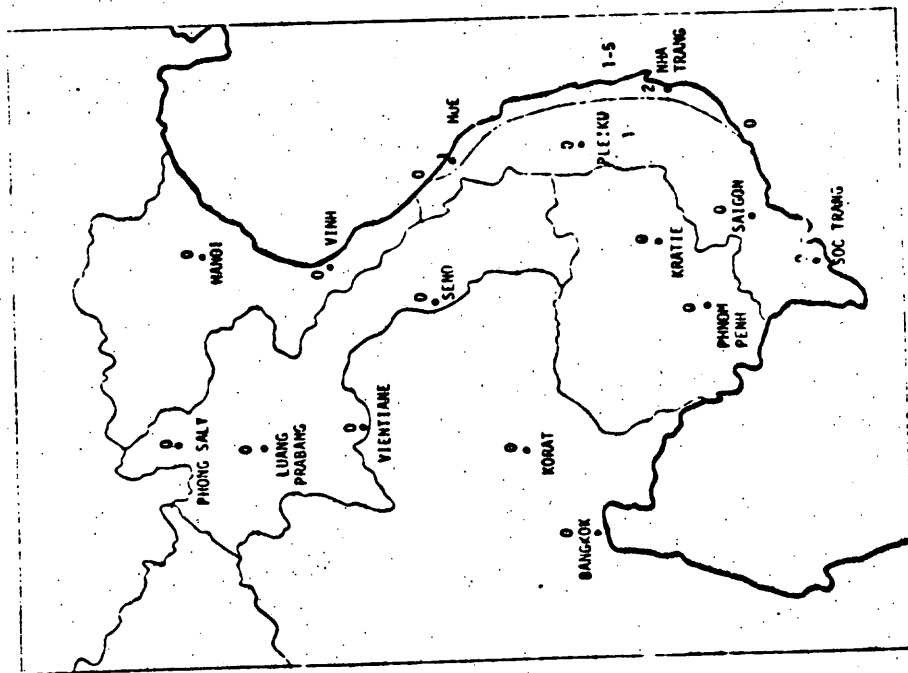
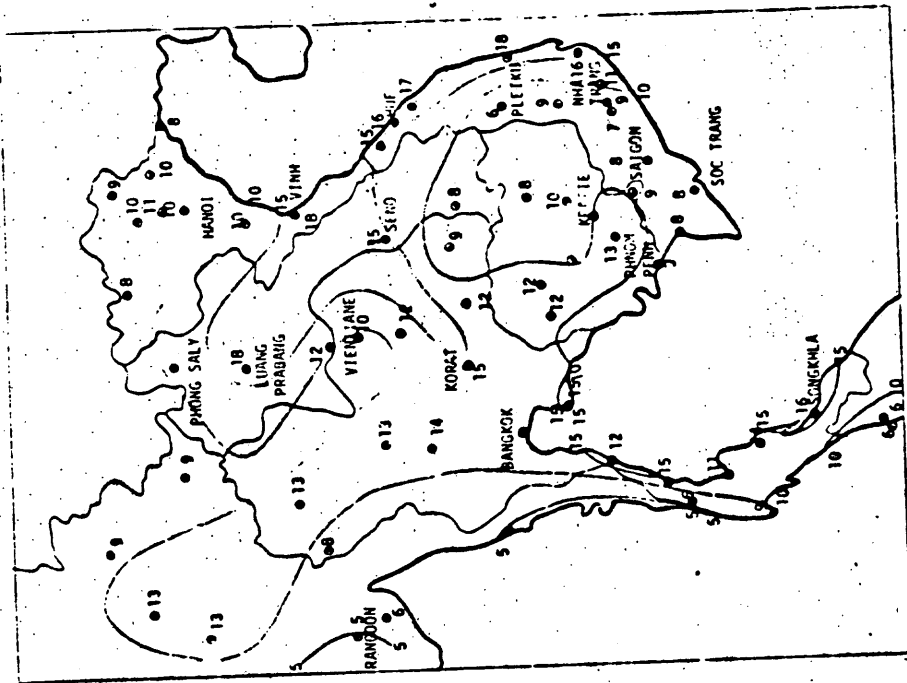


Figure 6.--Number of days that burning is possible in June given:

- (a) Five or more "drying days" have accumulated since the last heavy rain provided that 2 or more "drying days" have accumulated since the last light rain.
- (b) Three or more "drying days" have accumulated since the last heavy rain provided that 1 or more "drying days" have accumulated since the last light rain.

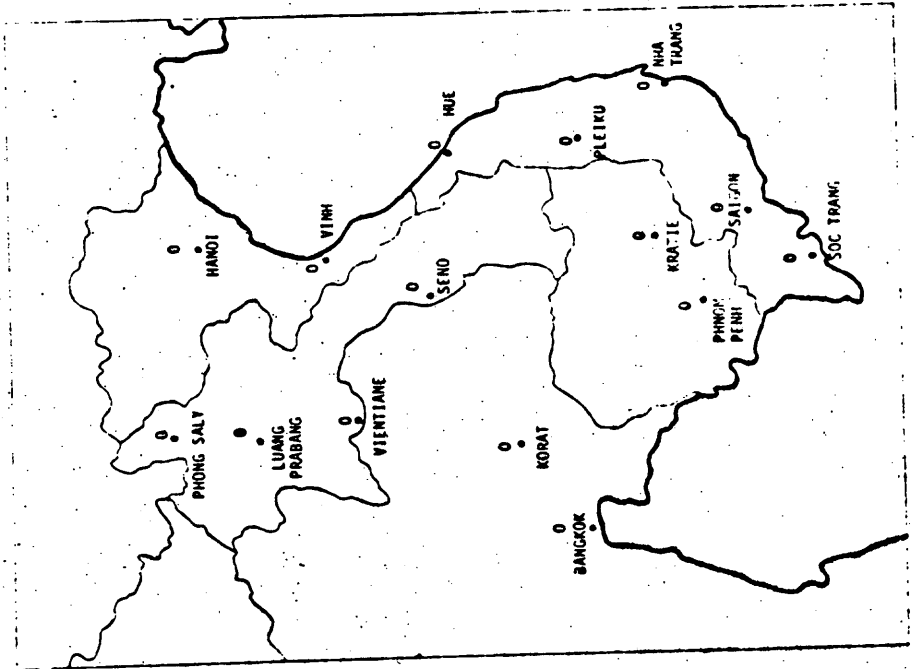
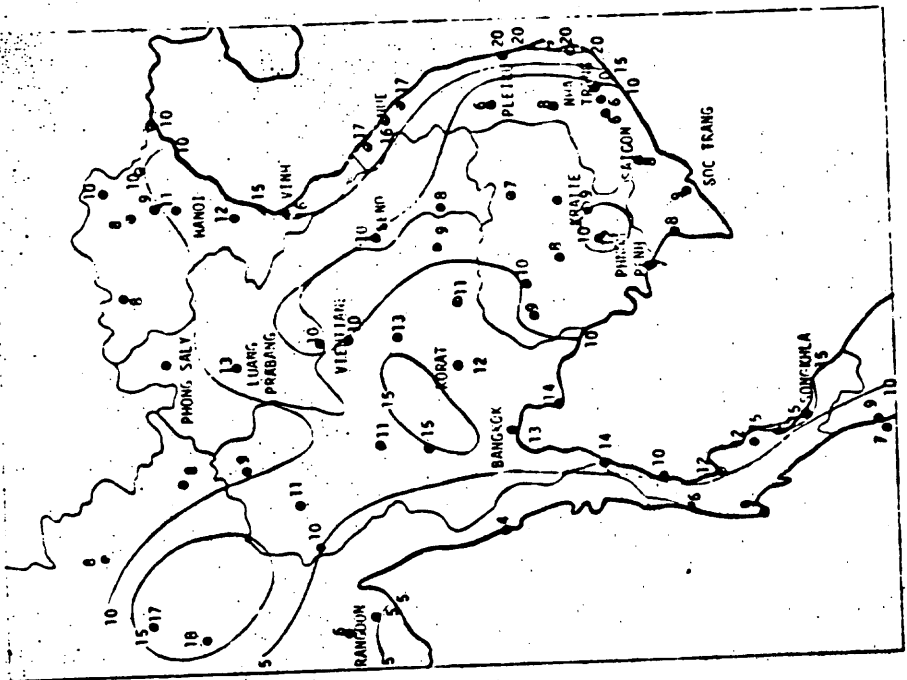


Figure 7.--Number of days that burning is possible in July given:

- (a) Five or more "drying days" have accumulated since the last heavy rain provided that 2 or more "drying days" have accumulated since the last light rain.
- (b) Three or more "drying days" have accumulated since the last heavy rain provided that 1 or more "drying days" have accumulated since the last light rain.

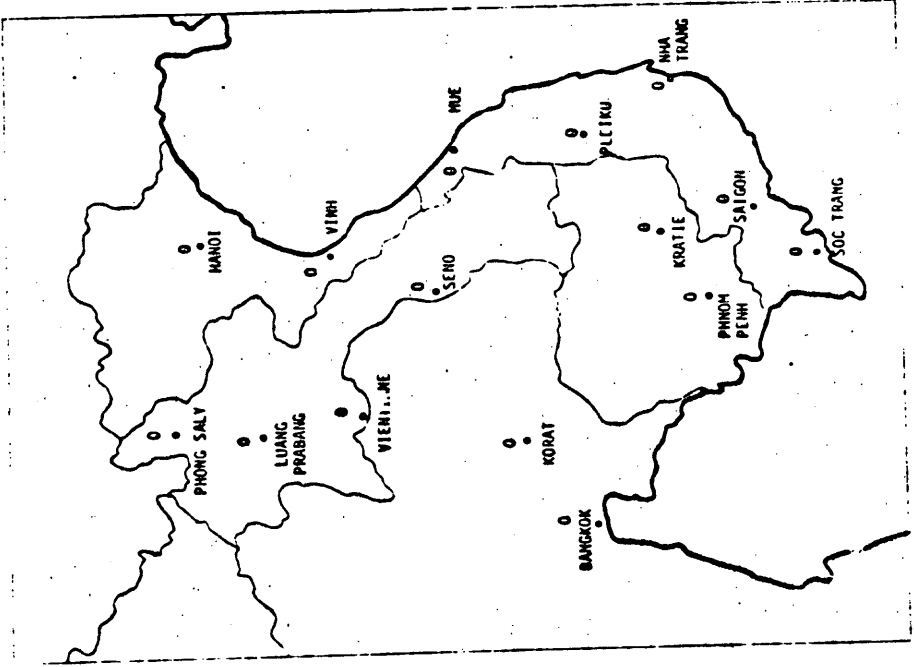
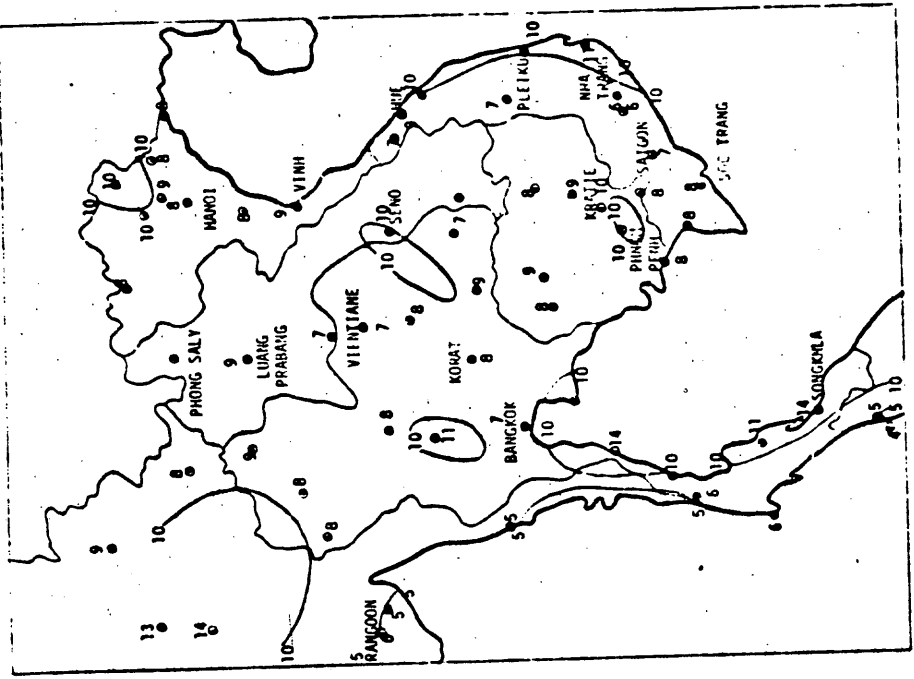


Figure 9.--Number of days that burning is possible in September given:

- (a) Five or more "drying days" have accumulated since the last heavy rain provided that 2 or more "drying days" have accumulated since the last light rain.
- (b) Three or more "drying days" have accumulated since the last heavy rain provided that 1 or more "drying days" have accumulated since the last light rain.

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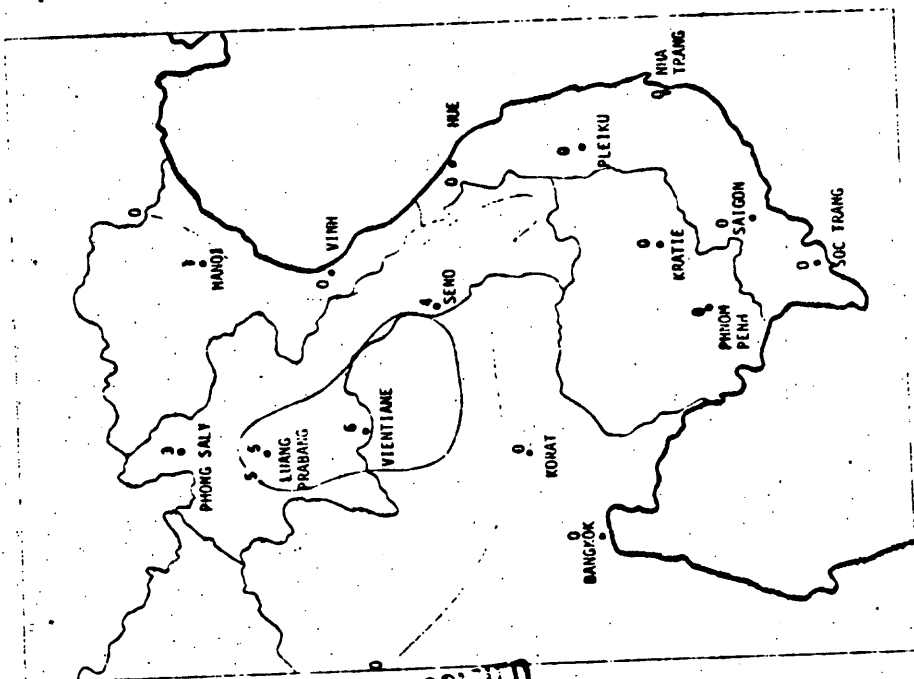
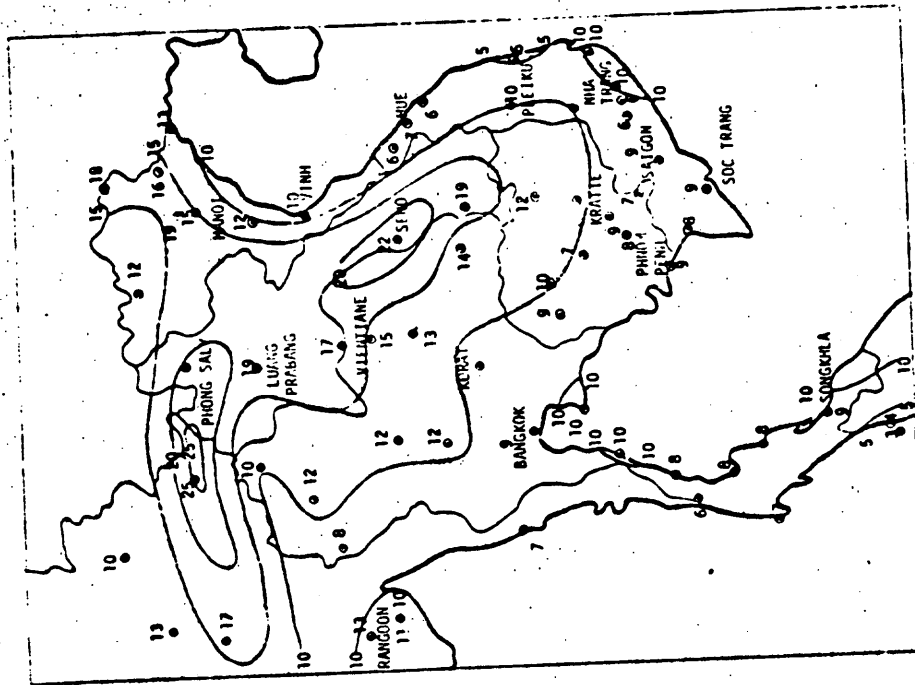


Figure 10.--Number of days that burning is possible in October given:

- (a) Five or more "drying days" have accumulated since the last heavy rain provided that 2 or more "drying days" have accumulated since the last light rain.
- (b) Three or more "drying days" have accumulated since the last heavy rain provided that 1 or more "drying days" have accumulated since the last light rain.

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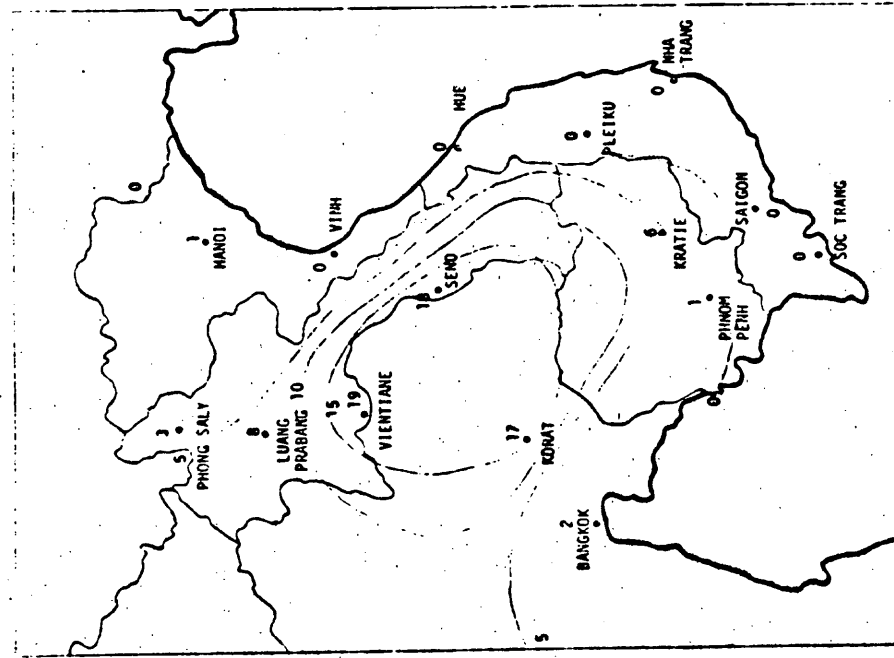
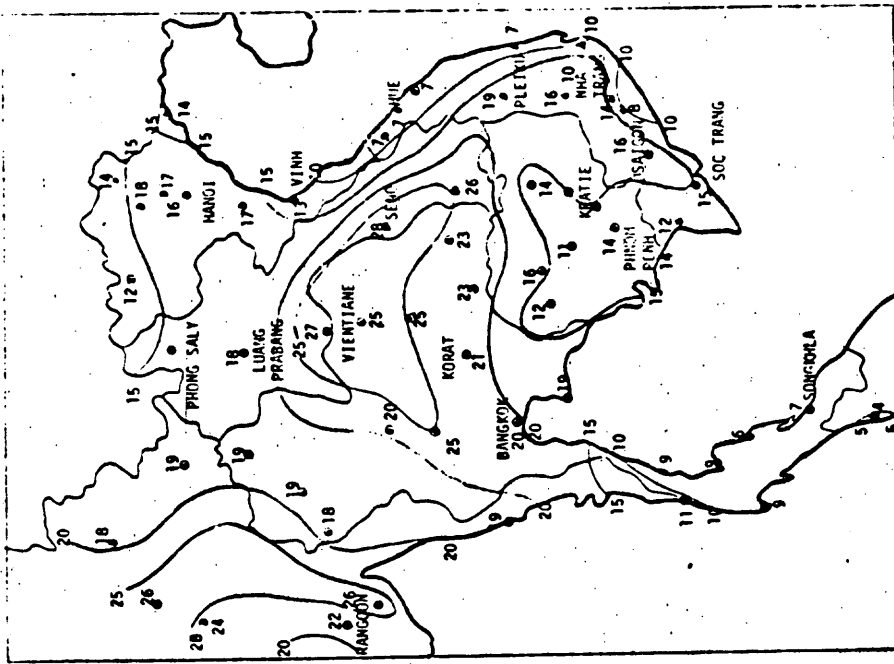


Figure 11.--Number of days that burning is possible in November given:

- (a) Five or more "drying days" have accumulated since the last heavy rain provided that 2 or more "drying days" have accumulated since the last light rain.
- (b) Three or more "drying days" have accumulated since the last heavy rain provided that 1 or more "drying days" have accumulated since the last light rain.

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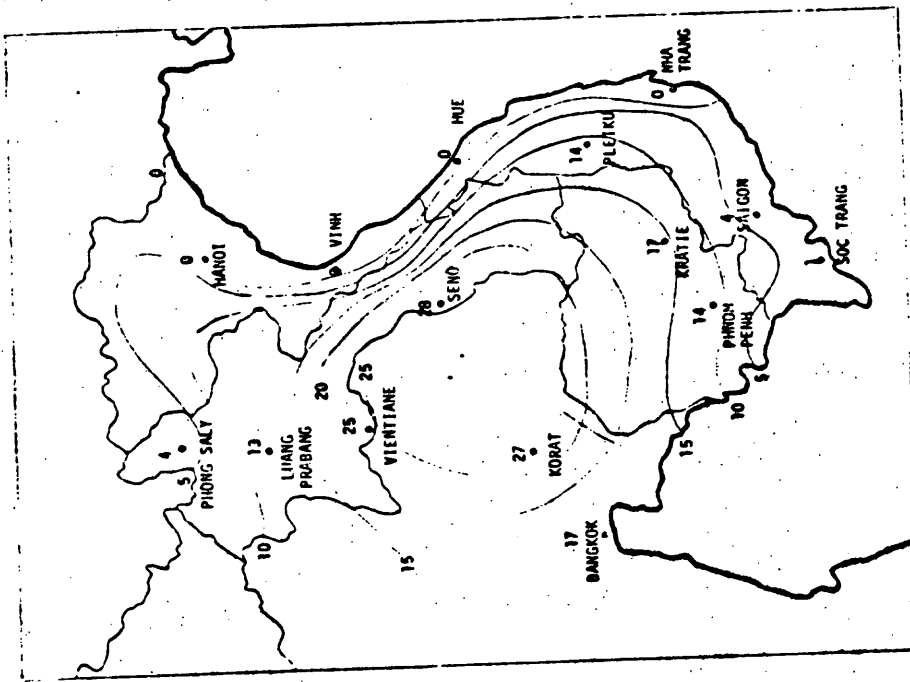
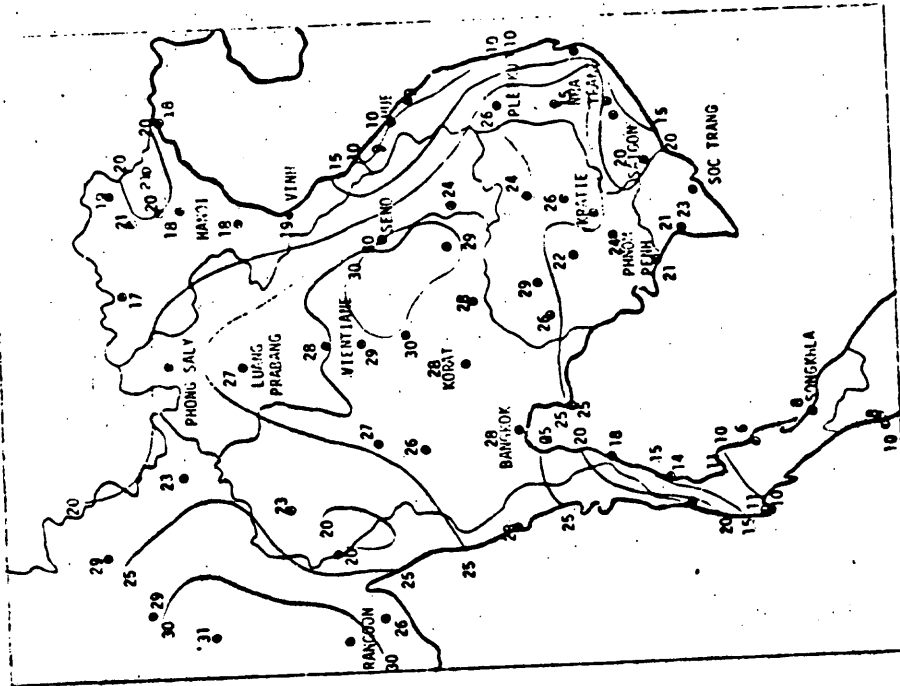


Figure 12.--Number of days that burning is possible in December given:

- (a) Five or more "drying days" have accumulated since the last heavy rain provided that 2 or more "drying days" have accumulated since the last light rain.
- (b) Three or more "drying days" have accumulated since the last heavy rain provided that 1 or more "drying days" have accumulated since the last light rain.

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Indochinese peninsula continues to be relatively dry from October to April when compared to the coast. From May to September the number of burning days in the interior are reduced relative to coastal areas. One would tend to conclude from these analyses that the total number of burning days are generally much greater in the interior Korat plateau region and variable with the seasons along the coastlines. The data are also sensitive to elevation with higher locations nearly always having more possible burning days than the lowlands. For this part of the world such a conclusion seems reasonable in light of the fact that when we talk of lowlands we generally mean high rainfall areas and lush jungle-type vegetation. Our test operations would tend to confirm that only under the most ideal conditions can moderately successful burning take place in the lower elevations. Two tests actually took place in January, the month when success was most likely and on only one of these days was modest success achieved.

THE BURNING EXPERIMENTS

Three burning experiments were conducted in South Vietnam in early 1967. They were referred to as "Pink Rose I, II, and III". The targets were ignited by clustered incendiaries dropped from B-52 aircraft on January 18, 1967 (Area "C"), January 28, 1967 (Area "A") and on April 4, 1967 (Area "B"). The civilian advisory team observed the experiments in Areas "C" and "A" only. Meteorological data for area "B" was provided by the First Weather Group, and comments on what was observed reflect the interpretation of personnel who saw the burn and reported on their observations.

The burns were not particularly intense, and in no case did an actual firestorm occur where all major burning elements contributed to

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a single convection column. There were hot spots in each burn, although in Area "C" these were short-lived. Ground reconnaissance after each burn indicated many areas of unburned fuel, which is ample evidence of the relatively light fire intensity.

PINK ROSE I, AREA C, 18 JANUARY 1967

The first experiment (Area "C", Figure 13) was ignited at 1409 LST, January 18, 1967 under extremely unfavorable atmospheric conditions for burning tropical forest fuels. The atmosphere at TOT was cool, moist and stable--characteristic of the periodic lulls in the relatively dry northeast monsoon.

The southern portion of the Siberian High was dominating flow over South Vietnam. Low level winds were light and northerly. Figure 14 illustrates a surface pressure analysis and gradient wind level streamline analysis for 00Z (0800 LST) for 18 January 1967. Southeasterly flow from the 850-500 millibar levels on January 17th (Figure 15) became much more pronounced on January 18th (Figure 16) with development north of the Philippines of a strong anticyclone in the upper levels through 200 millibars. Unfortunately, southeasterly flow advects moisture over South Vietnam and the result is evidenced by the dense cloud cover illustrated by the Nimbus II satellite photo in Figure 17. The Tay Ninh and Bien Hoa RAOBs, Figure 18, show considerable moisture on the 18th. Tay Ninh much farther inland near the Cambodian border has increased moisture in the middle layers and slight drying in the lower layers which is most likely caused by normal diurnal warming and mixing from afternoon heating.

Target area weather was represented by Bien Hoa--located about 12 statute miles southeast of target "C". Table 4 illustrates daily weather

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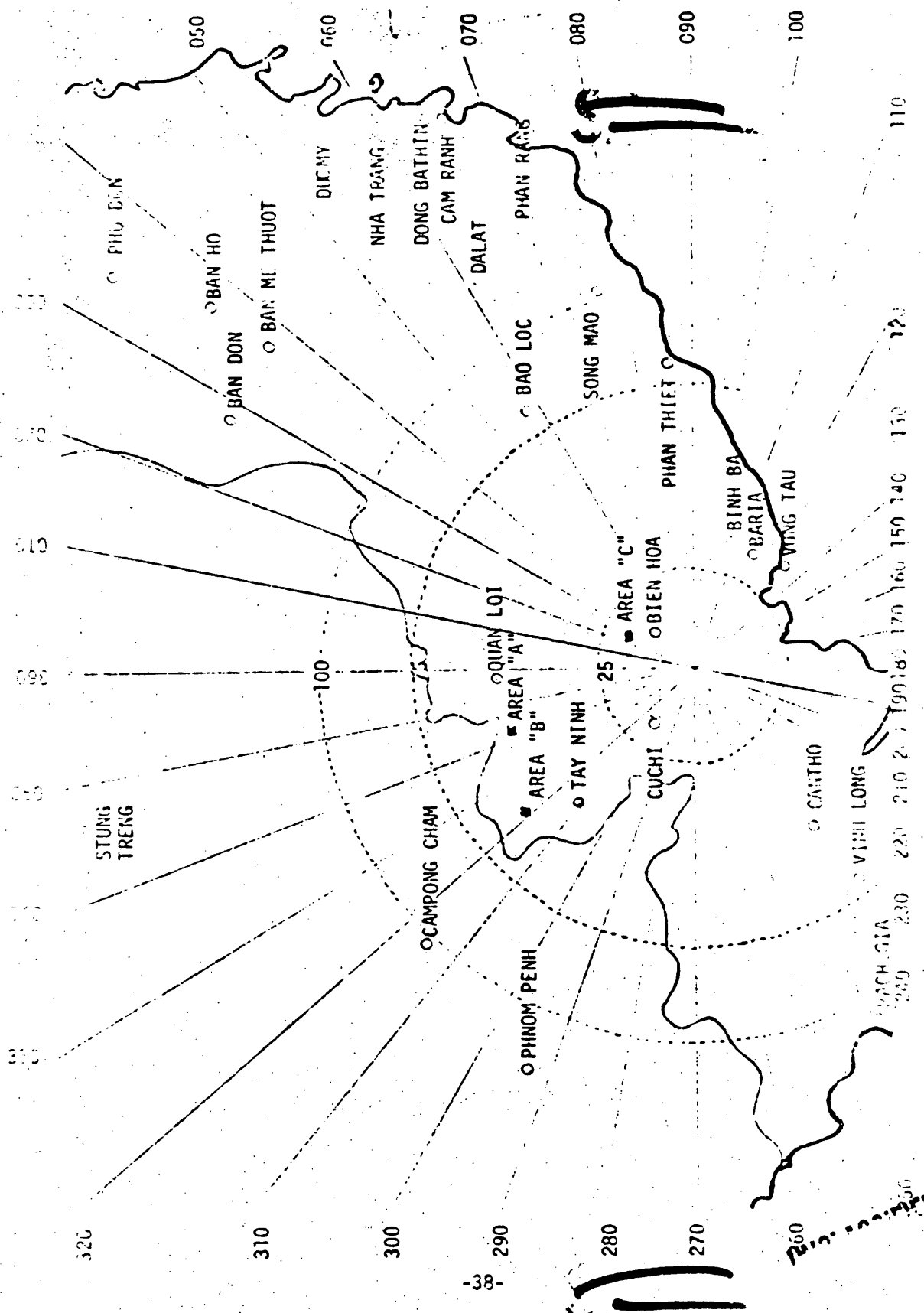


Figure 1. Location of area 'A', area 'B', and area 'C' in relation to the U.S. weather radar at Phan Rang Air Base.

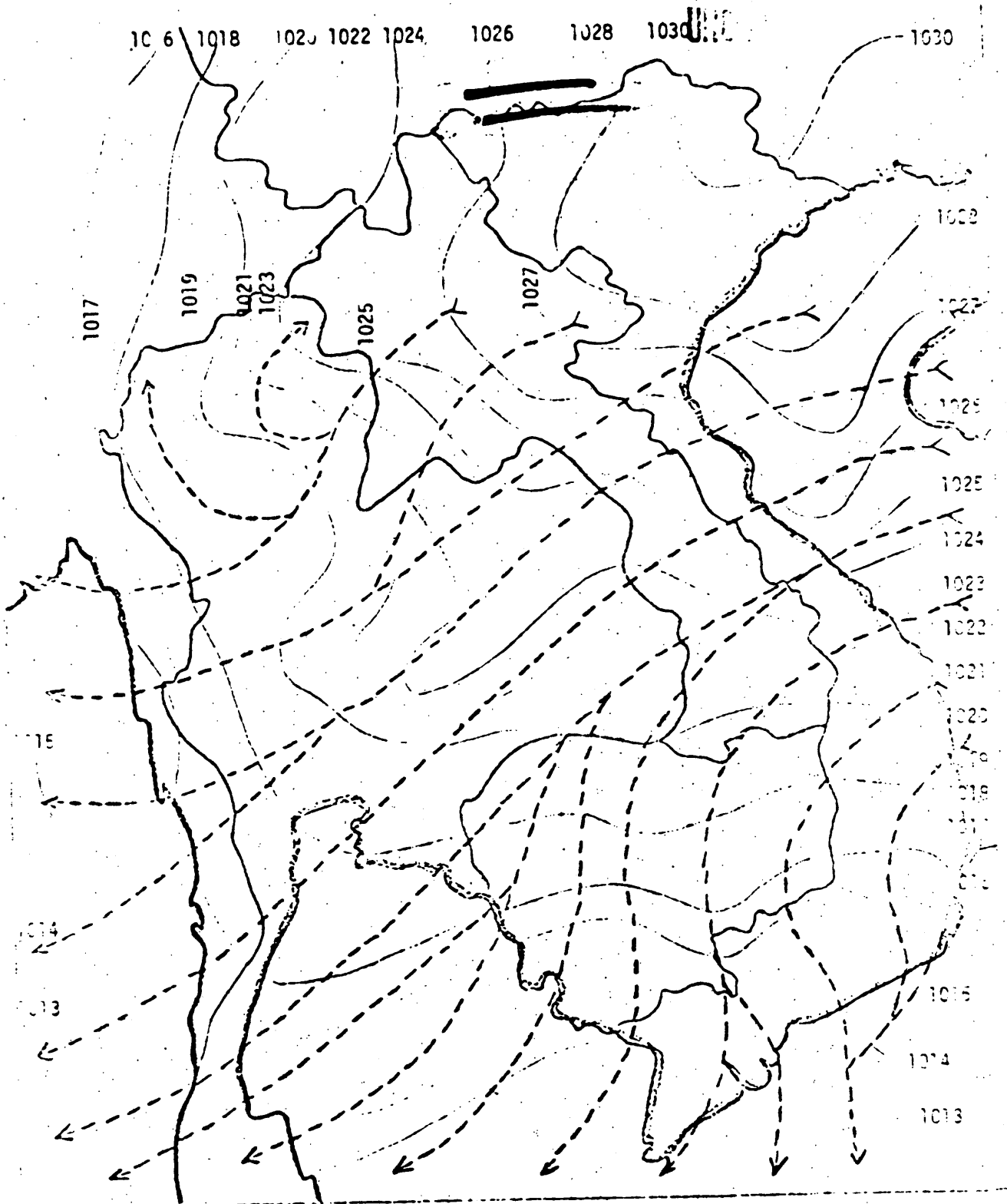


Figure 14.--Surface pressure analysis and gradient wind level streamline analysis, 00Z (08L), 18 January 1967.

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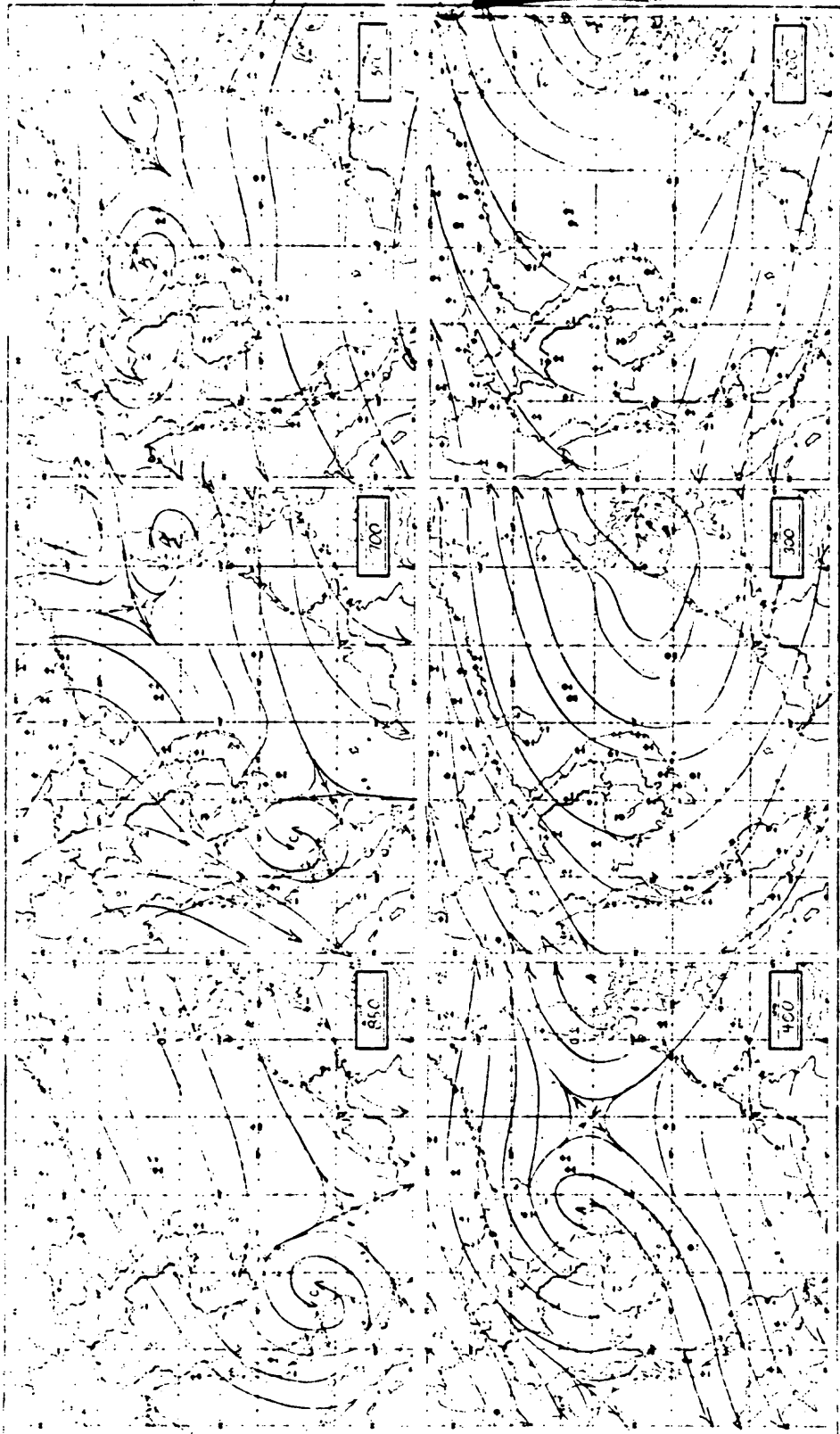


Figure 15.--850, 700, 500, 400, 300, and 200 millibar level streamline analyses for 00Z (08L),
17 January 1962.

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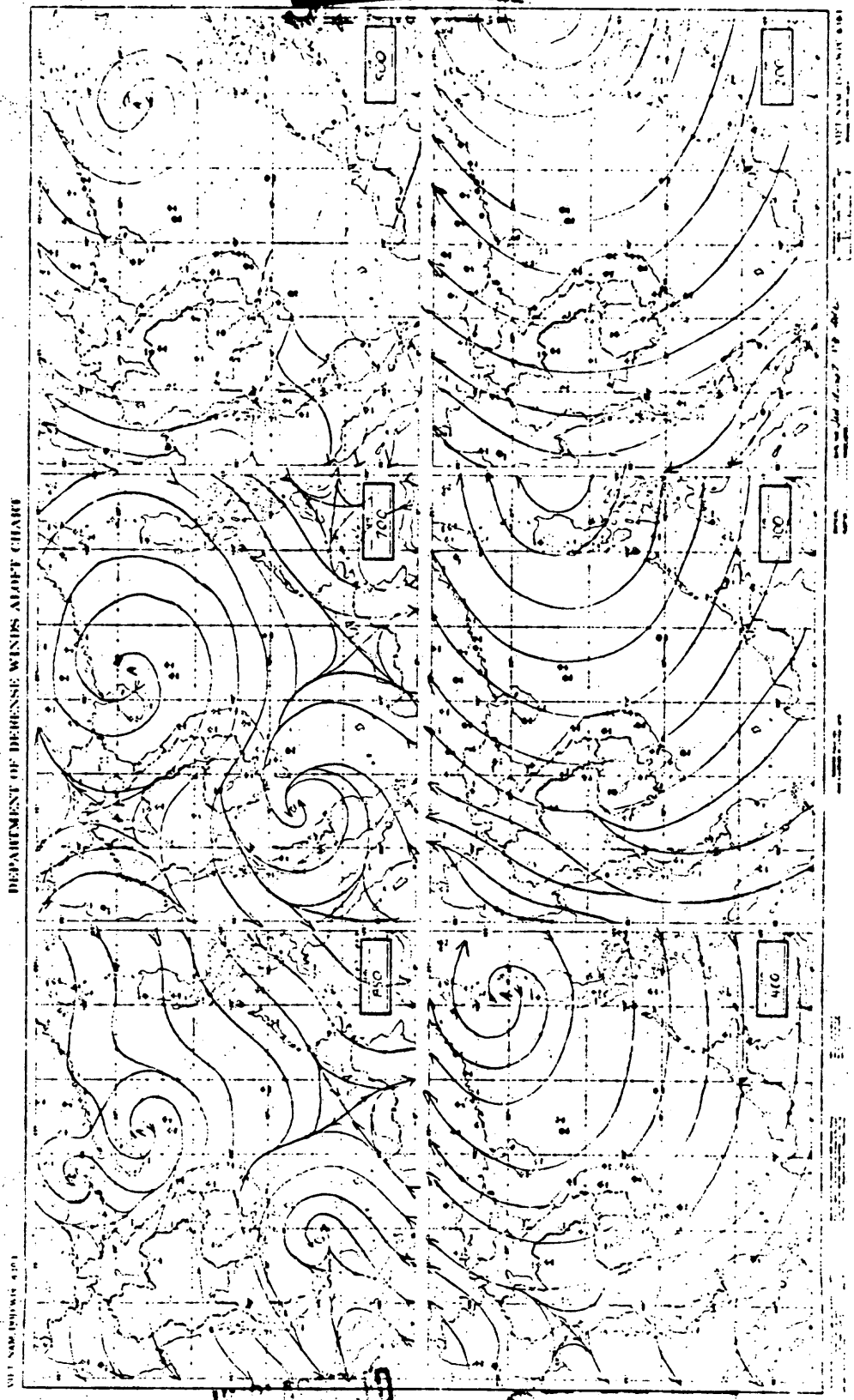


Figure 16-850, 700, 500, 400, 300, and 200 millibar level streamline analyses for 007 (06L),
18 January 1968.

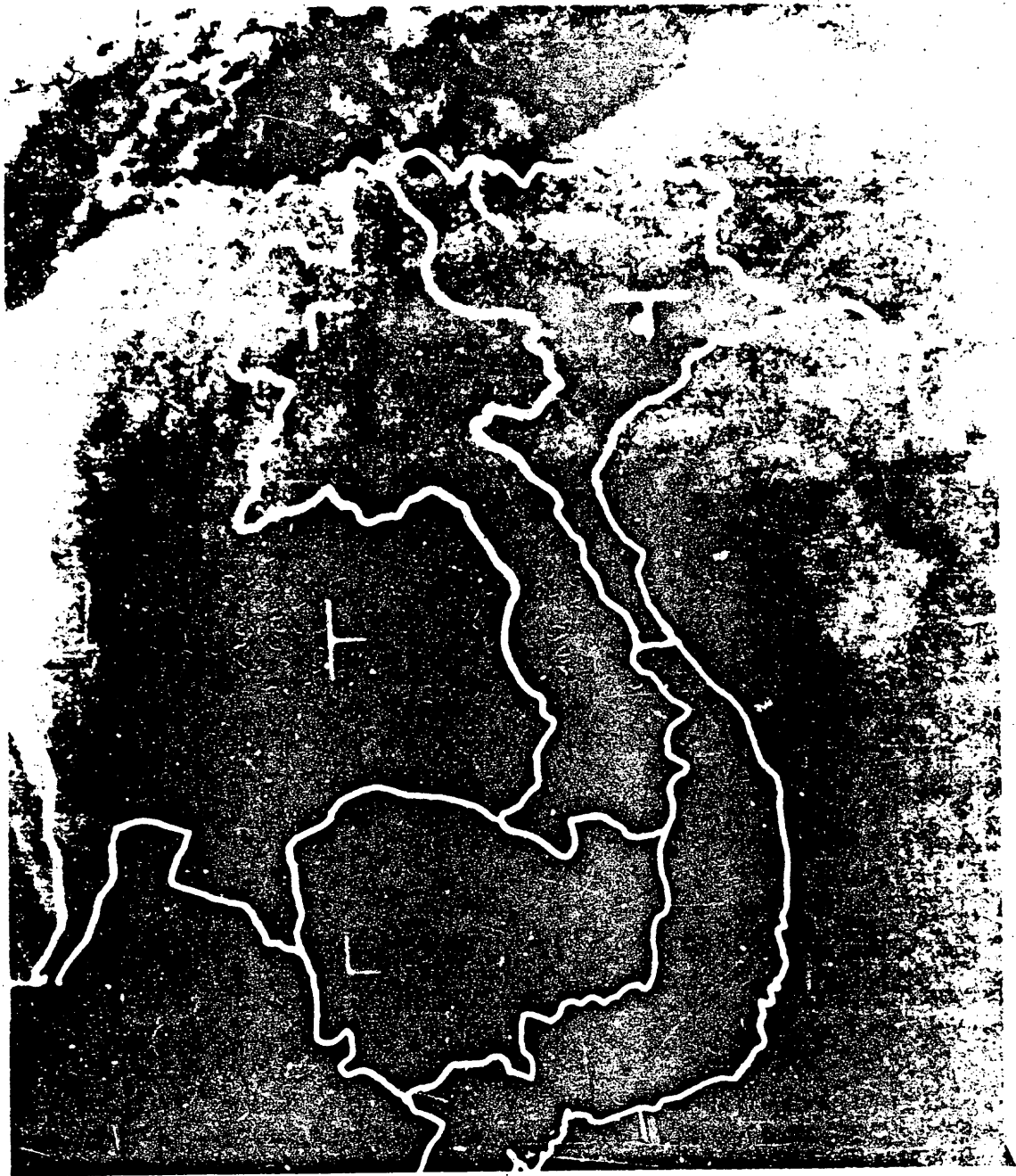


Figure 17.--Nimbus II satellite photograph for 0422Z (1222L),
18 January 1968.
Note: Clouds are black; white areas are land.

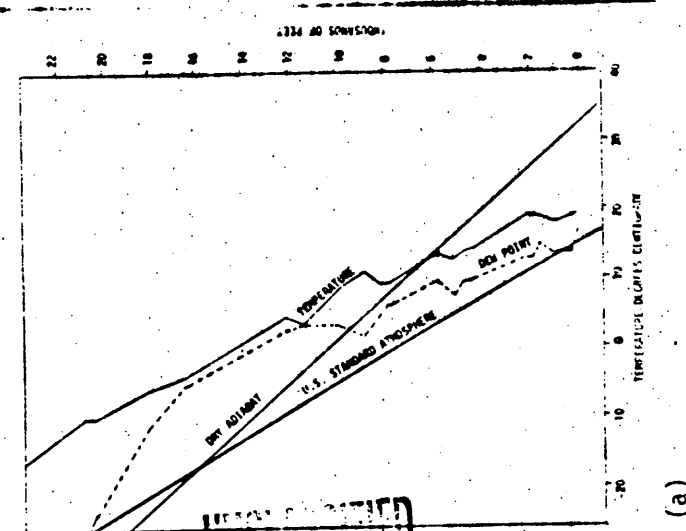
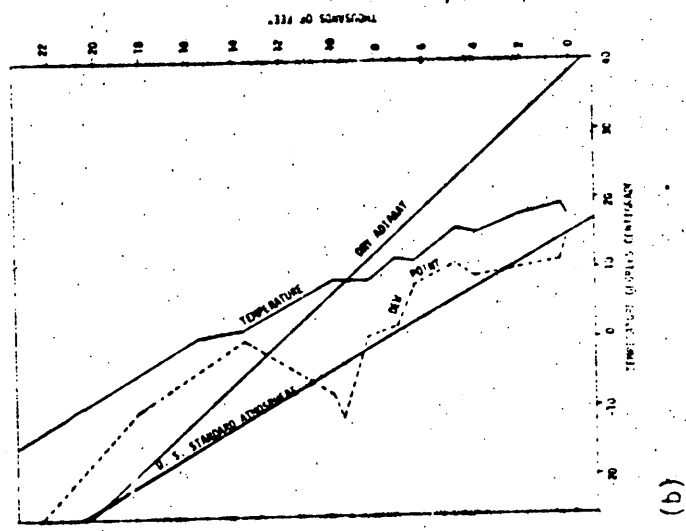
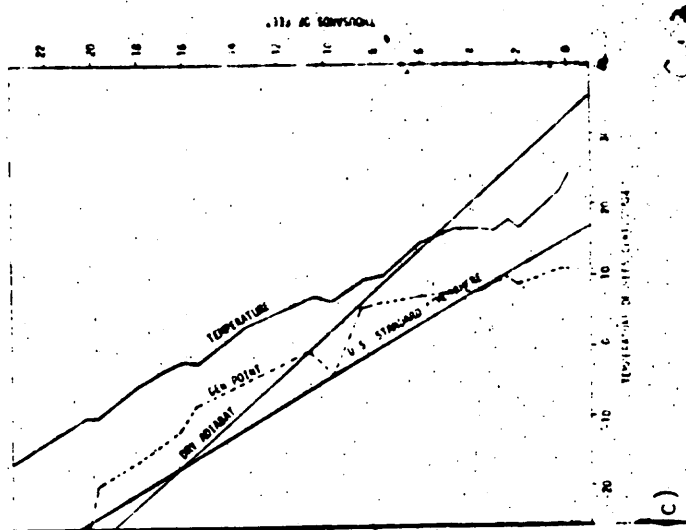


Figure 18.--RAOB's for (a) Bien Hoa, 18Z (02L), 17 January 1967, (b) Tay Ninh, 00Z (08L), 18 January 1967, and (c) Tay Ninh 06Z (14L), 18 January 1967.

TABLE 4. DAILY WEATHER OBSERVATIONS FOR BIEN HOA (BH) AND TAY NINH (TN)

Date	°F Temp		°F Td		% R. H.		PCPN		Sky Condition		Stab. 100	
	TN	BH	TN	BH	TN	BH	TN	BH	TN	BH	TN	BH
7 Jan 67	88	84	70	68	55	59	-	-	120☉/☉	20☉/20☉/☉	+4.0	-
8 Jan 67	87	84	65	67	49	57	-	-	150☉/☉	80☉/150☉/☉	+6.0	-
9 Jan 67	90	90	65	67	44	47	-	-	/-☉	25☉/☉	+6.0	-
10 Jan 67	88	88	65	61	47	41	-	-	/-☉	/-☉	+11.0	-
11 Jan 67	85	88	67	67	51	50	-	-	40☉/☉	35☉/☉	+5.0	-
12 Jan 67	84	90	63	67	49	47	-	-	/-☉/☉	25☉/☉	+4.0	-
13 Jan 67	86	84	61	65	43	53	-	-	/-☉	30☉/☉	+11.0	-
14 Jan 67	55	63	59	65	42	54	-	-	/-☉	28☉/☉	+11.0	-
15 Jan 67	81	83	60	65	50	54	-	-	120☉/☉	32☉/80☉/☉	+10.0	-
16 Jan 67	74	77	54	57	49	50	-	-	/-☉	80☉/☉	+12.0	-
17 Jan 67	79	81	59	59	50	47	-	-	150☉/☉	40☉/100☉/☉	+12.0	-
18 Jan 67	79	81	61	61	54	50	T	.02	120☉/☉	25☉/100☉/☉	+7.0	-
19 Jan 67	81	72	65	67	58	70	.01	.08	35☉/☉	10☉/100☉/7F-	+3.0	-
20 Jan 67	83	81	63	65	51	58	-	.08	150☉/☉	15☉/120☉/☉	+6.0	-
21 Jan 67	86	85	65	65	49	51	-	-	150☉/☉	100☉/150☉/☉	+3.0	-
22 Jan 67	90	88	68	68	48	51	-	.27	35☉/120☉/☉	30☉/120☉/☉	+5.0	-
23 Jan 67	92	88	63	72	38	59	.76	.02	35☉/☉	30☉/80☉/☉	+3.0	-
24 Jan 67	88	84	70	68	55	59	-	-	30☉/☉	40☉/☉	+3.0	-
25 Jan 67	86	86	72	68	63	55	-	-	30☉/☉	30☉/☉	+4.0	-
26 Jan 67	90	86	66	66	45	51	-	-	35☉/☉	30☉/☉	+6.0	-
27 Jan 67	88	88	72	68	59	52	-	-	35☉/100☉/☉	30☉/50☉/☉	+5.0	-
28 Jan 67	90	90	68	66	48	45	-	-	40☉/☉	25☉/☉	+4.5	-
29 Jan 67	88	92	72	66	59	43	-	-	30☉/☉	/-☉	-	-
30 Jan 67	90	84	72	68	56	59	-	-	25☉/☉	35☉/☉	+2.0	-
31 Jan 67	86	88	70	64	59	45	-	-	30☉	35☉/☉	+5.0	-

Observations at 1400 LST except as indicated

1600 LST; *1200 LST; ****1300 LST

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observations for Bien Hoa and Tay Ninh from January 7-31, 1967. Note the 81°F. temperature for Bien Hoa on the 18th is relatively cool for January. On the other hand the dew point of 61°F. and relative humidity of 50 percent appear to indicate moderately dry conditions. The atmosphere was quite stable, however, with a Showalter Index of +7.0 by 1400 LST at Tay Ninh. Earlier at Bien Hoa a +6.0 Showalter Index, together with the moisture advection, confirms the end of a warm, dry unstable period which began on January 9 and continued through the 17th, abruptly ending on the 18th. This can best be illustrated with the vertical time section of temperature minus dew point at Tay Ninh shown in Figure 19. Significant cooling and increases in moisture are apparent at nearly all levels starting on the 17th and continuing through the 24th. It rained at Bien Hoa on 5 days of this period and 3 days at Tay Ninh (Figure 20).

Based on the January 18 RAOB at Tay Ninh (1400 LST) the convective condensation level (CCL) at 13,000 feet MSL pre-determined a convection temperature of 113°F. to establish a good convection column (Figure 18c). With a maximum afternoon temperature of 81°F. at Bien Hoa plus a 10°F. effective increase from good combustion the necessary 113°F. was completely out of the question. Table 5 indicates observed weather parameters at ignition time on the 18th. Diurnal variation of temperature, dew point and relative humidity on January 18 are illustrated for Bien Hoa in Figure 21. Temperatures decreased rapidly after 1500 LST with corresponding increases in relative humidity. Of more significance, however, is the gradual rise in dew point throughout the day--indicative of the moist air advection already discussed.

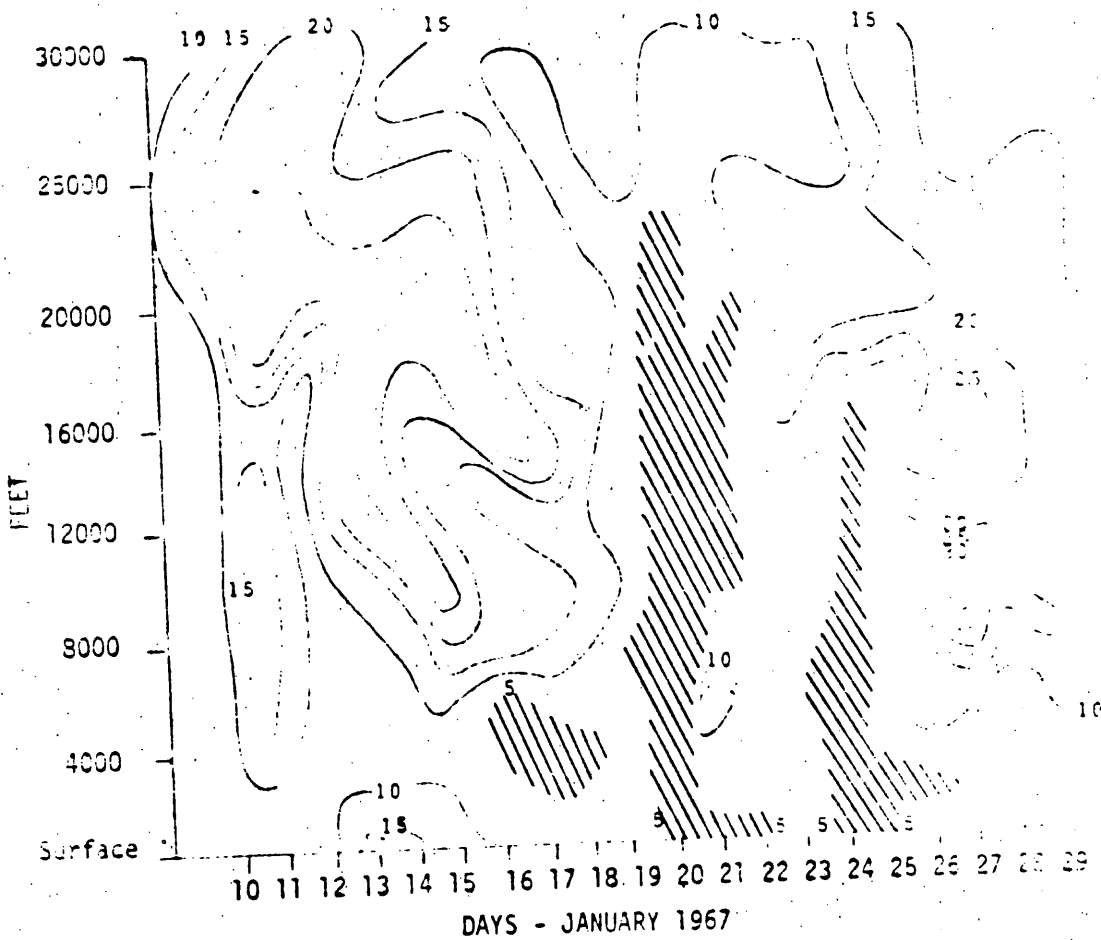


Figure 19.--Vertical time section of temperature minus dew point at Tay Ninh Airport, 10-29 January 1967.

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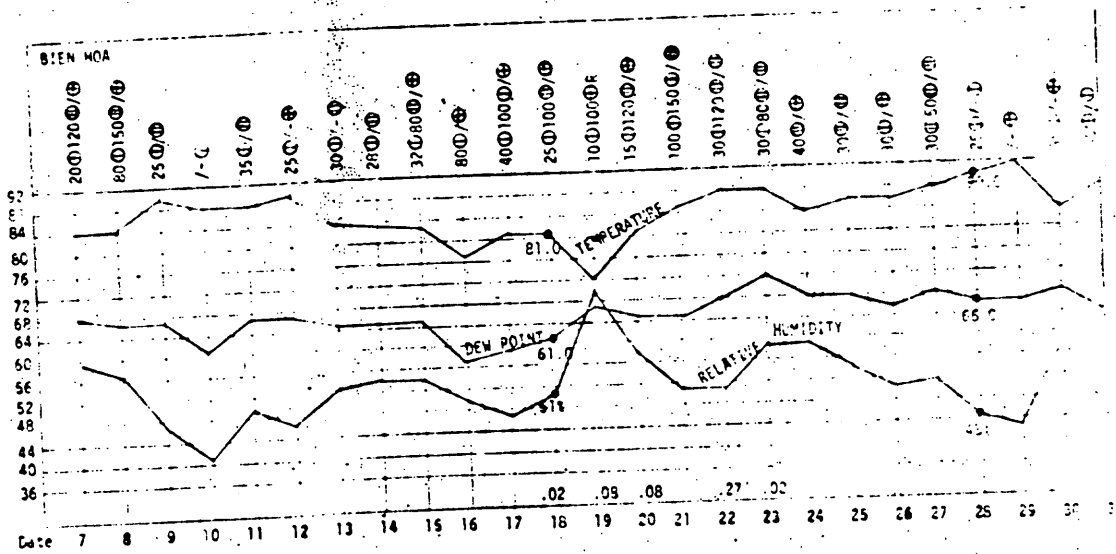
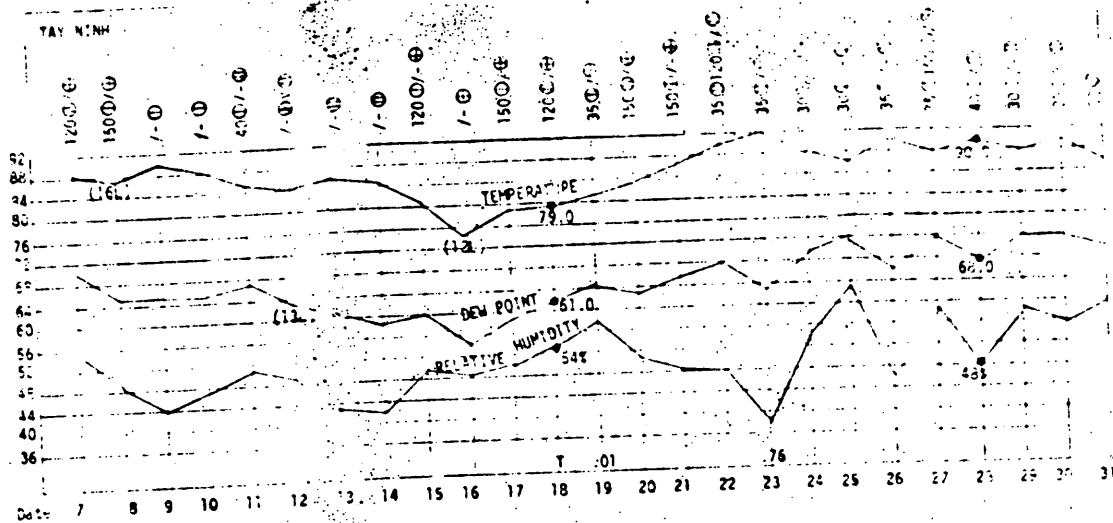


Figure 20.--Temperature, dew point, relative humidity, clouds and weather at Tay Ninh and Bien Hoa, 262 (14L), 7-31 January, 1962. Figures above the dates are the amount of precipitation for that day.

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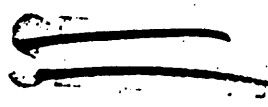
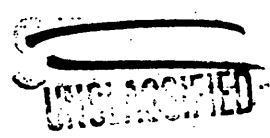


TABLE 5. WEATHER OBSERVATIONS AT 1400 LST, 18 JANUARY 1967

	<u>Bien Hoa</u>	<u>Tay Ninh</u>
Temperature	81°F	79°F
Dew Point	61°F	61°F
Relative Humidity	50%	54%
Sky Condition	25☉100☉/☉	120☉/☉
Stability Index	+6.0 (0200L)	+7.0
Precipitation	.02 inch (1800L)	T (Ton Son Nhut .05 inch)
Days since Precipitation	6 days	14 days
Drying Days	3+	3+ (0800L)
Precipitable Water	-	3.27 (0800L) cm.



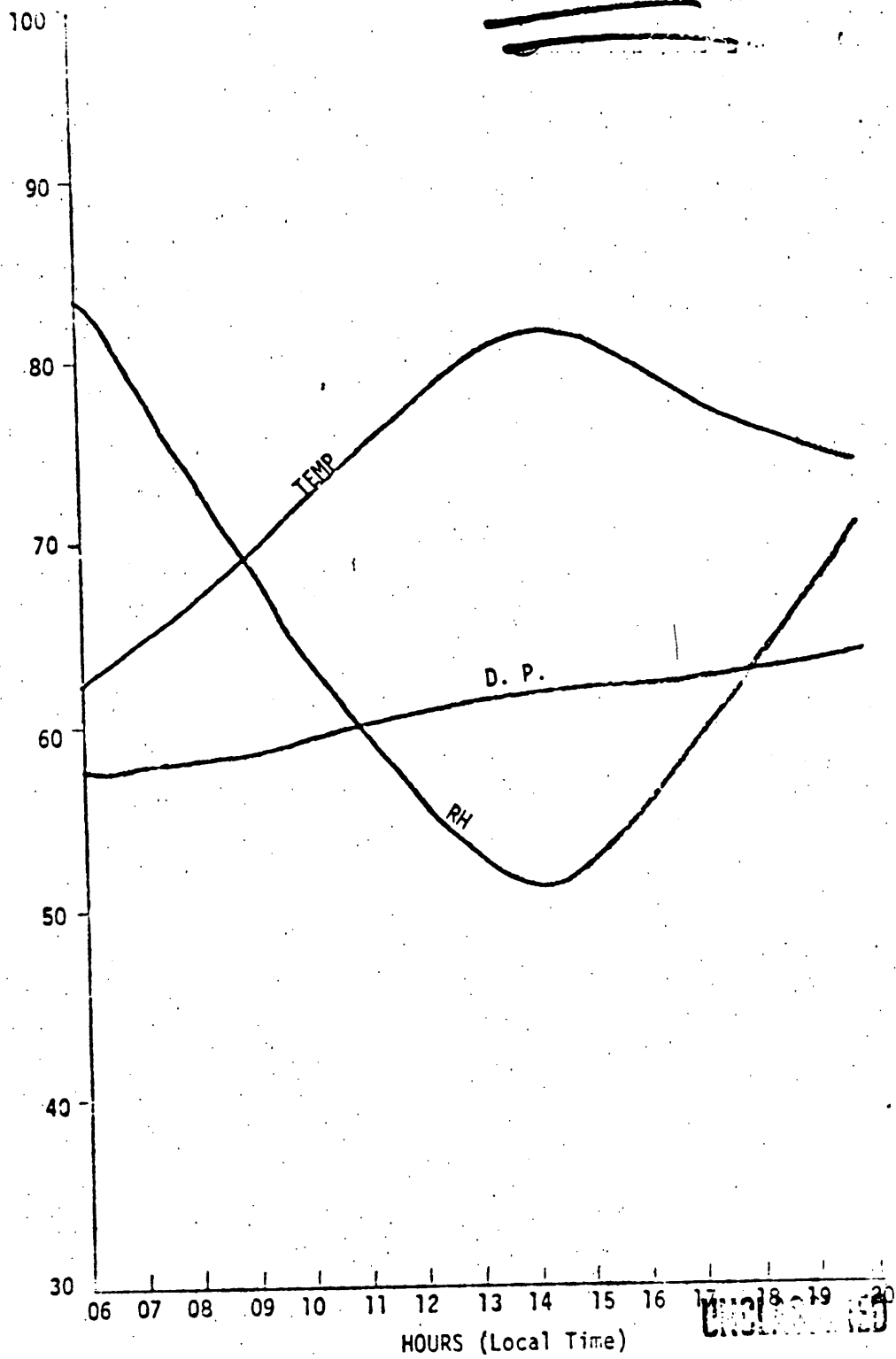


Figure 21.--Diurnal variation of temperature, dew point and relative humidity for Bien Hoa, 18 January 1967.

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Although fuels were dry (no rain had fallen for 6 days) and the target had accumulated the prescribed 3 drying days, low clouds and a high overcast limited solar heating significantly so that a cool temperature and rising dew point were enough to make the experiment a failure.

The convection column reached its maximum height at 1454 LST (TOT + 45 minutes) and was estimated by aerial observers to be at 4,000 MSL. This top was not detected by radar. Observers noted that only a small portion of the northwest corner of the target was burning with any great amount of flaming. Assuming the Tay Ninh RAOB as representative of the target at 1400 LST that small portion of fire was generating an equivalent temperature at the surface of approximately 50°F. , seven degrees of which might be attributable to the fire itself. An inversion near 2,000 feet effectively suppressed the remainder of the fire.

Although virga was observed between 1000 and 1100 LST over the target, no rain was measured at the surface (Bien Hoa) until 1800 LST when .02 inch was recorded. Precipitation had been forecast 24 hours prior to TOT.

PINK ROSE II, AREA A, 28 JANUARY 1967

The second experiment (area "A", Figure 13) was ignited at 1405 LST January 28, 1967 under nearly ideal atmospheric conditions. Northeast monsoonal flow was well established. No precipitation had fallen for 4 days and fuels were well conditioned by previous warm, dry days. Again under the influence of the Siberian High, Figure 22, the target area "A" was exposed to strong northeast monsoonal flow from the gradient wind level up to 300 millibars, Figure 23. A strong anticyclonic

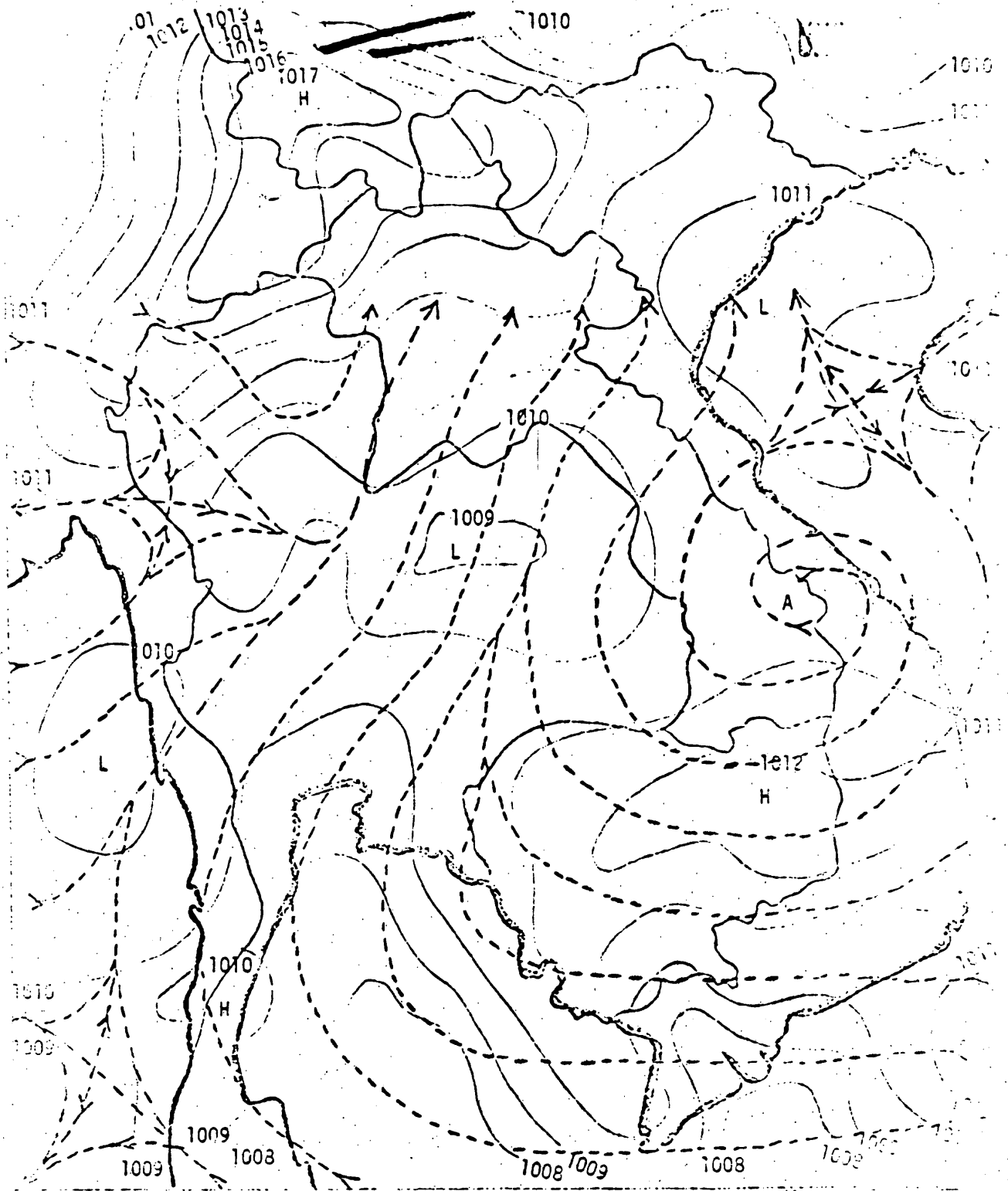


Figure 22.--Surface pressure analysis and gradient wind level streamlines analysis, 00Z (ORL), 28 January 1967.

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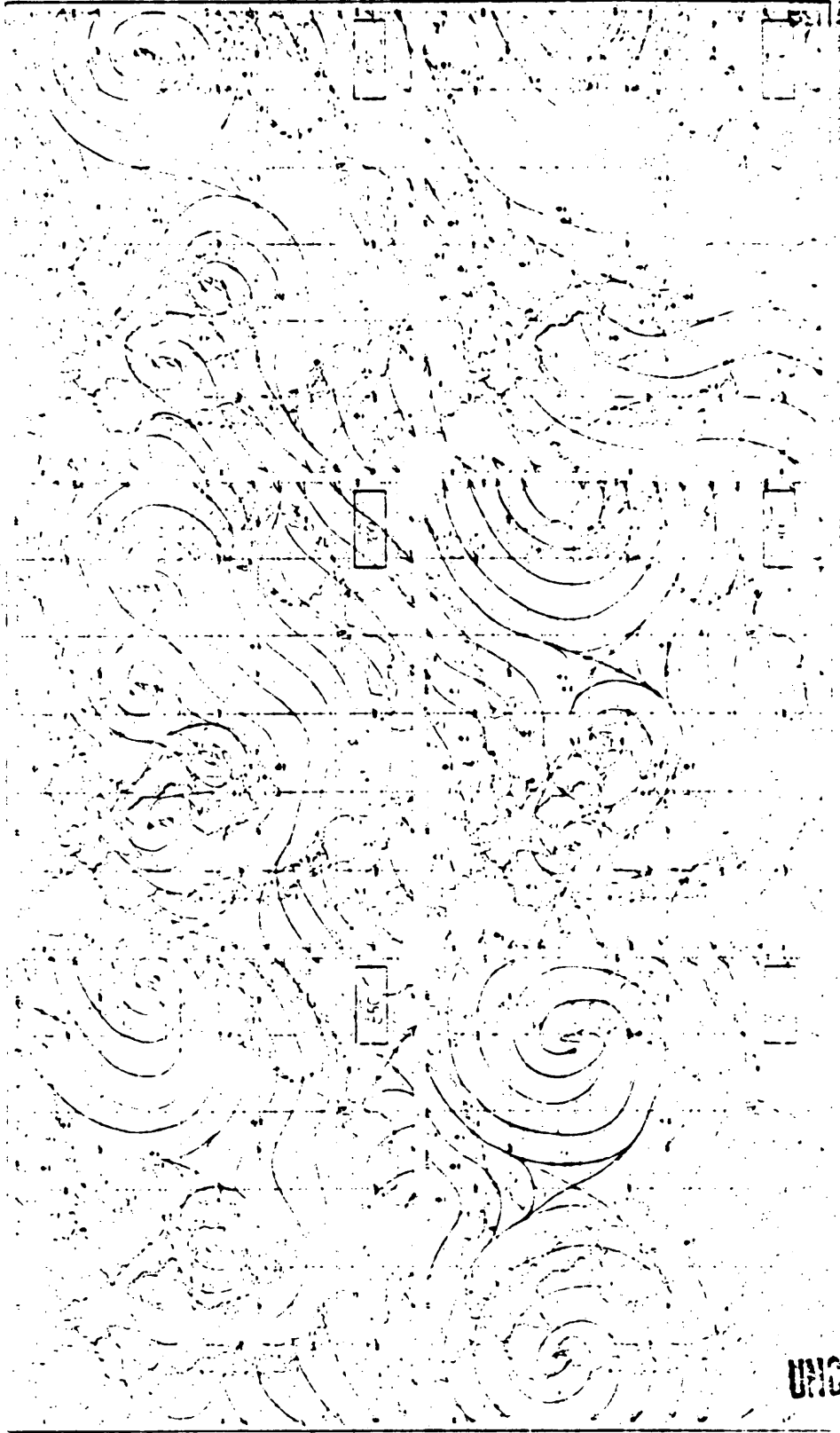


Figure 2. 700, 600, 500, and 400 millibar level streamlines, analysis for 0000Z (cont).

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located over the north Indo-Chinese peninsula on January 27 and 28. The atmosphere was moderately unstable at TOT due primarily to surface heating and dry air aloft. Thin clouds are apparent in Nimbus II photos for January 27, Figure 24.

Target "A" was located about 25 statute miles northeast of Tay Ninh which was the nearest regularly reporting upper-air station. Noting Table 4 and Figure 20, January 28 was one of the better days to conduct a burning operation. At Bien Hoa, temperatures at 1400 LST had been increasing and humidities had been decreasing daily since January 24. Tay Ninh continued to be quite warm although somewhat more variable. Dew point and humidity continued to drop after target ignition to minimum values of 66°F. and 46 percent while surface temperature remained at 90°F (Figure 25). Table 6 indicates weather parameters at TOT for Tay Ninh and Bien Hoa. Although the analysis in Figure 19 indicates January 28 to be at the end of a dry period similar in magnitude to the period ending January 17 and 18 there is one important difference between the two.

Surface temperatures are nearly 10°F. higher on the 27th and 28th. Also a stability index of +4.5 on the 28th indicates a relatively unstable atmosphere. The CCL at Tay Ninh at 1200 LST on the 28th (Figure 26) was at 9,400 MSL. A surface temperature of 107°F. was required to establish a good convection column. With a surface temperature of 90°F. this was nearly hopeless to achieve even with the estimated 10°F. assist from good combustion. At 1413 the smoke layer was at cloud base (TOT + 8 minutes). An inversion base at 5,600 feet MSL (Figure 26) coincided with measured cloud tops over target and vicinity. Aerial observers estimated column height at 9,000 feet MSL. Radar at Ton Son Nhut

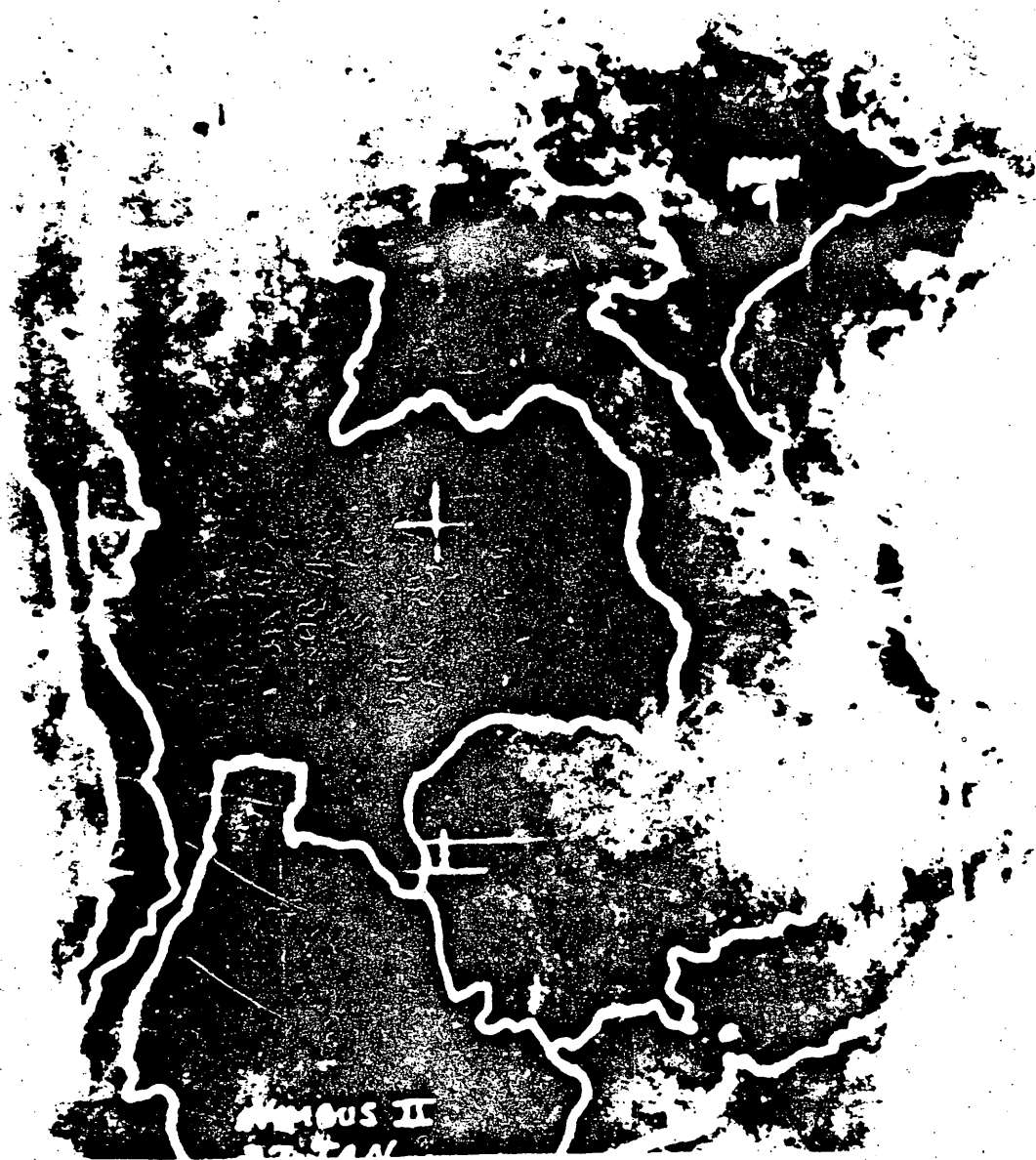


Figure 24.--Nimbus II satellite photograph for 0450 Z (1250L),
27 January 1967.
NOTE: Clouds are black; clear areas are white.

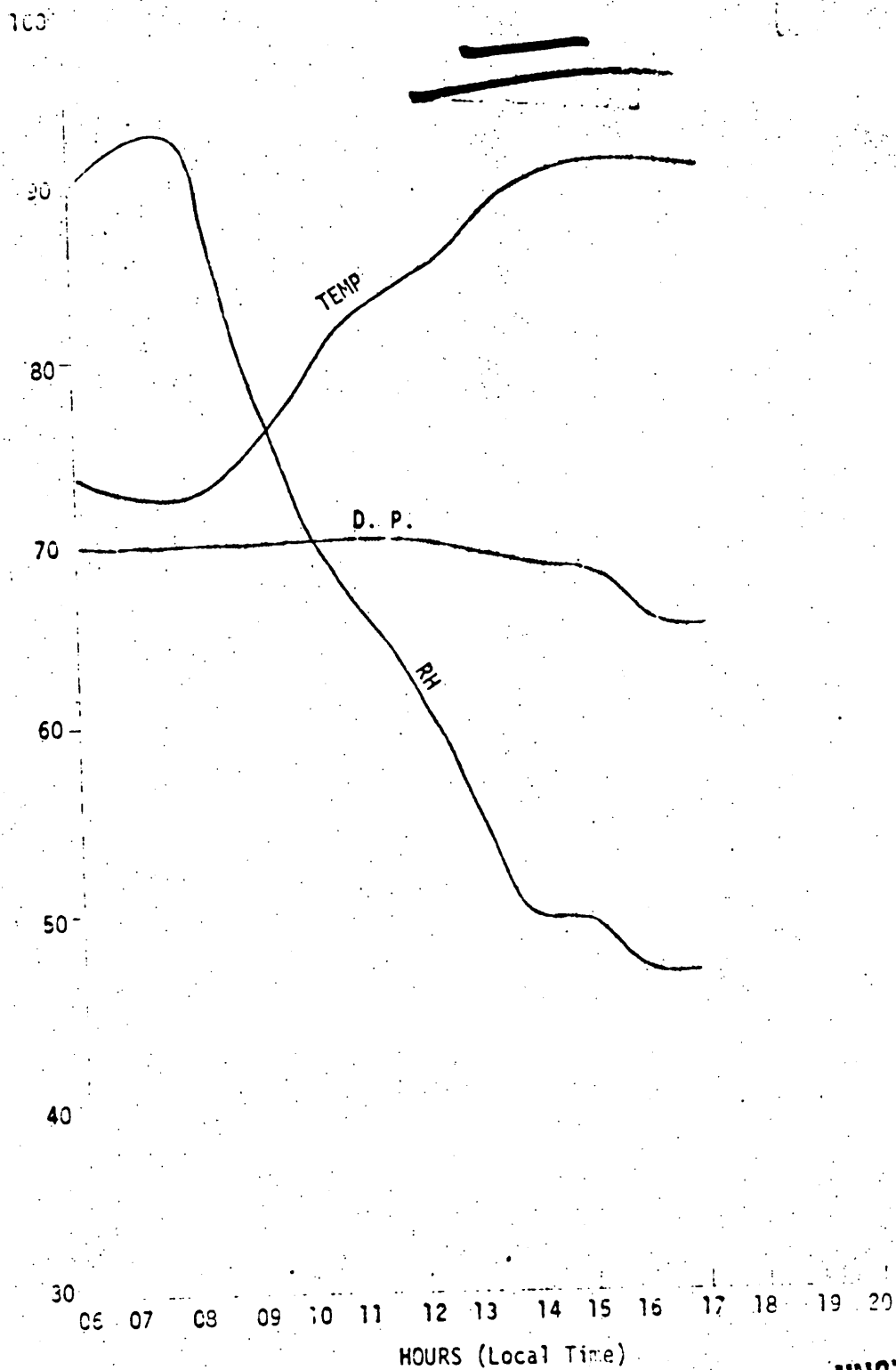


Figure 25.--Diurnal variation of temperature, dew point relative humidity for Tay Ninh, 28 January 1967.

TABLE 6. WEATHER OBSERVATIONS, 1400 LST, 28 JANUARY 1967

	<u>Bien Hoa</u>	<u>Tay Ninh</u>
Temperature	90°F	90°F
Dew Point	66°F	68°F
Relative Humidity	45%	48%
Sky Condition	25⊙/-⊙	40⊙/⊙
Stability Index	-	+4.5
Precipitation	0	0
Days since Precipitation	4 days	4 days (0800L)
Drying Days	3 + (.02 on 1/23/67)	3 + (.76 on 1/23/67 (Ton Son Nhut .25 on 1/23/67)
Precipitable Water	-	3.38 cm. (0800L)

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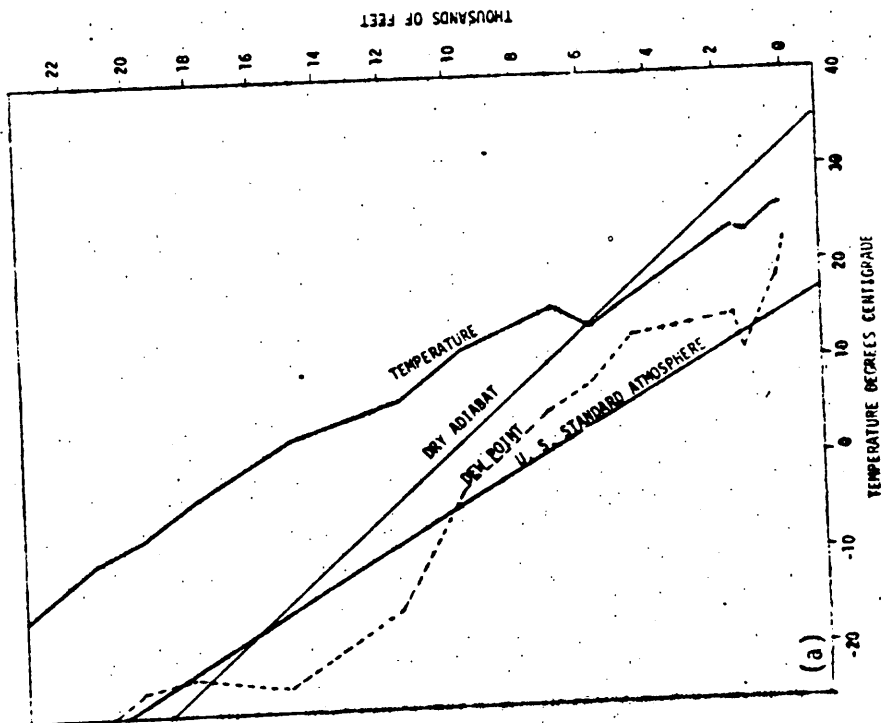
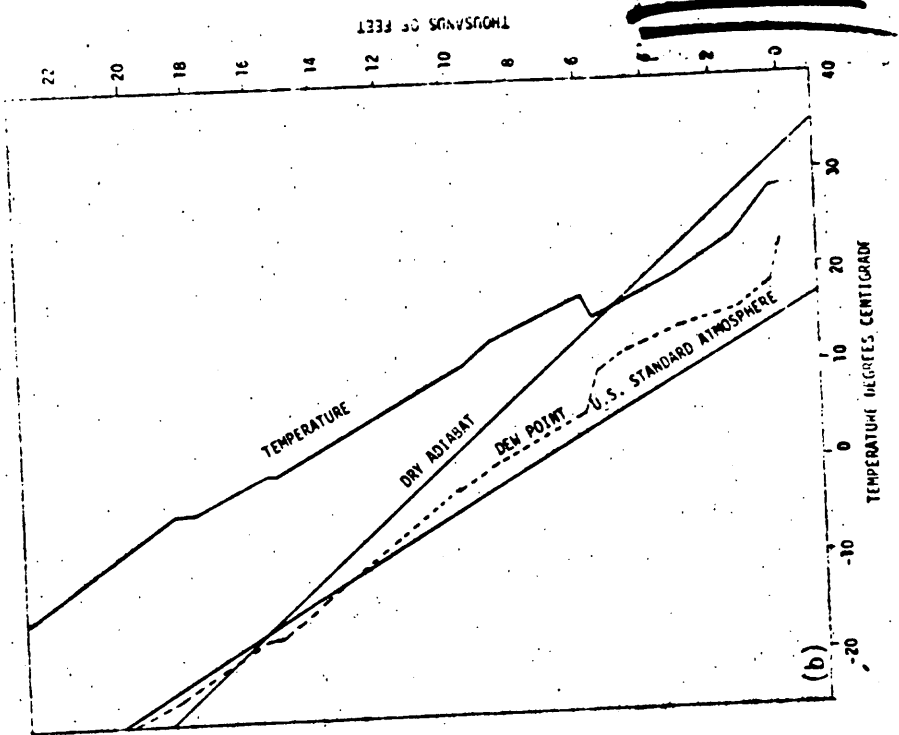


Figure 26.--RAOB's for Tay Ninh at (a) 04Z (12L), 27 January 1967 and (b) 04Z (12L), 28 January 1967.

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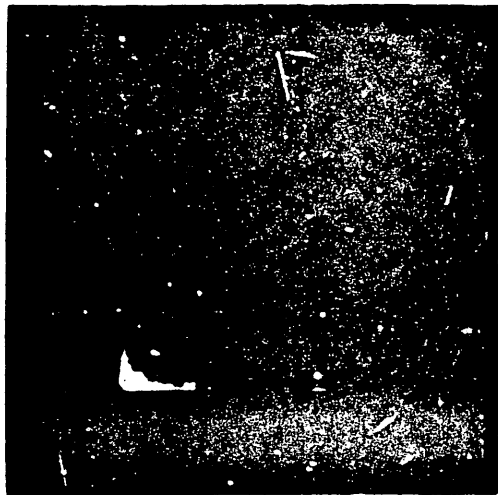
airport measured an echo height of 10,000 feet MSL. Beam width is the most likely explanation for the difference in values. A series of radar photos illustrates the fire image on the RHI and PPI scopes of the CPS-9 Weather Radar (Figure 27). The 9,000 foot top indicates an effective temperature of 105°F. was achieved in a small part of the fire. Maximum height occurred at 1445 LST (TOT + 40 minutes) and coincides with the period of most intense burning activity. However, 12 minutes later at 1457 LST the radar top had decreased to 8,000 feet and continued to decrease rapidly as did the burning activity.

PINK ROSE III, AREA B, 4 April 1967

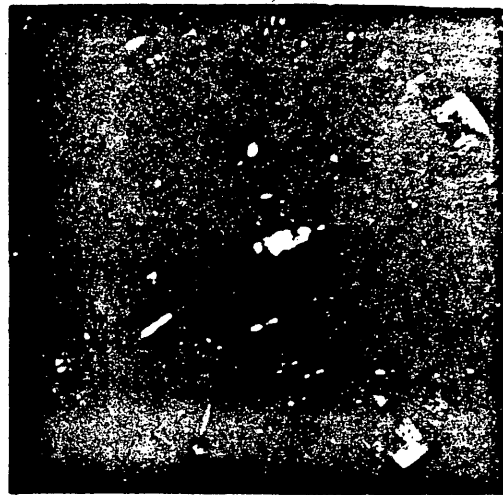
Area "B" (Figure 13) was ignited at 1400 LST, April 4, 1967 under fairly good atmospheric conditions in spite of the cloud cover present at TOT. A low layer of clouds existed at 3,500 feet MSL, along with an overcast of unmeasured height, but which was estimated to be 7,000 feet MSL until after 1300 LST. This cloud cover prevented early evaporation of dew in the general target area. Although the relative humidity dropped to 51 percent at 1300 LST and was estimated to be 45 percent at TOT, there was very little drying time available to properly condition fuels.

The upper-air streamline charts (Figures 28-33) from the period March 31, 1967 through April 5, 1967 were typical of the end of the strong northeast monsoon and its subsequent breakdown prior to the onset of the southwest monsoon. A low pressure center over northern Indo China was already apparent from the surface through the 850 millibar level, and accounted for the southwesterly flow over the southern half of South Vietnam. This southwesterly flow was supported by anticyclonic

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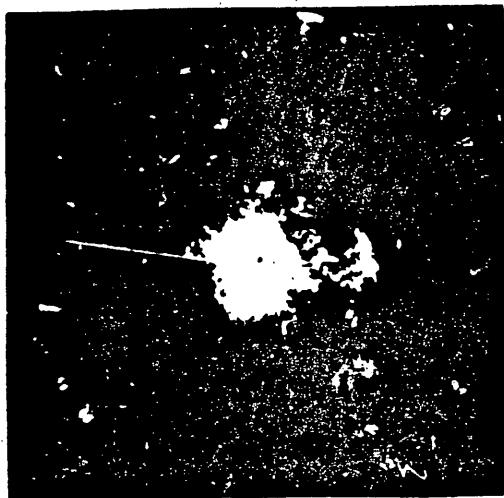


THOUSANDS OF FEET

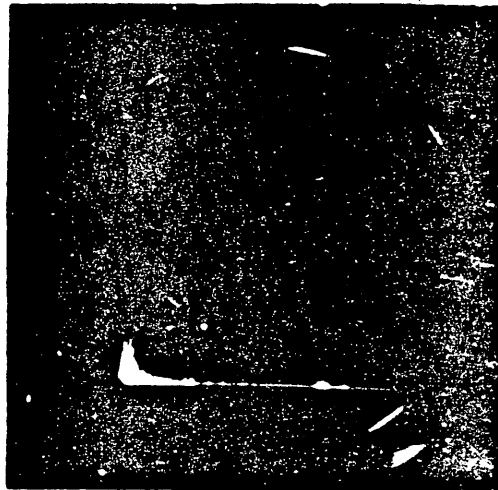


DATE: 28 Jan 1967 TIME: 1428 LST
AZIMUTH: 345°
HORIZONTAL SCALE: 75 mi.

DATE: 28 Jan 1967 TIME: 1430 LST
STC: Off SCALE (PPI): 75 mi.
PULSE LENGTH: Long
ELEVATION: 2°
REMARKS: Off center - returns at
57 statute miles



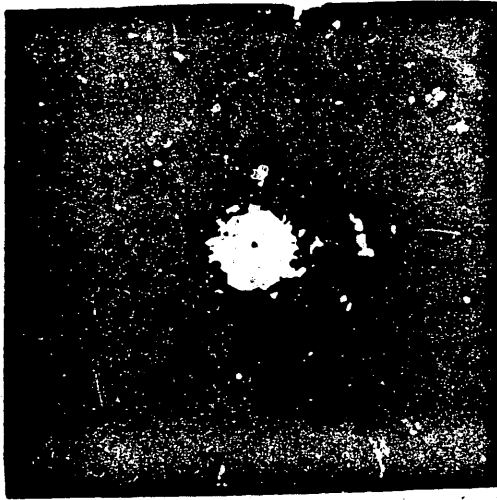
DATE: 28 Jan 1967 TIME: 1430 LST
STC: Off SCALE (PPI): 75 mi.
PULSE LENGTH: Low
ELEVATION ANGLE: 2°



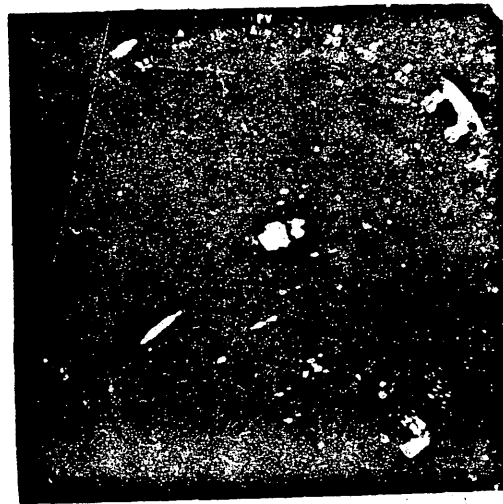
DATE: 28 Jan 1967 TIME: 1430 LST
AZIMUTH: 345°
HORIZONTAL SCALE: 75 mi.
REMARKS: Off center - returns at
57 statute miles

Figure 27.--C.P.S.-9 weather radar photographs taken at 1428 and 1430 LST on 28 Jan 1967 showing echos of target area "A".

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DATE: 25 Jan 1967 TIME: 1440 LST
 STC: Off SCALE (PPI) 75 mi.
 PULSE LENGTH: Low
 ELEVATION ANGLE: 2°
 REMARKS: Range marker at 57 st. mi.

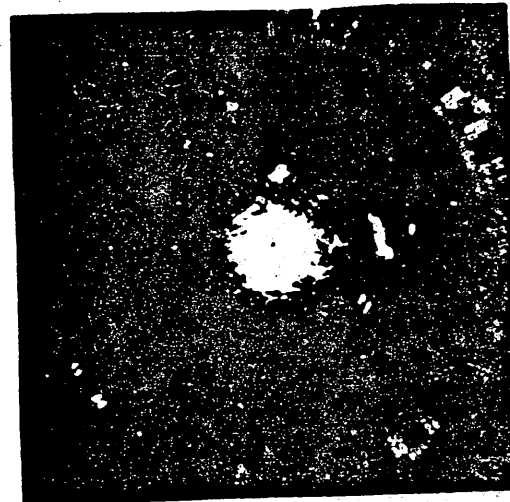


DATE: 26 Jan 1967 TIME: 1440 LST
 STC: Off SCALE (PPI) 75 mi.
 PULSE LENGTH: Low
 ELEVATION ANGLE: 2°
 REMARKS: Area of burn 10 mi. x 10 mi. at 54 st. mi.



DATE: 28 Jan 1967 TIME: 1445 LST
 AZIMUTH: 345°
 HORIZONTAL SCALE: 75 mi.
 REMARKS: Tops of echo at 9000 ft.

THOUSANDS OF FEET

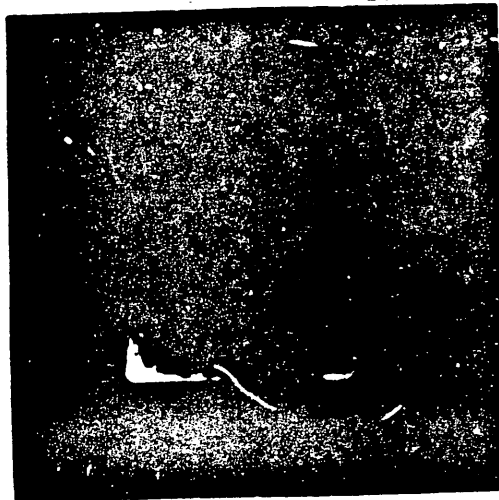


DATE: 28 Jan 1967 TIME: 1445 LST
 STC: Off SCALE (PPI) 75 mi.
 PULSE LENGTH: Low
 ELEVATION ANGLE: 2°

Figure 27.-- Continued



DATE: 28 Jan 1967 TIME: 1455 LST
 STC: Off SCALE (PPI): 75 mi.
 PULSE LENGTH: Long₀
 ELEVATION ANGLE: 2°
 REMARKS: Range marker 342°/57 st. mi.

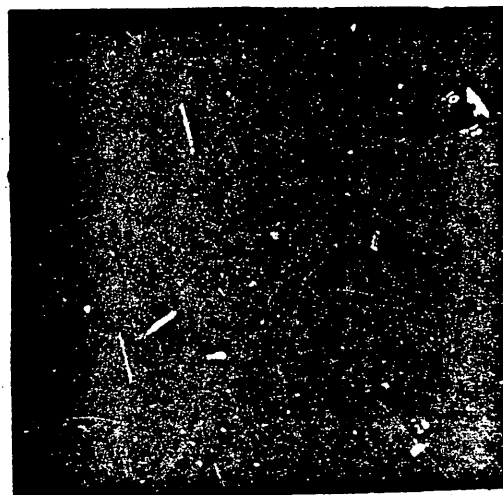


DATE: 28 Jan 1967 TIME: 1457 LST
 AZIMUTH: 344°
 HORIZONTAL SCALE: 75 mi.
 REMARKS: Tops of echo 8750 ft.

THOUSANDS OF FEET

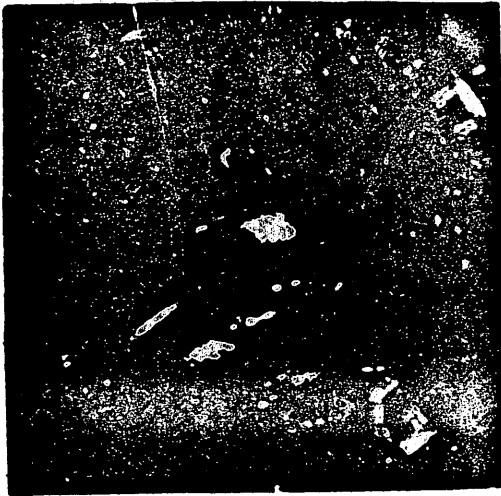


DATE: 28 Jan 1967 TIME: 1503 LST
 STC: Off SCALE (PPI): 75 mi.
 PULSE LENGTH: Long₀
 ELEVATION ANGLE: 2°
 REMARKS: Range marker 342°/57 st. mi.



DATE: 28 Jan 1967 TIME: 1512 LST
 STC: Off SCALE (PPI): 75 mi.
 PULSE LENGTH: Long₀
 ELEVATION ANGLE: 2°
 REMARKS: Range marker 342°/57 st. mi.

Figure 27.--Continued



DATE: 28 Jan 1967 TIME: 1520 LST
 STC: Off SCALE (PPI) 765 m.
 PULSE LENGTH: Long
 ELEVATION ANGLE: 2°
 REMARKS: Expandable scope,
 O/C 342°/57 mi.



DATE: 28 Jan 1967 TIME: 1521 LST
 STC: Off SCALE (PPI) 75 nat. mi.
 PULSE LENGTH: Long
 ELEVATION ANGLE: 2°



THOUSANDS OF FEET

DATE: 28 Jan 1967 TIME: 1523 LST
 HORIZONTAL SCALE: 75 st. mi.
 AZIMUTH: 344°
 REMARKS: Tops of echo at 5000 ft., 344°

Figure 27.--Continued

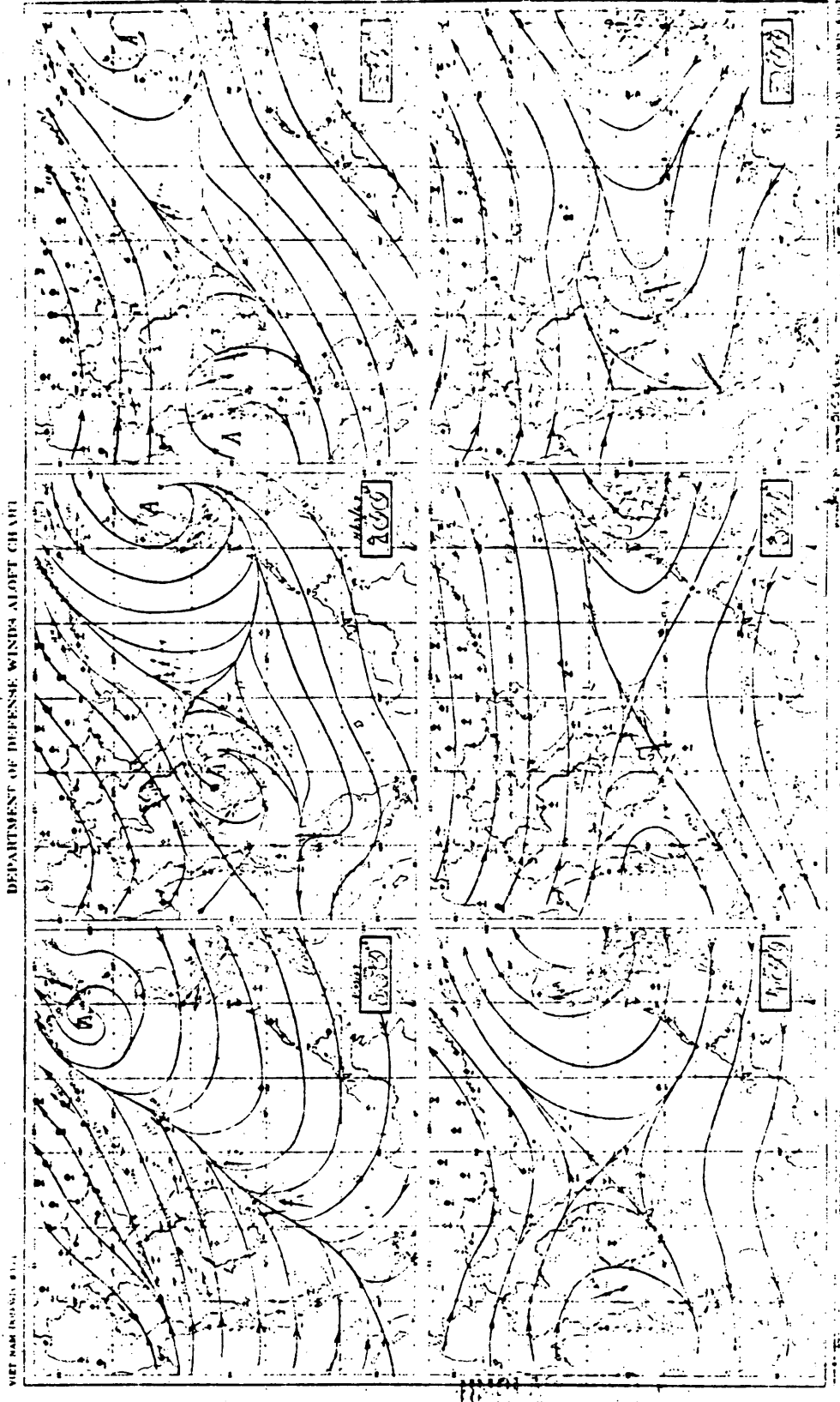


Figure 28.--850, 700, 500, 400, 300 and 200 millibar level streamline analyses for 00Z (08L), 31 March 1957.

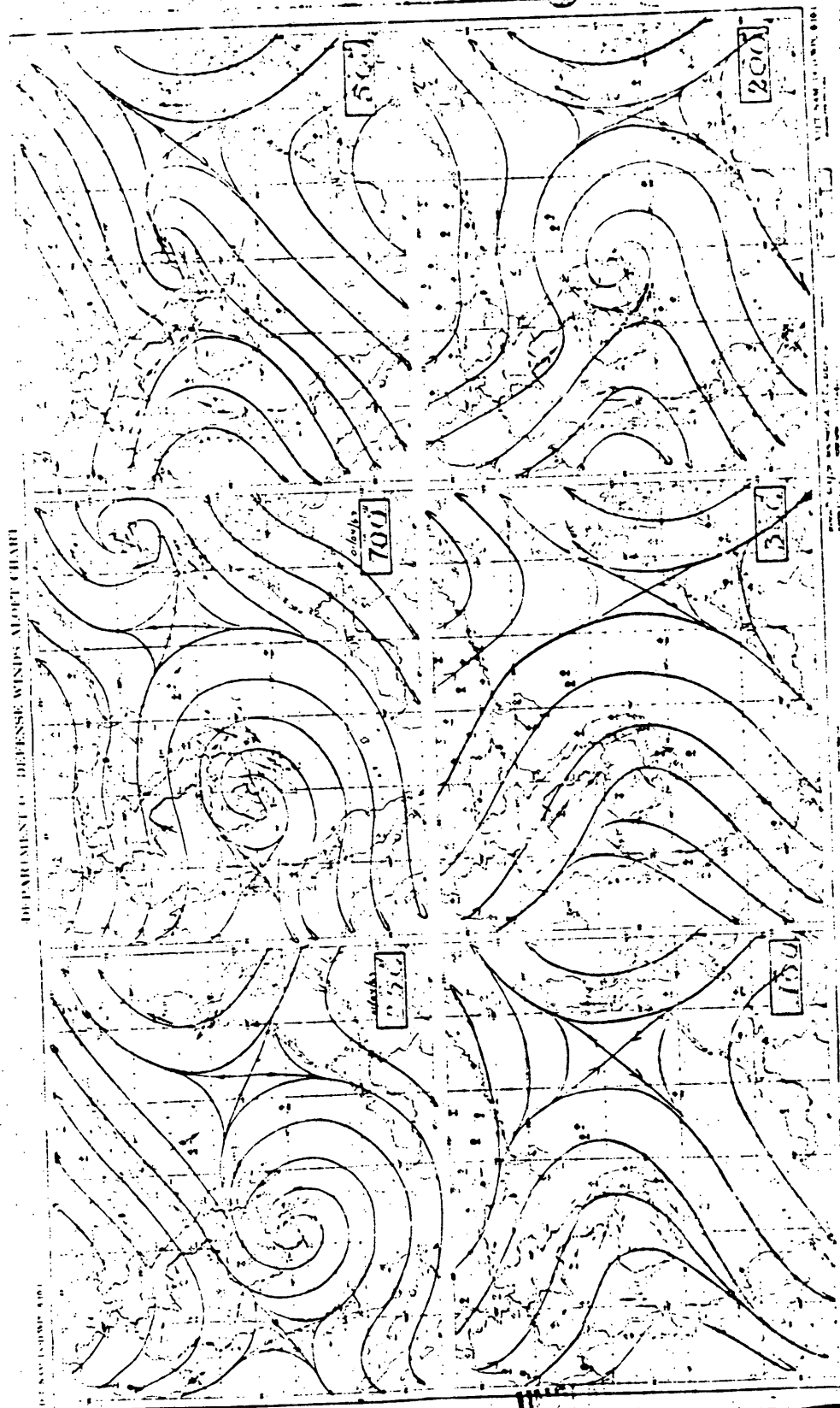
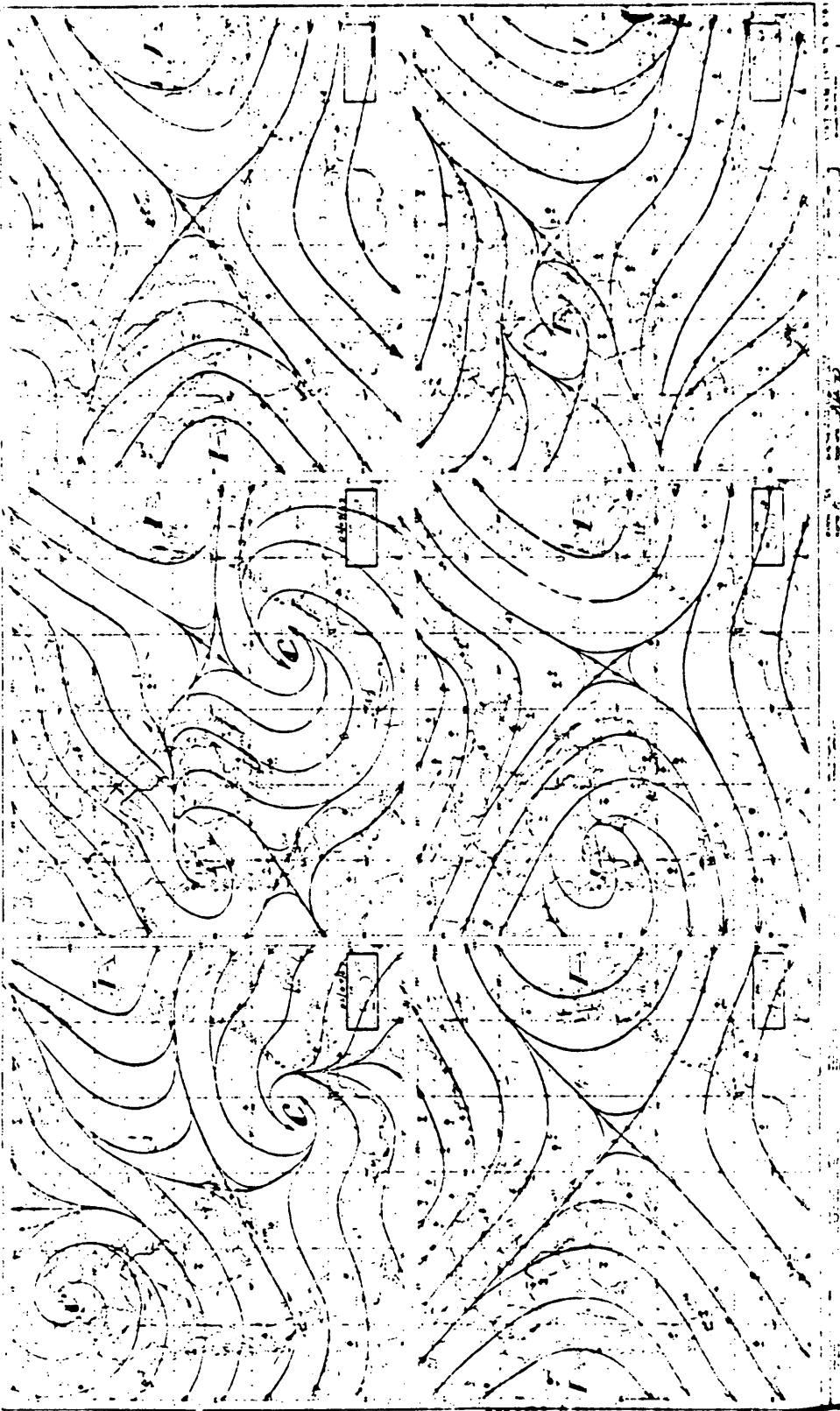


Figure 20 - 950, 700, 500, 410, 300 and 200 millibar level streamline analyses for 00Z (09L).

DEPARTMENT OF DEFENSE WINDS MODEL CHART



1000, 500, 200, 100, 500, 400, 300, and 200 millibars level streamline analyses for 04Z (03L).

DEPARTMENT OF DEFENSE WINDS AT 100 FT CHART



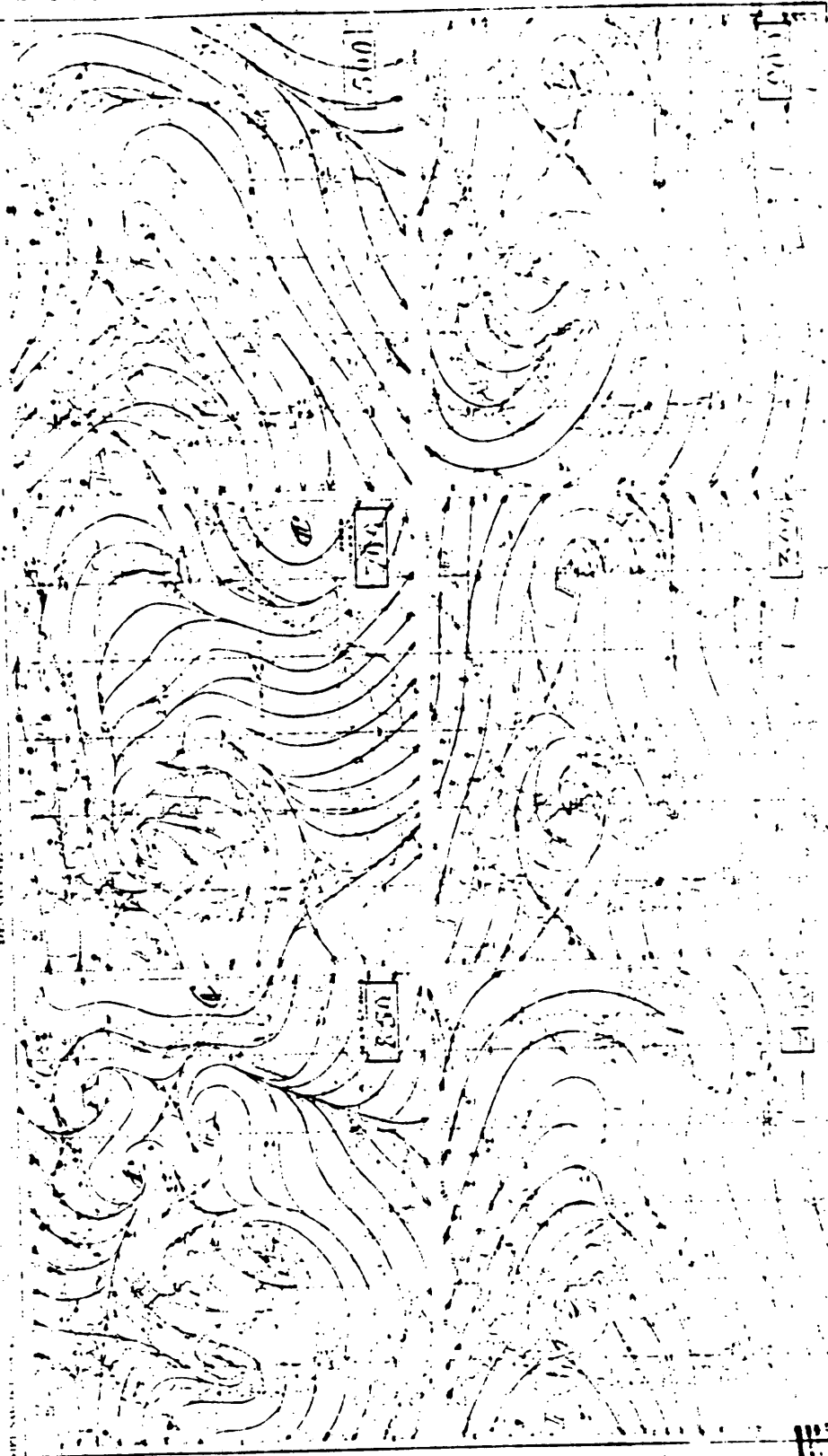
66

11

11

11 bar level stream line analysis for 0000Z
29 and 30 and 31 bar level stream line analysis for 0000Z
April 1967

DEPARTMENT OF DEFENSE WINDS ALBERT CHART



1000

streamline flow from a center located just off the South Vietnamese coast, which at times during the period April 1-5, 1967 was located as far east as the Philippines. The two flows caused the development of a convergence zone over the mainland intermittently during the period. Recorded rain fell only on the 3rd of April at Bien Hoa. No other moisture was noted other than fog at many stations in South Vietnam on the mornings of April 2, 4, and 5. Fog is of no surprise since the temperature-dew point spread was as low as 3-4°F. at 0600 LST. However, there was no fog in the target area on the morning of April 4. Clouds are apparent in Nimbus II photo prior to TOT, Figure 34.

Flow at 700 millibars and above was generally northeasterly with the center of a fairly intense anticyclone located over Thailand, Burma and Laos. Figure 35 shows the Tay Ninh RA08 for 0400Z (1200 LST). Tay Ninh is located about 10 miles south of the target and can be considered as representative of the target area. This sounding indicated a (Convective Condensation Level) of 2,300 feet and a LFC of 3,200 feet. A convective temperature of 99°F. was nearly achieved between 1200 and 1800 LST when the maximum temperature was estimated to be 97°F. at Tay Ninh and probably near 95°F. to 96°F. at TOT (Figure 36). The normal TOT boost expected from good combustion should have been more than adequate to establish a substantial convection column to 20,000 feet or higher. After TOT a cumulus cloud over the fire area developed to an estimated height of 50,000 feet. Therefore we can reasonably conclude that the forest fuels and the incendiaries together did burn intense enough to provide an equivalent surface temperature boost of at least 5-7°F.

Compared to targets "C" and "A" the atmosphere was more unstable

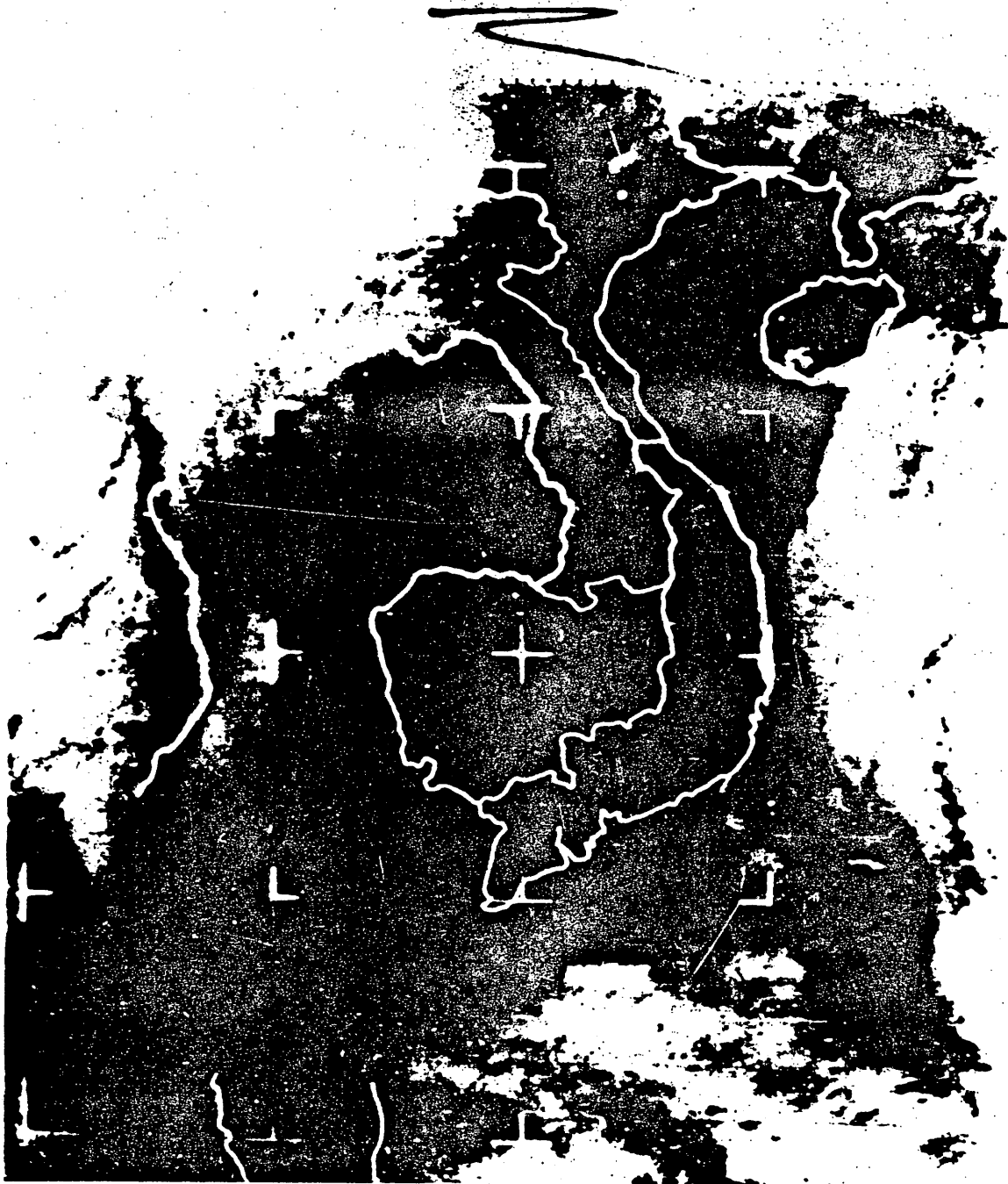


Figure 34.--Nimbus II photograph for 0435Z (1235L) 4 April 1967
Note: Clouds are black; clear areas are white.

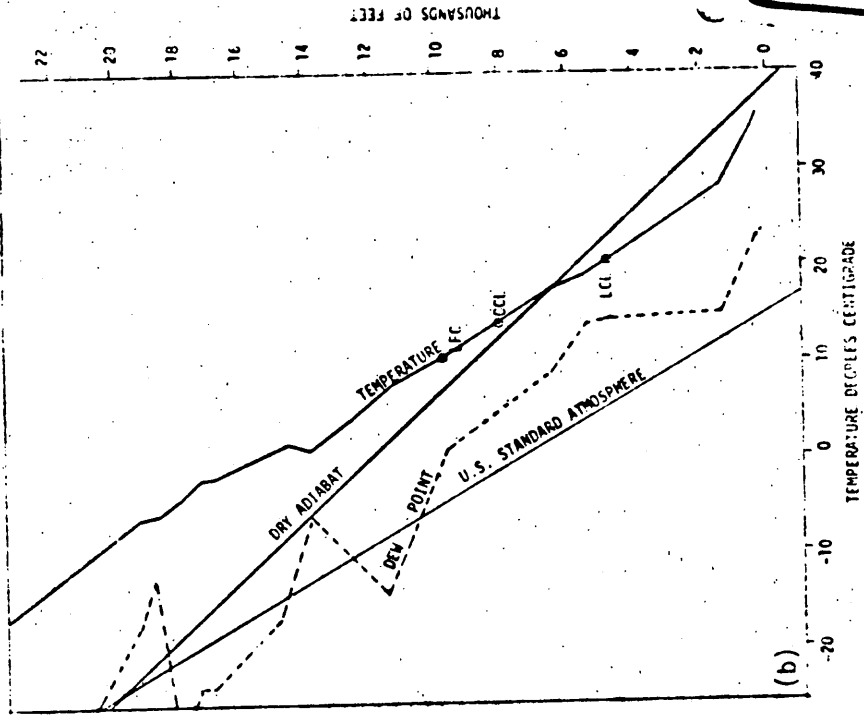
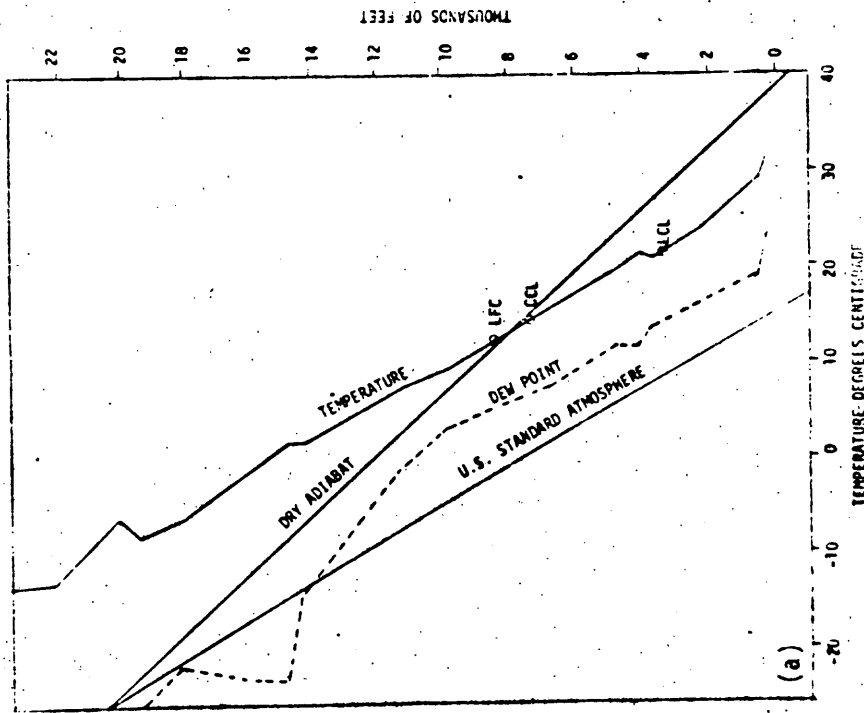


Figure 35.---RAOB's for Tuy Ninh at (a) 04Z (12L) 4 April 1967, and (b) 10Z (18L), 4 April 1967.

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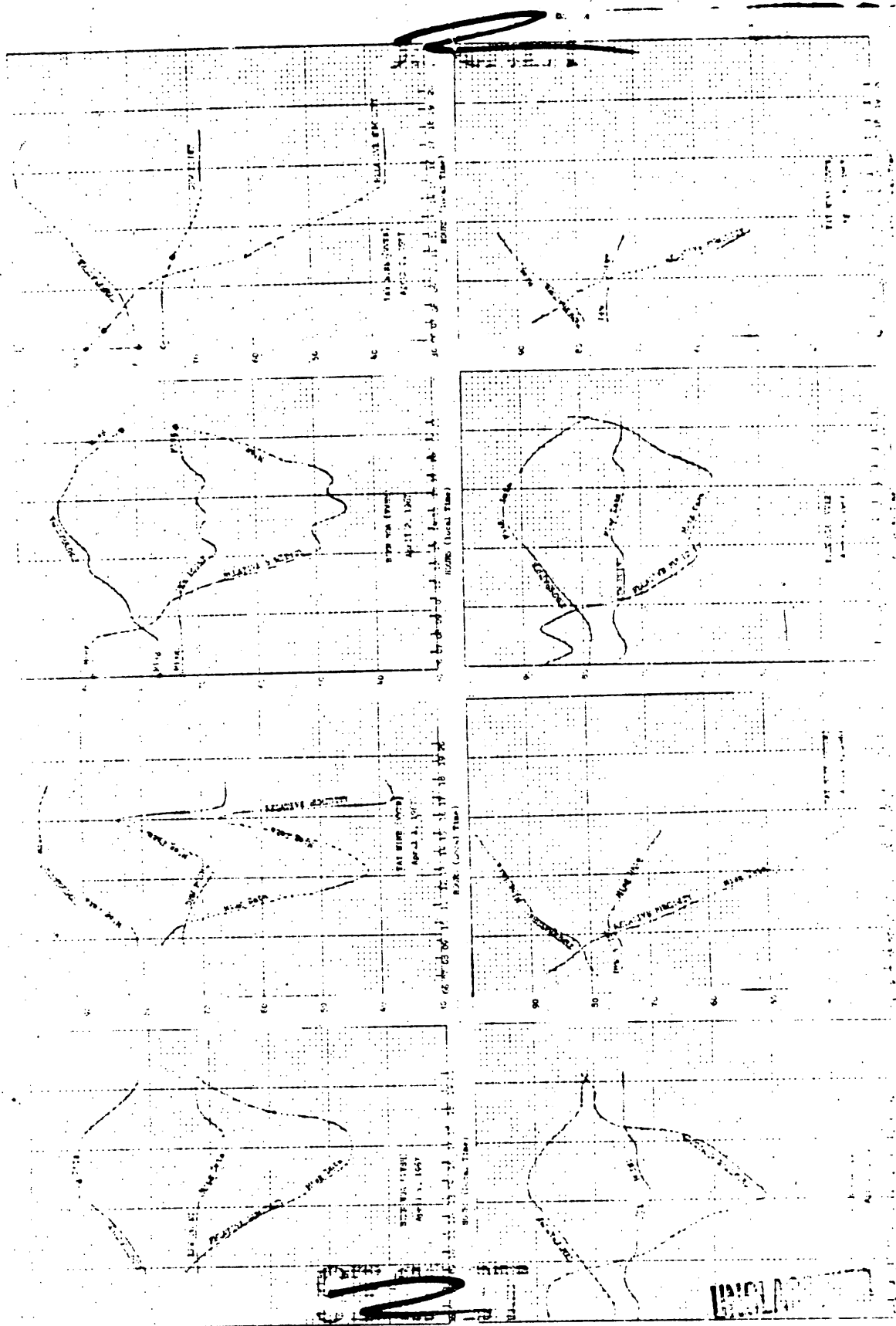


Figure 10. Hourly variation of temperature, dew point and relative humidity at Bangor and Jay High School, Bangor, ME, April 1-2, 1967.

at TOT over target "B". The Showalter Index over target "B" was
1200 LST decreasing to -0.5 at 1800 LST (Figure 35).

In spite of the size of the convective column, ground recon-
naissance indicated a relatively poor burn occurred. Cloud cover
over the target is a probable explanation for poor fuel conditions and
the resulting poor burn. Nighttime condensation permitted the light
and medium fuels to absorb moisture which was not evaporated between
1200-1400 LST--a time when cloud cover would normally be expected to
decrease. On April 4, 1967 at 1300 LST the target was still overcast.
Target weather is illustrated by daily weather observations at Bien Hoa
and Tay Ninh from April 1-5, 1967 (Figure 37 and Table 7).

Considering the meteorological conditions at TOT it would seem that,
in spite of fuel conditions, the energy developed in the fire (due to the
increased density of incendiaries) was enough to force the convection
column through the overcast layer at 7,000 feet to the LFC where additional
energy from the condensation process permitted the continued growth of
a cumulus cloud above the convection column from the fire. A cloud
reaching the estimated height of 50,000 feet would probably cause
precipitation and could account for the standing water observed by the
ground reconnaissance team the morning after the burn.

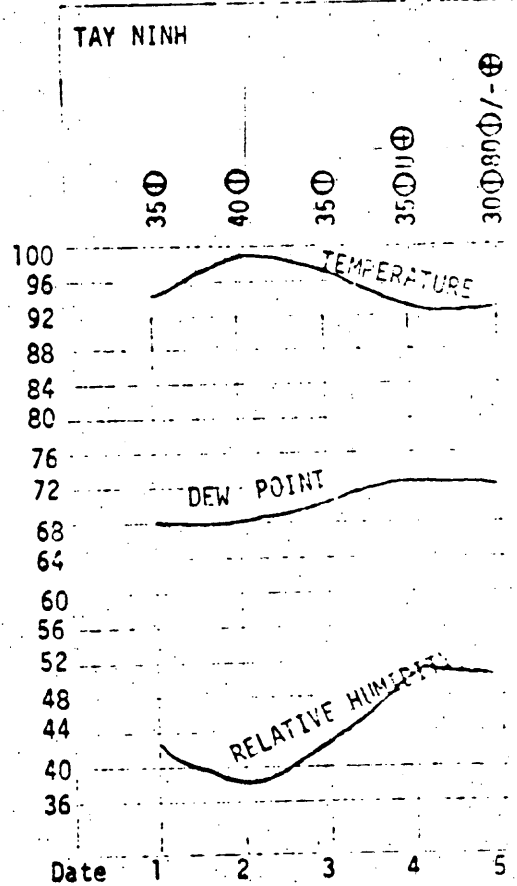
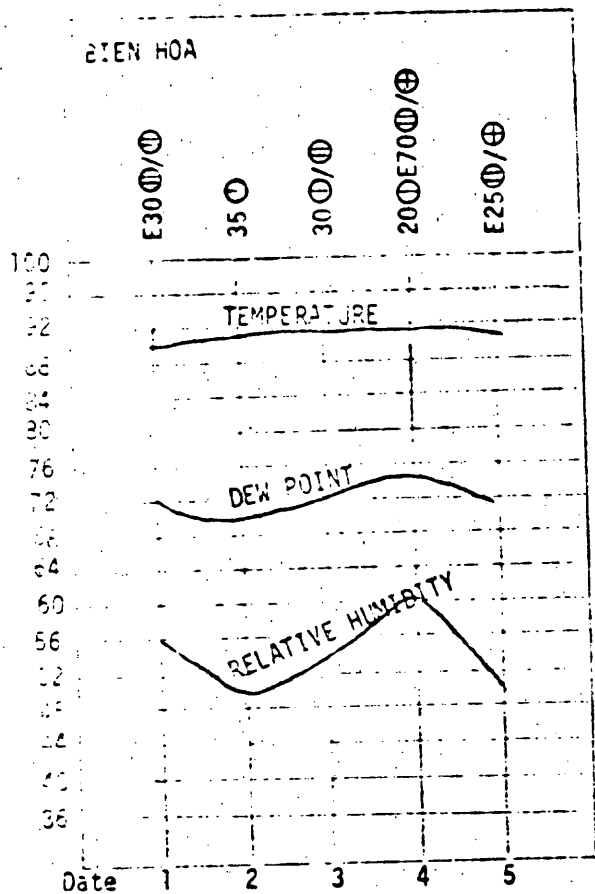
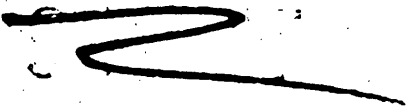


Figure 37.--Temperature, dew point, relative humidity and clouds at Bien Hoa and Tay Ninh for 1-5 April 1967.



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TABLE 7. WEATHER OBSERVATIONS AT BIEN HOA AND TAY NINH

Date	°F Temp		°F Td		% R. H.		PCPN		Sky Condition		Stability	
	TN	BH	TN	BH	TN	BH	TN	BH	TN	BH	TN	BH
1 Apr 67	95	90	68	72	42	56	-	-	35⊙	E30⊙/⊙	-	-
2 Apr 67	99	91	68	70	37	51	-	-	40⊙	35⊙	-	-
3 Apr 67	97	91	70	72	42	54	-	-	35⊙	30⊙/⊙	-	-
4 Apr 67	93	90	72	75	51	62	-	-	35⊙U⊙	20⊙E70⊙/⊙	+1.5	-
5 Apr 67	93	91	72	70	51	51	-	-	30⊙80⊙/-⊙	E25⊙/⊙	-	-

Observations at 1400 LST except as indicated
 *1500 LST; **1300LST; ***1200LST

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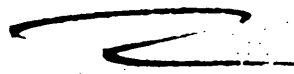
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APPENDIX 1

Dew Point Depression as a Forecasting Aid
For Pink Rose Operations

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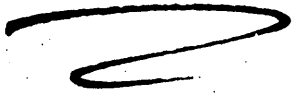
APPENDIX 1

Dew Point Depression as a Forecasting

Tool for Pink Rose Operations

As a limited time while I was in South Vietnam and had ready access to surface and upper-air data from field locations on a day-to-day basis I was able to tabulate dew-point depression with height. A sample of about 3 weeks of data appears in Figure 38 for Tay Ninh. This station is located about 49 nautical miles northwest of the DMZ, just inside the international border.

The relationship of moisture with height is readily seen to be associated with middle and upper-level cloudiness and to some extent with precipitation. Table 4 shows that precipitation occurred at Tay Ninh on 11-18, 1967, and on 21 January, 1967. This is closely associated with moisture in the lower levels (under 4,000 feet MSL) and cooling in the upper levels (6,000-20,000 feet). These changes in atmospheric structure would take place slowly enough for trend forecasts to be made based solely on cool advection aloft and low-level moisture, which together are conducive to shower activity. For operational work similar to that of the Pink Rose experiments it would appear that such information could be helpful in planning operations.



2

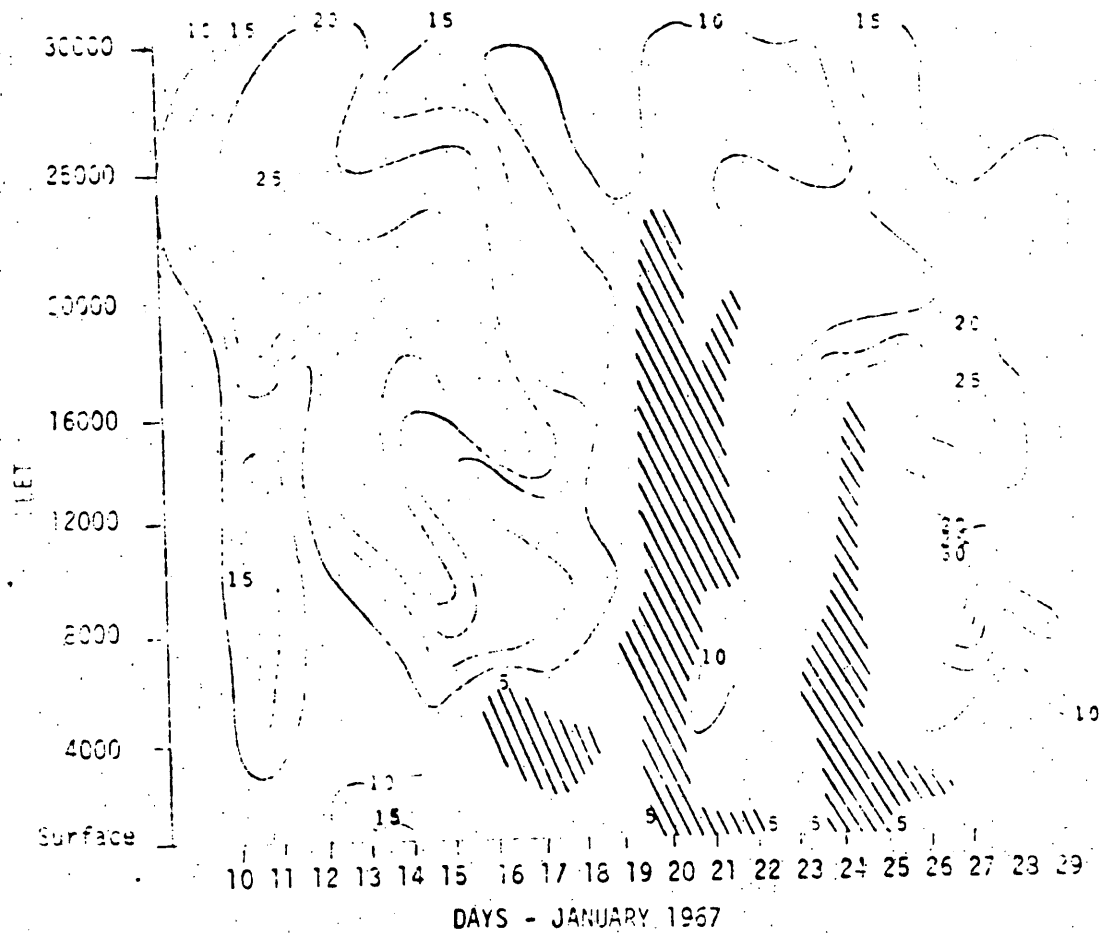


Figure 38.--Dew Point depression with height at Tay Ninh Airport
10-29 January 1967.

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APPENDIX II

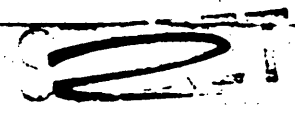
PROGRAM FOR MARKOV CHAIN

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Appendix II

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2

APPENDIX III
DICTIONARY OF NAMES

2

1950

HELFMAN PROJECT EMOTE

Z

IBLDR -- JGB 00000

MEMORY MAP

SYSTEM, INCLUDING IOCS

00000 THRU 12217

FILE BLOCK ORIGIN

12226

NUMBER OF FILES - 2

- 1. S.FBIN 12226
- 2. S.FBGU 12251

OBJECT PROGRAM

12274 THRU 16043

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- 2. DECK -DECODE- 12474
- 3. DECK -CHRTAB- 12640
- 4. DECK -CHRINS- 12740
- 5. DECK -STRING- 13022
- 6. SUBR -INSYFB- 13102
- 7. SUBR -OUSYFB- 13141
- 8. SUBR -POSTX - 13172
- 9. SUBR -CNSTNT- • 13311
- 10. SUBR -FC5 - 13321
- 11. SUBR -FO6 - 13322
- 12. SUBR -IOS - 13323
- 13. SUBR -RWB - 13601
- 14. SUBR -RWD - 14213
- 15. SUBR -ACV - 14721
- 16. SUBR -HCV - 14751
- 17. SUBR -XCV - 15054
- 18. SUBR -TMTARR- 15072
- 19. SUBR -FPT - 15243
- 20. SUBR -XEM - • 15631
- 21. SUBR -XIT - 16042

(• - INSERTIONS OR DELETIONS MADE IN THIS DECK)

INPUT - OUTPUT BUFFERS

77067 THRU 77776

UNUSED CORE

16044 THRU 77062

OBJECT PROGRAM IS BEING ENTERED INTO STORAGE.

EMOTE STATION INDEX

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SOCTRANG, SOUTH VIETNAM	48913
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NHATRANG, SOUTH VIETNAM	48877
ZFQRRJGF32QKLZBIFQCR	600YY
PLEIKU, SOUTH VIETNAM	48866
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Z

SEARCHED

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MANDALAY, BURMA CFRRKRHVJJKRC	48042 64016
KENGTUNG, BURMA TFBQGFVJJKRC	48060 64047
VICTORIA POINT, BURMA ILQUJ3RI3SFIVQJKRC	48112 69019
SANDOWAY, BURMA ZFR3WRDVENJKRC	42080 64040
THARRAWADDY, BURMA ZQJRRJR0WVJJKRC	48088 64000
BASSEIN, BURMA RV22IBVFJKRC	48094 64065
MINGALADON, BURMA CFIRGRH3WVFJKRC	48096 64075
AKYAB, BURMA TRRNVVJKRC	48062 64017
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BAN DON, THAILAND RVWFF3ZQIRRHWF	48551 60090
PHUKET AIRPORT, THAILAND SKZBTRQJISQJZQIRRHWF	48565 60007
RANONG, THAILAND KJ3FGFZQIRRHWF	48532 60018
CHUMPHON, THAILAND ZUCKZSF3ZQIRRHWF	48517 600Y9
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VIENTIANE, LAOS LBIQFRIBFRH23	48940 65046
SENO, LAOS B23FRH23	48948 65C06
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UDORN, THAILAND K3WFJZQIRRHWF	48354 68060
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UBON, THAILAND VKF3ZQIRRHWF	48407 660Y4
NAKHON-RATCHASIMA, THAILAND PTR3Z-FRJUQRZI2RCZQIRRHWF	48431 66098
BANGKOK, THAILAND VFRTGT3ZQIRRHWF	48455 66000
WELLESLEY, MALAYA DH8BHH2NBRCRHRN	48602 67014
MALACCA, MALAYA CHRURRURCRHRN	48665 67C07
PENANG, MALAYA SRFGFRCRHRN	48601 67094
MEIKTILA, BURMA CIBQTHIVRJKRC	48053 64080
LASHIO, BURMA MELVJDKRC	48035 64000

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HUE, SOUTH VIETNAM ZBK32QKLZBIFQCR	48852 60010
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BAOLOC, SOUTH VIETNAM RVH3U332QKLZBIFQCR	48884 60060
DJIRING, SOUTH VIETNAM WIEIJGF32QKLZBIFQCR	48883 6C08C
DALAT, SOUTH VIETNAM WHRQR32QKLZBIFQCR	48881 60090
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THANH HOA, NORTH VIETNAM ZQFRZZR33FQJLZBIFQCR	48840 60046
MONCAY, NORTH VIETNAM 3CUFNR3FQJLZBIFQCR	48838 60008
THAI NGYEN, NORTH VIETNAM QRZFINGF83FQJLZBIFQCR	48831 60098
LANGSON, NORTH VIETNAM HFR2GF33FQJLZBIFQCR	48830 60048
VINH, NORTH VIETNAM ILZF3FQJLZBIFQCR	48845 60006
HANOI, NORTH VIETNAM ZFRI33FQJLZBIFQCR	48820 60041
CHAPA, NORTH VIETNAM URZRS3FQJLZBIFQCR	48802 60014
STUNG TRENG, CAMBODIA Q2FKQGBJGFRUVCW3RI	48972 6501Y
SVAY RIENG, CAMBODIA ZRLJNBIGFRUVCW3RI	48998 65005
KAMPOT, CAMBODIA	48985

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CHIANG MAI, THAILAND
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