

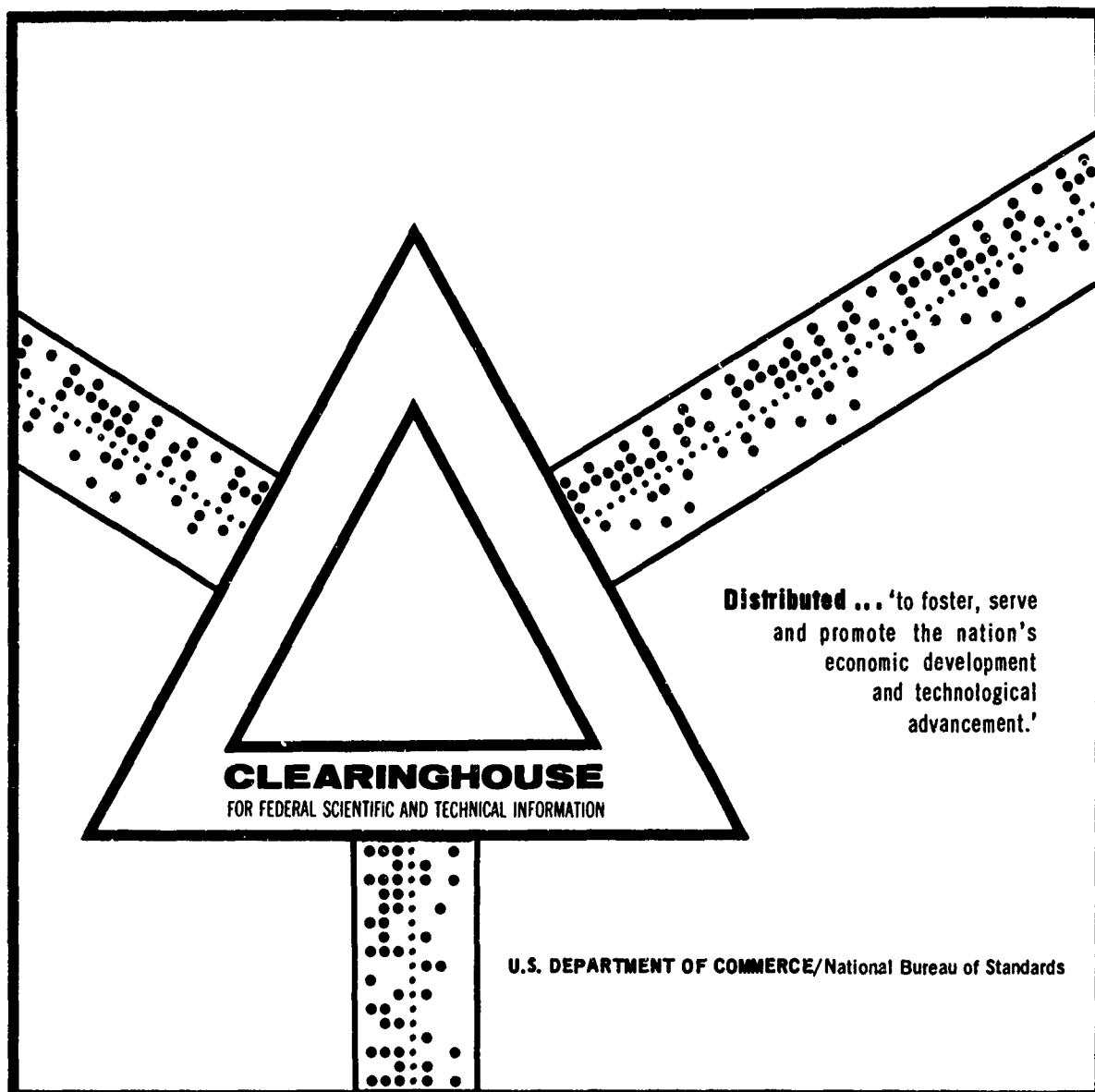
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**OPERATION FLAMBEAU - CIVIL DEFENSE EXPERIMENT
AND SUPPORT: EYEWITNESS ACCOUNTS OF A MASS FIRE**

Clay Preston Butler

**Naval Radiological Defense Laboratory
San Francisco, California**

May 1969



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AD 698135

OCD Work Unit No. 2561B

~~NAVAL RADIOLOGICAL DEFENSE LABORATORY~~

Final Report

OPERATION FLAMBEAU -

CIVIL DEFENSE EXPERIMENT AND SUPPORT

Eyewitness Accounts of a Mass Fire

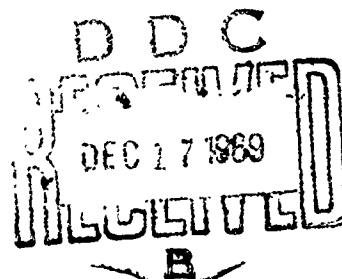
by

C. P. Butler, Editor

Prepared for Office of Civil Defense under Contract No. ~~DANC20-67-C-0149~~
Work Unit 2561B

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This report covers a portion of the work authorized
by the Office of Civil Defense under Work Order Number
DAHC20-67-C-0149, OCD Work Unit 2561B (continuation of work
of Work Unit 2536G).

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Eyewitness Accounts of a Mass Fire

by

C. P. Butler, Editor

Final Report Prepared Under Contract No. DAHC20-67-C-0149
Work Unit 2561B

for

Office of Civil Defense
Office of the Secretary of the Army
Washington, D. C. 20310

through

U. S. Naval Radiological Defense Laboratory
San Francisco, California 94135

May, 1969

OCD Review Notice

"This report has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense".

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ABSTRACT

Seven men, skilled in fire research were stationed around the periphery of FLAMBEAU FIRE 760-12 and recorded visual impressions of its magnitude. Their testimony furnishes indices of fire severity which is available to officials immediately.

At each of the times when eyewitness accounts are given, instrumental data were taken both inside the fire zone and outside, so that visual magnitudes of this mass fire may be compared with its measured physical parameters.

Visual magnitudes for this fire are:

- a. Flame heights up to 300 feet, horizontal flames 100 feet;
- b. Thermal radiation uncomfortable at 75 feet.
- c. Able bodied men might escape from center of fire.
- d. Cap cloud at 3000 feet.
- e. Streets filled with smoke.
- f. Fire whirls lifted bushes 100 feet.
- g. Downwind side of fire showed much more severe activity than the upwind.
- h. Firebrands were carried more than 200 feet out of the fire on the downwind side.

SUMMARY

The Problem

Visual impressions of the magnitude of a large fire are the sole method by which officials may make immediate decisions on its severity. Past impressions from eyewitnesses lack instrumental verification of physical parameters defining the magnitude or severity inside the fire zone. FLAMBEAU FIRE 760-12 offered an opportunity for witnesses to describe their impressions of an instrumented fire.

The Findings

From an analysis of the testimony of seven (7) eyewitnesses, all skilled fire researchers, the following magnitudes were estimated for FLAMBEAU FIRE 760-12.

- a. Flame heights up to 3000 feet, horizontal flames 100 feet.
- b. Thermal radiation uncomfortable at 75 feet.
- c. Able bodied men might escape from center of fire.
- d. Cap cloud at 3000 feet.
- e. Streets filled with smoke.
- f. Fire whirls lifted bushes 100 feet.
- g. Downwind side of fire showed much more severe activity than the upwind.
- h. Firebrands were carried more than 200 feet out of the fire on the downwind side.

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1. INTRODUCTION

The objectives of Work Unit 2536G, initiated under OCD Task Order 2530(68), are as follows:

Objective: The purpose of this work is to assess and increase the usefulness to OCD of data gathered during Operation FLAMBEAU fire 760-12 and to insure coordination of the efforts of OCD contractors in performing any experiments that OCD may sponsor at future Operation FLAMBEAU fires.

Scope: This is a continuing study. The work to be done in the first year of effort will include analyzing and evaluating the usefulness to OCD of the data gathered in past Operation FLAMBEAU fires, collecting or abstracting the appropriate data in a form suitable for OCD use, and making recommendations concerning the use of Operation FLAMBEAU fires for the gathering of supplemental data or data more pertinent to OCD needs. In subsequent years, the effort will include additional work on these items and also the coordination of efforts of OCD contractors in the performance of any experiments that OCD may sponsor in connection with Operation FLAMBEAU fires.

Historically, man's response to fire has been tempered by the size and threat posed by fire. When a fire is out of control we concentrate on escape and rescue. Normally, effectiveness of such efforts is enhanced by advanced planning and practice. Consequently, the world's great fires, such as those started by aerial bombing in World War II, have been studied in great detail and provide guidance in preparing for disaster control. Of course, these classical fires were not instrumented and fire reports must depend on visual sensations.

The FLAMBEAU series of burns which were both carefully instrumented and observed, provides an important link in establishing a picture of a mass fire environment. Beginning in 1962, with single fire environments of approximately 20 tons of pinyon and juniper trees piled in a square area 50 feet on each side and 6 feet high, the characteristics of this type of fuel burning freely in the open air have been studied in great detail. In succeeding burns, the number of piles was increased, culminating in the FLAMBEAU fire 760-12 in September 1967.

As part of this test, seven men, experienced in fire research recorded their visual impressions throughout the course of the burn. This report examines excerpts from these transcriptions for factors which place restraints on escape and rescue. In particular, we look at the chronological development of the fire, the street level environment and factors relating to magnitude. The time element is important in establishing the initial escape possibility, the period of confinement in shelters and the time when the fire area can be reentered. The street level environment determines the life hazards in the fire area. This environment is complex and involves temperature, heat loadings, the extent of flames, smoke, noxious combustion products and fire generated winds. Such visual observations as scampering rabbits or unburned weeds influence our concept of the magnitude of the life hazard.

Finally, the factors relating to magnitude play an important role in extrapolating to the fires anticipated following a nuclear attack. The visible extent of the flames, and the diameter and height of the smoke column give dimensions to the fire. FLAMBEAU fire 760-12 was a big fire involving 342 piles of pinyon trees spread over an area of 44 acres. The life hazards were very real and lethal levels of heat and noxious products restricted access to the burn area for substantial periods of time. However, the total fire area is one to two orders of magnitude smaller than such fires as Hiroshima, Tokyo and Hamburg, so the concepts of escape will require considerable extrapolation.

2. THE WITNESSES

The following seven men whose transcripts are given in this report, together with their respective sponsoring institutions, are:

1. Theodore G. Storey
Research Forester
Pacific Southwest Forest and Range Experiment Station
Riverside, California 92507
2. Richard C. Rothermel
Project Leader
Intermountain Forest and Range Experiment Station
Missoula, Montana 59801
3. Michael Woolliscroft
Fire Research Station
Boreham Wood, Herts.

4. Clive M. Countryman
Project Leader
Pacific Southwest Forest and Range Experiment Station
Riverside, California 92507
5. A. M. Western
Home Office
Horseferry House, Dean Ryle Street
London, S.W. 1
6. Abraham Broido
Pacific Southwest Forest and Range Experiment Station
Berkeley, California 94704
7. Thomas Y. Palmer
Project Leader
Pacific Southwest Forest and Range Experiment Station
Riverside, California 92507

All observers stood about 200 feet from the outer edge of the fire in the beginning at ignition time and were able to see the entire length of each street. The streets were laid out in straight lines; hence, smoke obscuration could be easily estimated. Some observers ventured down into these streets at some time after peak burning time and were able to walk between piles on the upwind side.

Figure 1 is a diagram outlining the fire area and showing the position of each of the eyewitnesses. After ignition, some of the men moved around the fire perimeter to more advantageous points, some remained in the same place throughout the narrative.

The accounts which follow are transcriptions of tape recordings made by these men who were supplied with portable recorders so they could walk around the outer edge of the fire and make continuous comments. Each had seen big fires before, and was familiar with the problems of identifying characteristics of a mass fire. Each knew beforehand where he would be stationed and the direction of the wind at the time of ignition. None was under the emotional stress associated with unplanned fires where lives and property may be at stake.

In reading these accounts, it will soon be apparent that some observers speak as though narrating a script for a movie, while others capture the magnitude of the fire as though they were watching a holocaust about to engulf them. Each man reflects a different technical background and interest, hence two observers standing near each other see and describe different phenomena.

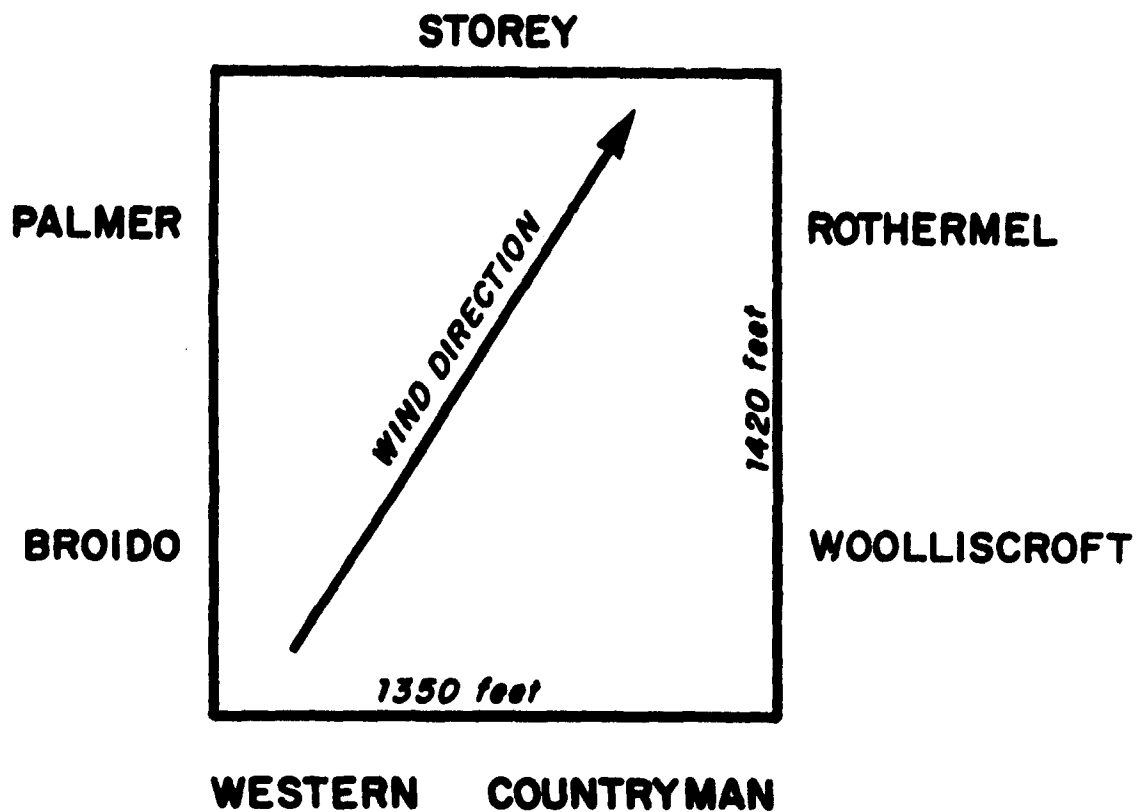


Fig. 1. Position of each eyewitness at start of FLAMBEAU Fire 760-12.

3. CONCLUSIONS

All the evidence so far accumulated indicates that FLAMBEAU 760-12 was a big fire. Its magnitude remains in doubt, largely because we have no scale on which to measure the effects responsible for what is called a mass fire.

This fire showed remarkable differences between fire effects on the upwind and downwind sides. Even though the ambient wind was only 1-2 miles per hour and the ignition pattern was uniform, all fire effects were less severe on the upwind side. Bushes in the middle of streets were not burned for at least 300 feet down from the upwind edge, whereas all vegetation in the streets was completely burned on the downwind edge. The intensity of the fire was visually very different from the two sides.

The conclusions presented below are drawn from the narratives of these eyewitnesses. It should be clear that these conclusions were never analyzed and were available immediately after the sentence had been dictated. If FLAMBEAU had been an urban area of equal fuel loading and burning rates, these conclusions would have been the only input data for civil defense officials responsible for the safety of the people trapped inside the fire zone.

This time, however, the conclusions are backed by the most extensive series of instrumental data so far employed in a big fire. Detailed intercomparisons between the material given by these eyewitnesses and that obtained by instruments will add valuable meanings to the words employed as descriptors.

4. MAGNITUDE OF FLAMBEAU FIRE

The following phrases taken from eyewitness accounts indicate the magnitude of this fire:

- a. Flame heights 25 feet high upwind, 200 to 300 feet downwind.
- b. Horizontal flames near ground 100 feet downwind, barely 25 feet on upwind side.
- c. Thermal radiation appreciable upwind at 50-75 feet from flames, 5 minutes later downwind observer reported danger from flames at 200 feet.
- d. An able bodied man could escape via shortest road (700 feet) if he started at zero time and did not tarry.

- e. Cap cloud formed over column at 300 feet.
- f. Streets filled with smoke, visibility very low.
- g. Bushes lifted 100 feet in the air.
- h. Firebrands were carried more than 200 feet out of the fire on the downwind side.

APPENDIX A

T. G. STOREY

This is Test Fire 760-12-67, September 29, 1967. Start of transmission of observations on the operation at the control point or fire headquarters.

- 0722 Ignition is tentatively set for 7:30, but it doesn't look like they'll make it. The weather is fairly clear with high cirrus clouds over about 50% of the sky and darker clouds along the horizon. They appear to be at a distance of about 20 or 30 miles. Wind is very light. It appears to be from the south at the present time, not more than one or two miles per hour. It appears to be gradually increasing.
- 0723 The Navy photo people are checking out their camera stations by radio from here at headquarters. The chief in charge is checking with them. They seem to be coming along pretty well.
- 0725 The fuel sampling part of the burn was completed on schedule at about 7:15. Ice has all been placed in the containers and junctions for the thermocouples.
- 0727 Northcutt just announced that they are tentatively planning for an 8:00 ignition. At about 7:20 Northcutt tested the horn, the little air horn or signal horn, to see if the distant stations could hear it across the plot. Apparently someone, one of the instrument stations, started their recorders thinking that it was the signal for ignition. But they've straightened that out.
- 0730 The helicopter has just landed from a short scouting mission next to headquarters. Countryman just phoned (radioed) in to headquarters that he would like to get the burn off as soon as possible. Meaning shortly after 7:30, apparently.
- 0732 Air officer Rossi just talked to the helicopter informing them that the B-52 is expected shortly on a dummy run. Apparently still coming, planning to come in from the north-northeast over Mina.

It is now 7:32 and the B-52 is just appearing to the west, almost due west. It came down from the north swinging in from the west, now approaching the plot. Appears to be planning to fly directly

T. G. STOREY

over the plot. I'll check on the elevation. On this run, coming in from the west, the B-52 was apparently just arriving to check out the lay of the land. He's now heading back to the northeast toward Mina and is supposed to turn and come back in on his dummy run at 350 feet above ground shortly.

- 0733 This is Ted Storey from headquarters.
- 0734 At 7:34 they have just requested radio silence, I believe that this is for the dummy run of the B-52. The helicopter has taken position to the north of the plot a little to the northwest, apparently. They may be just delivering a camera crewman.
- 0735 They are still on their radio silence. Radio silence is started a half hour before ignition. They plan ignition now at approximately 8:00.
- 0737 The B-52 is approaching from the northeast on his dummy run supposed to be at 350 feet above the ground, although he appears to be a little higher than that. He is flying directly across the plot at this time. Yes, directly across and then just over the plot he banked to the west, banked slightly to the west and circling, seems to be circling back, toward the west and then to the north. The first aid team from Hawthorne Naval Ammunition Depot is at the headquarters on standby.
- 0740 Northcutt just announced that the radios are going back on the air, they broke radio silence.
- 0741 Lou Rossi, air officer, was just telling me that the B-52 came over the plot on this run, this dry run, to get lined up whereas on his final run he will break a mile out and turn and climb to his right toward the west.
- 0742 The helicopter just landed on the pad at headquarters. Apparently they have been out on a run to the camera stations.
- 0743 Northcutt is checking with all the camera stations for readiness, one after the other.
- 0745 Now Northcutt is having trouble reaching Bill Charlton, fire control officer, on the Inyo frequency. Charlton is stationed on the ridge to the west of the plot. The B-52 just made another dry run from the northeast breaking a mile out from the plot and banking and climbing toward the west circling to the

T. G. STOREY

north-northeast again apparently for the final fire run. The safety officer is about to take off in the helicopter for a final safety check of the plot and the area.

- 0746 Ignition will be in approximately 10 minutes.
- 0747 Northcutt is still having trouble contacting the fire crew on the hill on the Inyo frequency and I believe that they are trying them on the fire lab. frequency without success. They also were unable to get them on the handi-talkie that they had sent along with them. A small aircraft, which appears to be a Cessna 172 appeared to the west, almost due west over the ridge, but has been keeping out of range, as far as I know he is unidentified at this time.
- 0749 Safety officer Schimke announced from the helicopter that he has checked the plot and it is clear, no one in the plot, and he is coming down. The chief Navy cameraman here at headquarters reports that all of his cameras are set and ready to go; all camera systems operating fine at 7:49.
- 0750 Safety officer Schimke is landing in the helicopter at the headquarters. There appears to be 35% of the sky covered with cirrus and darker clouds.
- 0751 The wind seems to be holding at just about a calm to 1 or 2 miles per hour. It was reported that the winds aloft weather reading taken earlier this morning showed winds very light, not over 6 mph up to 6,000 ft. above the surface in the vicinity of the site.
- 0752 The beacon and radio for the Boeing B-52 is set up here at headquarters.
- They announced ignition for 5 minutes from now which would be at 7:57.
- 0754 They just announced ignition minus 3 minutes so it is now 7:54 meaning ignition will be at 7:57.
- The B-52 is visible circling to the northeast over Mina waiting for its final run on the fire at ignition.
- 0755 The helicopter took off apparently to get in position for the B-52 run.

T. G. STOREY

0756 It should be ignition minus 1 minute. Can see several persons at the visitor area 2 (the nearest visitor area on the hill).

45 seconds to ignition.

30 seconds to ignition. Now 7:56 and 1/2 which agrees with my watch.

Counting down to ignition.

0757 IGNITION. Beautiful ignition. Appeared that all piles detonated; all igniters detonated. Fire in all piles near as I can tell from here. In all piles visible the fire is ignited in at least two places; most of them have many ignition points. Fire is building up. Smoke is darkening but mountain boundary is still visible through the smoke.

0758 The smoke is now thick. Boundary peak is not visible. The B-52
+ 01 made its run about a few seconds after ignition, banked, turned to the west 1 mile out and climbing away toward the west side. Apparently timing was proper. It's now 7:58 and the wind, at least to the height of the column now, which would be 200-300 feet, is coming from the south and west a little bit and the column is starting to lean over headquarters and over NRDL trailer out toward the northeast.

0759 1/2 The fire is building, the smoke is dark; it is almost solid
+ 02 1/2 black. It is now 7:59 1/2.

0800 8:00 the column is continuing to build. Wind is rising; a draft
+ 03 is felt here at headquarters which is 400 ft. north of the north edge of the plot. It is not believed to be an indraft. It is driving the fire now more toward the east from the west.

0800 1/2 Now 8:00 and 30 sec. the column is building up. Columns from
+ 3 1/2 the individual piles appear to be bending toward the center now as the column builds. The drift toward the northeast has been overcome by indrafts at least in the lower portion of the column where the heat is most intense. The upper column is still leaning toward the north; north slightly to the east. The column is leaning over headquarters a little to the east.

0801 8:01. They alerted the fire crews to be alert to the northeast
+ 04 but I can't see any spots set as yet. There was an explosion heard from the direction of the plot. It is not clear what that

T. G. STOREY

was. Now the column is starting to pinch in at about 100 feet above ground, still doesn't appear to have reached maximum intensity. A fire whirl is visible, two fire whirls near the north edge of the plot, where I can see them here from headquarters, extending maybe 50 to 80 feet into the dark column. The column is now rising higher before bending off toward the north and the east. Smoke drift now quite a distance off towards Mina.

0802 $\frac{1}{2}$ Helicopter is visible to the east hovering well out about a mile
+ 05 $\frac{1}{2}$ or half mile from the column. It is now 8:02 $\frac{1}{2}$.

0803 Fire is probably near maximum intensity now at 8:03. It should
+ 06 be 6 min. past ignition at 7:57. B-52 has not come back yet following its run at ignition; not just sure of its schedule. An explosion was heard from the direction of the plot.

0804 There was another one. Not clear just what they are. It is now
+ 07 8:04; it appears to be slightly past maximum intensity although it is still dark. The smoke is dark. There appears to be a cloud, a white condensation cap, forming over the top of the column. A little past headquarters toward the direction of Mina - white condensation forming at (hard to estimate) perhaps 3,000 ft.

0805 Many, many fire whirls are observed. Fewer fire whirls are ob-
+ 08 served in the right hand portion of the plot particularly to the north or the northwest corner although the flames from individual piles are bending in from all sides, at least all sides visible. That would be the east side and the west side and the north side that I can observe. No one has reported failure of any instruments; all systems seem to be go. Ignition was fine. Apparently the cameras are working; this is 8:05. There is an extremely violent fire whirl just to the north edge of the plot. Right near the center a little to the east. It is making very violent roaring noises; crackling. There it goes again. Extremely violent fire whirl here on the north central edge of the plot (same one). This one pile seems to be doing it. Large pieces of bush, apparently green bush, were carried into the air and deposited apparently outside the plot; continues to whirl in this one pile. Look at that! Extremely violent fire whirl and smoke whirl is continuing. The flame doesn't shoot very high into the column but the smoke may obscure it. It is now whistling - making a very violent whistling noise. Now it has calmed down, but pieces of bush which appear to be mostly green material is being sucked in and carried up maybe 30, 40, 50 ft.

T. G. STOREY

into the air and then they drop out apparently outside the plot here to the north.

- 0807 Blue sky can be observed in the center of the plot. Clouds and
+ 10 blue sky. The smoke is lightening considerably in color now. The drift is still to the north. The B-52 just made another run, breaking at 1 mile out, turning to the west and back to the north.
- 0808 This is now 8:08 (the B-52 run). Condensation cap has now built
+ 11 to a considerable size over the dark portion of the column below. The column is lightening considerably now in color although the flame is still very high and burning intensely. There is a violent smoke and fire whirl now on the northeast corner of the plot. Two of them visible at this time. Very violent and loud roaring noise can be heard. Very strong noise here in the fire whirl, smoke whirl at the northeast corner of the plot.
- 0809 Another violent smoke whirl in the northeast corner of the plot.
+ 12 Two rows in each way. Appears to carry material above the ground and when it gets out of the plot the material falls out of the whirl. It appears to fall back to earth. That was at
0810 8:10. 8:10 is 13 minutes past ignition which was at 7:57.
+ 13
- 0811 The helicopter is still aloft not visible at headquarters, I
+ 14 don't know his exact position. This is 8:11; pretty violent smoke whirl on the northeast corner of the plot. A roaring sound is heard now. As it builds up I see a bush, it appears to be a portion of a juniper bush, up at about 150 ft. above the ground apparently carried up in the whirl and is now drifting into the center of the convection column, center of the column which is bending off toward the northeast. The whirl is roaring.
- 0812 This is Storey reporting his observations from headquarters on
+ 15 Burn 760-12-67, September 29, 1967. Another bush, apparently a small sagebrush, (probably those bushes are sagebrush from inside the plot area) is being carried into the air.
- 0813 The convection column continues to lean to the northeast. It
+ 16 is difficult to tell from this angle just what the shape and orientation is because it is coming pretty much overhead here at headquarters.

T. G. STOREY

- 0814 Smoke whirls continue to form on the northeast corner which is
+ 17 down near the edge since the wind is from the southwest pretty
much. One smoke whirl on the extreme southeast corner. Bushes
and debris apparently mostly made up of sagebrush bushes or
parts of bushes are being carried up and whirled around in the
smoke whirls up to altitudes up to about 500 ft. perhaps.
- 0815 The crews are approaching. Some of the crew are observers,
+ 18 Britishers.
- 0816 Helicopter at 8:16 is visible through the column, apparently
+ 19 circling or patrolling on the southwest side of the plot. The
B-52 is visible off to the northeast toward Mina circling. It
is not clear if he is coming in for another run or not. This
is 8:16. The B-52 is coming in on another run from the north-
east from Mina. Check that he is due in here at 8:17, but I
don't see him yet. The Cessna or small private aircraft is
visible to the north and northwest well back, about 2 miles back,
from the edge of the plot.
- 0818 Check that, it is now 8:18. The B-52 just made another run and
+ 21 broke away to the west about a mile out, his standard procedure
apparently. The B-52 is circling off to the west and north.
Cessna hugging the deck; it is not in the path, not in the way
of the B-52. The smoke column is continuing to drift off to the
northeast. The convection column still is over east of the head-
quarters and off toward Mina gradually growing in size. Fire
whirls continue in the northeast corner of the plot. Sagebrush
bushes continue to be carried up, but seldom getting very high
in the column. Shortly after ignition, near maximum intensity,
there was one that appeared to be carried well up into the
column maybe 200 or 300 feet. The individuals are approaching
now within 60 to 100 feet of the plot with no ill effects. The
towers are now visible through the smoke. The smoke is a light
gray color. The mountain boundary peak is now visible through
the smoke.
- 0820 A spot fire - no two spot fires - can be seen to the east on
+ 23 the east side of the plot across the fire line or dozer line
very near the outer edge of the dozer line. Probably carried
there by the burning particles and sagebrush bushes that were
carried up vertically by the smoke whirls. The smoke from the
spot fires to the east of the plot very near the north edge
(northeast corner) is being sucked back toward the column which
is against the direction of the wind being felt here at the
headquarters trailer.

: T. G. STOREY

- 0821 At 8:21 a four engine commercial plane is passing well above the
+ 24 plot in approximately the northwest to the southeast. A four-
engine propeller driven plane. It appears to be a commercial
plane. It apparently has nothing to do with the operation.
- 0822 A number of spot fires have appeared on the east side of the
+ 25 plot inside the fire line. It could be individual sagebrush
bushes. It is not clear, actually, if they are spot fires or if
they are from ground fire burning through sagebrush that has
spread out to the inner edge of the fire line. The spot fires
over the line is, two spot fires; it appears that their smoke
still is being sucked back into the plot.
- 0823 Whirls continue to form in the northeast corner.
+ 26
- 0831 The B-52 is going to make another run along the plot from the
+ 34 north northeast. Dust devils forming over the fire line;
occasional one forming over the northeast corner of the plot.
Smoke whirls from beside the northeast corner of the plot
occasionally moving out a little past the end perimeter of the
plot itself. Considerable crackling is heard as the piles burn.
- 0832 Men, individuals, approaching within 50 to 80 feet out of the
+ 35 edge of the plot at this time. Fire boss Charlton is having a
cup of coffee and surveying the situation here at 8:32.
Satisfied smile on his face. George Flatman standing on the
ramp here at headquarters his hands in his pockets (assume they
are cold). The weather aloft, cirrus clouds. Darker clouds
hanging over the mountains to the northeast and the east; some
now visible to the west. It is a clear blue sky over the plot
area. Winds still approximately 10 miles an hour from the west
southwest, I would say, although on the east side of the plot,
the smoke from the little spot fires still is being drawn back
to the west against the direction of this strong prevailing
wind felt at the headquarters here at 8:34.
- 0834 The light plane is still off to the west circling back and forth
+ 37 beyond the ridge well out of way of the plot; out of danger.
Helicopter landing after taking Smith and, I believe, Northcutt
on a scouting mission quickly around the plot.
- 0836 The general drift in the column here is still to the northeast
+ 39 or north northeast, probably. Tilt apparently pretty well
straight away not twisting to another direction with altitude.

T. G. STOREY

Column appears not to be rising quite as high as burn 460-7-66, I guess it was, (the previous burn to this one).

- 0837 The smoke whirls continue to form in the northeast corner but
+ 40 not as many nor as violent as a few minutes ago. The pumper continues to patrol the northeast side, pumping on spot fires across the line (just across the line) holding them in check. A burning bush was observed to rise a height of 20 feet above the ground in the northeast corner of the plot.
- 0839 This is Ted Storey recording a 760-12-67 on September 29, 1967.
+ 42 The helicopter has taken off again and is circling the plot from the east apparently to observe the spot fires that have been burning or just crossed the line. But the smoke is being sucked back into the convection column against (directly into) the prevailing wind felt at the headquarters. This is 8:39; Loyall Smith and John Murray approached right to the edge of, north edge of, the plot in the aisle. Apparently Murray doesn't have any hat on or any protection of his face or head and he stayed there for a couple of minutes without ill effect.
- 0840 All towers still standing without evidence of buckling or sag-
+ 43 ging nor does the gear of the calorimeters above the piles that are now visible, two calorimeters now visible from here at headquarters appear damaged. Again (still) the piles not ignited or the extra piles haven't caught.
- 0841 The B-52 just made another run at the plot, turned off again
+ 44 about a mile off, appeared to be a trajectory slightly more to the east of his previous ones on that run from Mina toward the plot. He is now circling back to the north. The Cessna is still visible patrolling over the ridge to the west. The cirrus is thickening a little directly over the plot area up to at least 60% of the sky covered. The convection column is lightening in color still drifting off toward Mina, perhaps over Mina now.
- 0842 Regarding camera operation, Myra Hoffman - who has been taking
+ 45 longhand notes at the radio at headquarters, has noted some troubles in the performance of some cameras. She has made detailed longhand notes of these with times and these data will be available, I understand. These are notes she made at about 8:30 from the radio check of the camera station. It is now 8:43.

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0844 Here at 8:44 talking to safety officer and ignition expert
+ 47 Schimke, he reports that his observations are that several
igniters did not fire. Probably this explains the explosions
in the plot in the first five or ten minutes that I reported
earlier. The napalm cans exploding after heating up. But the
detonations appeared to be distributed around the plot so
probably there was at least one igniter in each plot that worked
and spread fire. I couldn't observe any pile or groups of piles
that were not ignited. (This is a report on what happened
earlier, a few minutes after ignition.)

0845 A smoke whirl has moved out of the plot and appears to be
+ 48 approaching the pumper that is putting water on the spots over
the tractor line. But it stopped short of them and apparently
didn't bother them. The pumper truck on the east is still
proceeding down the plot toward the south. Smoke whirls are
continuing to form. Spots continue to burn outside the plot
inside the fire line.

0847 Here at 8:47 are my observations of the buildup and the general
+ 50 intensity of burning of this plot compared to 460-7-66 and
760-2 (which was burned a couple of years ago). 760-12-67 did
not appear to burn as intense as, maybe slightly less intense
as the previous plot which was 460-7 in the Mono area that was
burned last year. Just slightly less intense, perhaps.
Intensity was considerably less than 760-2, the five acre plot.

0848 The helicopter is landing from a scouting mission over the spot
+ 51 fires at the east of the plot. The convection column continuing
to drift to the north northeast. Contrail (from aircraft)
visible through the smoke at a very high altitude to the south-
east. I didn't see the aircraft that made it.

0849 The pumper is continuing to work on the spot fires on the east
+ 50 side of the plot. They're handling them. Smoke from them
tending to drift as before, back into the plot and/or to the
north in the general direction of the convection column. Al-
though the wind, as I said before, continues to blow fairly
steadily from the west at about 8 mph. 6 to 8 maybe, down a
little from the 10 mph earlier. The Cessna is still visible
over t.

0851 Observe very few, if any, smoke or fire whirls toward the center
+ 54 of the plot although for a period I couldn't see in, but even
now I don't see any. I haven't seen any in awhile here at 8:51

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but they do continue to form on the northeast corner. This is somewhat similar to plot 460-7 in the Mono area; the fire whirls, smoke whirls form on the northeast downwind corner. They appear not to be as numerous or intense as on 460-7.

- 0852 Cliff Auvil just came into camp. They continue to work on the
+ 55 little spot fires, but they are no problem.
- 0853 The B-52 is making a run from the east to the west approximate-
+ 56 ly one mile to the north of the plot. East to west about
1 mile north of the plot at its normal 350' altitude. Smoke
has thinned out considerably now in the plot and individual
piles burning; little flames. Smoke drift is going off toward
the east slightly north of east in response to this apparently
prevailing wind or gradient wind which is pretty much from the
due west or south; west southwest, I would say. That is the
smoke drifting off near the ground, hugging the ground off to
the north and the east. Convection column breaking up
considerably. The convection column aloft at higher altitude
over Mina is a very lightish color and broadening to some
extent, broadening and spreading out sideways but still drifting
toward that same direction, northeast.
- 0855 Air officer Rossi apparently is in touch with the Cessna.
+ 58 Apparently this Cessna to the west that I have been reporting
has been patrolling to keep airborne visitors out of the area.
There is now some concern about a small unidentified private
plane observed to the east out toward Coaldale. Our Cessna has
been dispatched to warn him off because the B-52 is coming in
from that direction. In fact I see the B-52 rather close to
this unidentified plane off to the east and north. The B-52
apparently is circling in from the east now preparing for
another run on the plot.
- 0856 The recon plane is heading full tilt to the east to warn off the
+ 59 unidentified plane. A precautionary measure so it won't inter-
fere with the run of the B-52. The 52 is now approaching from
the east, I believe, due east at a might higher altitude than
previously.
- 0857 The B-52 is approaching the plot. Rossi doesn't know the exact
+1:00 altitude, but he's high up there. I'd say 8,000 or 10,000 ft.,
but it's only an estimate. 8:57 $\frac{1}{2}$ He has just passed over the
plot at this high altitude on his east to west run. He passed
over the plot I'm not sure if he went through the column or not
because it is bending to the northeast.

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- 0858 Rather intense smoke whirl here in the extreme northeast corner
+1:01 of the plot. It didn't last long, about 20 sec. The fire crew is continuing to work on the spots over the line, but apparently they are not being threatened by any smoke or fire whirls. They're just over the fire line.
- 0859 The helicopter is visible through the smoke and is apparently
+1:02 scouting the south edge of the plot. The cirrus continues to spread slightly overhead. I would estimate that 80% of the sky is covered with cirrus.
- 0900 The wind here at the headquarters is from the west. The smoke
+1:03 is drifting more near the surface now, towards the east in response to this apparently stronger wind from the west (and decreasing convective updrafts). The helicopter is coming in for a landing. The B-52 is observed circling around to the east apparently preparing for another run on the plot, still at high altitude.
- 0901 Very few smoke whirls observed at 9:01 in the plot center. They
+1:04 are concentrated to the northeast corner and not very intense. They form and dissipate within a few seconds not moving out over the fire line, beyond the fire line. Seldom moving that far. This is Ted Storey observing from headquarters 760-12-67, September 29, 1967. I repeat again that Myra Hoffman is taking longhand notes here at headquarters and has picked up some valuable information on performance of the camera stations that she heard over the radio.
- 0904 According to the Boeing beacon man infrared readings from the
+1:07 B-52 aircraft show a heat zone near the ground and another at high elevation, but a blank in-between. There is a gap in the heat profile. Lou Rossi, who has been talking to them, says they have no explanation of this at this time.
- 0905 Mr. Countryman just passed with a satisfied smile on his face.
+1:08 Now walking out the road toward the plot for a little closer inspection there.
- 0906 The fire crew - the Job Corps crew - has been moved over to the
+1:09 northeast side of the plot to work on the little spots that showed up across the line. Two pumpers there, also. There is not much activity; they are just standing there at the time observing the fire. There is no problem in that area now.

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0908 A few minutes back I saw the B-52 apparently circling preparing
+1:11 to run east to west over the plot, but I haven't observed him
pass over. He is at high altitude now. I may have missed his
run (thought I'd make a note of that). I may have missed the
latest run.

Now he is passing over at this minute it is 9:08 exactly. Pass-
ing over at high altitude at least 10,000 ft. directly over the
fire area on an east to west run, now banking to the west and
back to the north. He appears to be making these runs period-
ically at this time. I don't believe he's passed through the
smoke column because it is leaning off to the northeast and
would pass under him at that altitude. Although he may have
experienced some turbulence. This was at 9:09.

0910 I've already reported that they lost some anemometers in the
+1:13 plot and that there are 2 towers down. This is just a run down
on the performance of the instrumentation. Myra Hoffman
recorded this, incidentally, longhand about the anemometers.
The west wind (wind from the west) is apparently being felt
strongly now on the spot. I can see some of the wrappings
flapping apparently indicating a strong wind in about two rows
getting to the smoke about 20 feet above the ground carrying it
down more on the surface, follows on the surface now off to the
east. The convection column is drifting more off to the east
rather than the north. The high white cap is now stringing down
the sky still off toward Mina. Same direction it has been ever
since ignition. Surface smoke going off to the east now in
response to this wind. The Cessna is visible due south of the
plot apparently returning from the mission to chase off the
intruder aircraft. Apparently some light private plane.

0913 Radio contact with our Cessna works very well and they continu-
+1:16 ally check to see that it is out of the way when the B-52 is
coming around for a run as he appears to be doing now.

0914 He seems to be circling off to the east to make another run over
+1:17 the plot again at high altitude. This is at 9:14. Our Cessna
reported another plane to the southeast of the fire and Rossi,
air boss, had the Cessna get his number and chase him away, if
possible.

0915 The strange plane was to the south of our plot fairly close here
+1:18 at 9:15 and our Cessna has been dispatched to chase him back off
to the east.

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- 0917 Just talking to Countryman and asked him how he would rate the
+1:20 intensity of this fire against any of the others. He said he would rate it higher than 460-7, the last fire they burned in the Mono area. But not as intense as 760-2 that was burned several years ago. I would rate the present burn a little less than 460-7, but, like Countryman, much less intense than plot 760-2 which was burned a couple years ago.
- 0918 The B-52 just made another pass, incidentally a little lower
+1:21 altitude than it was earlier, again from the east to the west over the center of the plot. The B-52 is circling off to the north again. Countryman reported some fire whirls visible from his position on the southwest side of the plot. I reported I didn't see any near the center but I couldn't see his position. His side of the fire apparently did have some. This burn, of course, was set up for a northeast wind, whereas the actual wind was from the southwest or just opposite and this may have presented a problem to some of the studies. The smoke drift is now coming into headquarters, smoke drift and ash particles. Appears that maybe the wind is switching more toward the south than the west, but it varies. More smoke drift low against the ground toward the east.
- 0924 Navy reported that camera one was secured. This has been given
+1:27 to Myra who took longhand notes, so she will have those, that information, in more detail.
- 0925 The Cessna, our Cessna passing overhead. Murray earlier
+1:28 reported that he had lost two towers and some anemometers; the loss of the anemometers was due to the collapse of the towers. One tower was reported to have collapsed vertically so that it lost a number of feet out of it. It landed upright so that the anemometers continued to function as reported by Clive Countryman.
- 0926 The B-52 is making another run. It appears to be at the same
+1:29 elevation. East to west over the plot at fairly high elevation.
- 0927 The helicopter is on the ground now at the headquarters. No
+1:30 smoke whirl activity here for several minutes. Even on the northeast corner where these are most prevalent.
- 0928 The smoke is hugging the ground more and more now. Drifting off
+1:31 toward the pumpers on the east side of the plot. Occasionally some drifting into headquarters.

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- 0929 The helicopter is taking off. McCarter came in on the heli-
+1:32 copter apparently he has secured his photo work. The chief in
charge of the Navy camera unit reports that the cameras "did
fair". They had two of them jam up 5 to 10 minutes apiece. One
70 mm apparently ran only 3 or 4 exposures and stopped. All but
this one, I believe, apparently got back into operation within
5 or 10 minutes.
- 0930 UCLA's gas unit reports that due to trouble with their pressure
+1:33 regulator they lost the first 5 minutes of readings, but was op-
erational from that time, 5 minutes after ignition, to now
continuously. So they think they lost the first 5 minutes,
which was before maximum intensity by 2 minutes. This was re-
ported at 9:32.
- 0933 The cirrus seems to be clearing out directly overhead, though
+1:35 cumulus seems to be building over a peak to the south and to the
west clearing out to the north. Column is dissipating aloft
spreading it out and drifting off downwind over Mina. That is
in the Hawthorne direction.
- 0934 McCarter reported on his instrumentation. He had to come on
+1:37 short notice so he didn't get everything up on the towers as he
had planned. Instead he had to put it down on the ground or
wherever he could which won't give him the information had he
more time and could place it wherever he wished.
- 0937 Apparently at Camera Station 2 the Veritron 70 mm camera had
+1:40 troubles and they got only a few exposures before it quit. This
was operated by the Navy photounit. Smitty reports that tower 4
melted right above the insulation. It is one of the two they
lost apparently. The water calorimeter apparently collapsed on
the platform with the water running out. It apparently ruptured
the line. Jon Menand reported two fire whirls on the southeast
corner which was the corner I couldn't see from our headquarters.
Jon Menand will tell us what time he observed these two fire
whirls: "The fire whirls in the southeast corner of the plot
(+18 to occurred at approximately 0815 to 0830 hours then about 0845 hrs.
+33 and It was in the interior southeast corner, not near the edge."
+48) Thank you, Mr. Menand.
- 0945 The B-52 is now approaching the plot from the east. It is flying
+1:48 east-west at a much lower elevation. I imagine it is about 350
ft. He just passed over east to west and is now peeling off
toward the north again. The helicopter is coming in for the

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landing. Surface smoke is drifting toward the east pretty thick; wind holding it down. Wind still about 6 or 8 mph at this time and has been fairly steady at that the last several minutes.

- 0949
+1:52 There is a report that in pile A-1 on the southwest corner the cans blew but the napalm didn't ignite. Possible explanation would be that the napalm leaked out of the can. A report was received that observers with cameras on the west side on the ridge had good shots of the ignition which should indicate which piles ignited or did not ignite. This could be determined from pictures that were taken. This was reported by Lee Northcutt (the existence of this film). Boeing reports that the map coordinates of 760-12-67 are 118.25° and 38.01° . Reported by Lou Rossi.
- 0955
+1:58 Correction on the position of the B-52 on that 9:55 run. The B-52 is at 500' elevation rather than 350' and 1,00 yds. south of the fire not over the fire. This was the 9:55 run, east-west. My previous report of a pile not igniting (it had igniters but didn't burn) reported as being in the extreme southwest corner was actually in the extreme northwest corner, pile 1-A.
- 1005
+2:08 The B-52 made another east to west pass at 500 ft. at 10:05. This run is about 100 yds. south of the plot so he didn't pass directly over the plot.
- 1008
+2:11 NBC news representatives came into headquarters here and reported: good recording day, good position, and got some real good TV film shots. Estimates they'll put it on the news tonight or tomorrow night at 6:00 NBC News. It will be on the 30th or the 1st of October. He says "maybe for tonight the 29th at 6:00 and if not, be tomorrow the 30th".
- 1017
+2:20 The B-52 made an east to west pass and appeared to be more over the plot or just south still about 350'. Just as he was pulling out passing over the plot and turning to the west and north another unidentified B-52 was coming in from the northwest and banked towards the south (took evasive action)-- appeared to be a little too close for comfort.
- 1018
+2:21 Smoke is drifting still over to the east northeast. Smoke aloft continues to drift to the north northeast.

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1020 About this B-52 incident: the Boeing man here at headquarters
+2:23 stated that he doesn't know where this other B-52 came from nor
does his B-52, the one that has been flying over the the fire.
The man at headquarters has asked his B-52 to check Tonapah to
get identification and information on why he was in the area.

10:22 An aircraft passed over from the southwest to northeast possibly
+2:25 over the plot at high altitude. This was a military fighter
aircraft of some sort; no problem interfering with the B-52.

End of observations of T. G. Storey on 760-12-67, September 29,
1967.

APPENDIX B

RICHARD C. ROTHERMEL

Observations during Project Flambeau Test Fire 760-12-67, September 29, 1967.

- 0700 Reporting from the east side of the burn near the NRDL station. We have a very light wind out of the south.
- 0730 The sun is now completely on the plot. The wind is still very light out of the south.
- 0750 The wind is freshening somewhat out of the south-southwest, ribbons in the plot can be seen to be fluttering. At T-1 the wind is again very light out of the south-southwest. Ignition now appears to be complete as far as can be seen on all plots. Smoke drifting lightly to the northeast. Smoke coming pretty much over us now--not very heavy as yet. Flame diameters appear to be some 2 to 3, some 4 feet in diameter, some 5 feet. Flame lengths may be as much as 10 feet and growing--this is at
- 01 1 minute.
- 01 $\frac{1}{2}$ At 1 minute and 30 seconds smoke from the northeast plot is standing more vertically now, getting somewhat of a pull from the fire although the smoke is still laying pretty much over us. It's getting pretty dark now. Cannot see very far into the plots. Can see about 5 plots into the fire. Smoke on the southeast corner laying over almost flat about 50 feet up.
- 0759 We are getting a pretty good indraft from my back. Ash flowing
02 over my head pulling back into the fire. Flames getting quite large now and beginning to get turbulent. Noise picking up at 2 minutes and 15 seconds. Some pulsing beginning to take place. Indraft getting quite strong at my back--estimate perhaps 8 to 10 miles per hour. Smoke is now cupping back under, that which had blown away is now pulling back into the fire at 2 minutes and 45 seconds. Flames getting very violent, now reaching up 40 to 50 feet into the air, pulses breaking off, in other words
0800 discontinuity of the flame at 3 minutes.
03
- Plot on northeast corner pulling in strongly towards the center laying almost horizontally. Appears to be a fire whirl--strong fire whirl forming at about 6 plots in from the northeast

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corner--is died out now. Another one forming at 3 minutes and 39 seconds. Good cooling on my back. The smoke is still moving out somewhat from the southeast corner coming over our heads and then being pulled back into the fire at low level. A lot of smoke over our heads still coming out of the fire. Big roll coming off the southeast corner sucking it into the fire. Smoke from the north side is moving off towards the northeast and forming a big umbrella over us. A large fire whirl here on the east side, strong indraft pulling into it. There's another fire whirl--I see 3 of them now--pulling up. They are not continuous. This is at a--oh there's a beauty right here on the edge lasting a good 15 to 20 seconds. Flames going I would say a good 200 feet in the air--it is turning counter-clockwise--getting very noisy, ashes coming out this way. It is still persisting for this length of time that I've been talking. It is just about mid-way along this side--but on this edge--now tending to die out. Another one just in the north corner into the plots approximately 2 from the east and 5 in from the north. The one I was watching before is really going to town again and that's about mid-way along the east side and right on the edge. Flames going 200 to 300 feet into the air--lots of sparks coming off of it--they are being swirled around this fire whirl up to 50 to 75 feet around it. The base of the fire whirl is pulling out of 2 plots, primarily centered however directly over one plot. Still turning counterclockwise. Two of the plots pulling into it. Very interesting, the fire over on the corner is laying horizontal into the plots. A fire whirl is moving out of the plots and pulling up a lot of dust on the east side here. I think we better pull away here a bit. Fire whirl pulling out of the plots into the sagebrush and is burning by itself--not burning but just dust pulling directly off the ground near the flame. The source is not above the fire but above the ground. Now it's moved back into the plots. This is at 6 minutes and 53 seconds. This fire whirl has been continuous almost this full time I have been describing it. Right in this same location another whirl not as intense as that one is still just in from the northeast corner right in line with the NRDL observation signs. Very strong indraft has picked up now at 7 minutes and 30 seconds at my back which would be from the east and has moved a fire whirl that was on the edge pretty well into the fire and it has moved to a new location about 2 plots in from the east side. There are others, approximately 2 others that I see. This one appears to be the same whirl that has moved from that one location. It is still turning counterclockwise.

0804
07

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The other whirl that I see in this corner is turning clockwise I believe--this is in the northeast corner. The indraft has picked up considerably; the smoke from the south now is going probably pretty much over the fire, not so much over the edge as it was. Over here on the northeast corner at perhaps 300 feet it is still moving out over the headquarters station, going up away from us here leaning way out; to the east I can see white smoke or condensation--anyway it looks like a white cumulus cloud--way off to the east of the fire. Another large fire whirl has formed--it is approximately 2 plots to the north of where the previous one was on the edge and is very violent as was the first one. It is closer to us than the other, approximately 250 feet from us here at the NRDL station. It is about--I would say--10 feet in diameter. Going up remarkably straight and very intense straight up. A B-52 just flew over a little to our right. This fire whirl is influencing all the fire in this northeast corner. All of the fire seems to be pretty well pulled by this fire whirl--it is getting very noisy now and rather large, very, very intense. Its influence--the actual whirl itself--is still maybe 15 feet in diameter. A much more intense swirl than I've seen before. Very fast and very tight. It seems to be picking up in a circular velocity all the time. Appears to be a tornado now--much larger--maybe 20 feet in diameter. Hey you guys (manning NRDL station) let's get out of here. The fire whirl is moving out of the pile area--come on you guys. Out over the edge of the sagebrush has gone back in. One of the simulated English housing structures was pulled up into it and carried aloft for approximately 40 feet. It has now moved a little farther to the south, is throwing branches around in there. This whirl is still 10 to 15 feet in diameter--is not very high any more if you consider the flames as being high but it was very powerful. It is now letting up somewhat, this is at 12 minutes and 13 seconds. The fire whirl is persistent, moving into the fire area about 2 plots, now is decreased in whirl intensity somewhat but has picked up a little more fuel. All this time the wind has been at my back pulling in from the northeast, mostly east, east northeast. The whirl activity area has been in this same area. It moves around from plot to plot, is picking up in intensity again. This is turning counterclockwise and I can see the smoke that is going up from it--very far columnated manner. Getting very intense again right over one pile. Now it is influencing a second pile. The flames of one pile are laying flat--the flames flat pulled into it about 100 feet horizontal flames. I see a firebrand. It was 6 feet long and 1-1/4 inch in diameter being carried along in the--

0808
11

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0812

must have been carried up by the fire whirl and pulled back into the fire by the indraft. But I see now another fire whirl over on the north side in front of headquarters. Not as intense as this one--something very large and light just was carried aloft by it. This particular whirl center does not seem to have let up. There seems to have been a whirl here almost continuously during this time, (it is 14 minutes and 52 seconds). Not quite as active as it was before. The smoke is letting up considerably. I can see across the top of the gray smoke now and clouds on the far side of the plot. The smoke column over my head has drifted off to the northeast and is almost detached from the fire. The fire whirl is getting very noisy again, it has moved into the plot about 2 plot widths--still very, very active. Mostly smoke and sparks aloft but heat being pulled into the base of it, the flame at the nearby base is laid over horizontally as they are pulled into it. This seems to be the dominant feature in this area, the flames themselves on the piles are burning in a turbulent fashion leaning pretty much towards the fire whirl from all directions. The, oh now we are getting a definite smoke column or the white smoke in the center being carried along stream lines way up into the convection column over our heads. The fire whirl has found new fuel, the flames are standing now maybe 75 feet high--not very intense, mostly sparks above the plot. I can see considerable debris in the smoke column drifting back into the fire area. Let's see, that is sage-brush being pulled into the fire by the inflow. It seems to be coming down from the convection column.

0815
+ 18

(Stop watch has been accidentally reset.) The smoke has let up enough so that I can see some of the towers within the fire. I can see the helicopter on the far side. There are still large flames above all the plots, everything is still burning but the intensity has gone down considerably. We apparently have burned off the fine fuels and now the larger fuels are cooking and burning at a much slower rate. The smoke has changed in character from the dark black to the grey color and is white along the edges. The piles are still distinguishable, they haven't collapsed much, and I can see limbs one inch in diameter--probably the smallest I can see (maybe an inch and a half). A whirl has moved out towards the headquarters unit from the north side.

0817
+ 20

Now we are getting another one here on the east side--quite intense. Very strong whirl now again, probably 10 feet tall

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at the base, lots of sparks being carried aloft. Centered over one pile. The piles near its edge pulling directly into it and the piles to the south, there flames are leaning this way and piles to the northeast are leaning towards the south again. We have a spot fire here--190 feet from the fire assuming the NRDL station is 200 feet from the fire. And I see another spot fire outside the lines about 100 feet out from the east edge of the line. The smoke being pulled directly into the fire.

- 0820 My stop watch must have been hit on the recess button.* At
+ 23 20 minutes after 8:00 a.m. we still have another strong fire
 whirl on this northeast corner. Press Butler just saw a
 rabbit come out of the fire and run back into it again.
- 0822 One of the NRDL street signs was picked up and blown over by
+ 25 the fire whirl. The activity seems to have moved more towards
 the northeast corner. The wind has shifted more to the south-
 east. Fire whirl forming in this northeast corner going right
 over the NRDL street signs now. Fire whirl right in front of
 the NRDL instruments--they're taking readings on it. We have
 2 or 3 spot fires here on the east side. Now he's got a
 5-foot in diameter fire whirl right in front of the radiation
 instruments.
- 0824 Now it's moved off somewhat to the north. This is at 8:24 a.m.
+ 27 The fire whirl just blew the instrument off--blew McCarter's
 instruments off the top of the NRDL radiation stand at 8:24.
 Repeat, blew McCarter's radiation instruments off at 8:24. The
 whirl has moved into the northeast corner, is picking up sage-
 brush in this area, throwing it around. We have a good spot
 fire just in front of us, just about half way between us and
 the fire now burning in slash here.
- 0825 The wind has picked up considerably out of the southeast. The
+ 28 fire activity has picked up quite a bit and now we have another
 whirl here on this east side, 4 rows in from the north. It
 picked up when this strong wind came in from the south. It has
 moved out of the fire area out into the sagebrush and is moving
 off towards the northeast and diminishing in intensity as it
 goes. It is throwing up sagebrush but remarkably I've seen very

* Rothermel coordinated his watch with clock at instrument trailer prior to ignition. Hence ignition was 7:57 by his watch. (Edward M. Gaines)

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few large limbs carried off by any of these whirls. One reason may be that the intensity of swirls seems to be so great that whatever is in there is broken up and comes out as a shower of sparks.

0827
+ 30

The wind is still out of the southwest but not quite as intense. The fire appears diminished somewhat in intensity, that is the overall fire. A pumper truck is moving in here on the east side of this northeast corner and is starting to attack the brush piles (spot fires) that are burning here in front of us. There is a little bit of a fire whirl, but below them 125 feet I guess I'd say to the fires edge. There is a dust devil formed just off the northeast corner that was not originated over the fire. It is gone out now. Wind picking up more from the east now, slightly south, not having much effect on the fire. Fire seems to be burning now with heavy flames about every 3 piles I would say. Other piles more just glowing in nature with low flame heights. This is at 8:30. Interesting to note, the pumper truck squirted water on 2 brush piles as it went by but they quickly dried out and began burning again as though they had not received any water. Here's a fire whirl forming--not a fire whirl but a dust devil just 100 feet in front of us here on the east side of the fire. It is moving off to the north past the corner--no fire in it at all.

0830
+ 33

Here is a spot fire behind the NRDL station. It's probably 135 feet from the fire and looking at it closely we have a piece of bark lying burning in the center and it appears to be bark that was carried out of the fire and has fallen in some needles in the duff on the ground. This particular piece of bark is 2 inches wide and 3 inches long and is burning out. And here is another piece of wood that apparently came out of the fire. It is 2-1/2 feet long, 3 inches in diameter, one end to the other end and is burning scorched all along its length. It has one hot spot glowing on one side and it has fallen across a dead log on the ground and the two have reradiated to each other and are burning in this pocket. One of the NRDL men is taking a picture of this ember now. None of us saw this particular piece of wood land here. This appears to be a piece of pinyon branch wood. Press Butler just looked at this and was very amazed to see that this large piece of wood has fallen this close to us and no one had seen it come in and he is going to measure the exact distance from the fire. Measured with a tape now it is 3 feet long, exactly

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2-1/2 inches at the butt length in diameter and 1-3/4 inches in diameter at the other end. It is still burning where it fell across the other piece of apparently pinyon pine or juniper that is laying here. The spot is 40 feet beyond the NRDL stand which is supposed to be 200 feet from the fire--that would make it 240 feet from the fire.

0836
+ 39

Meanwhile back at the ranch at 8:36 the fire is getting somewhat smokier again--don't know if this is due to the wind action or to poorer combustion. Grey smoke--no fire whirls right now. Can see one of the visibility markers that NRDL put up. The nearest one was knocked over but this is apparently the second one from the edge. It is white and the letters are black on white--I cannot distinguish them through the smoke but it has not been discolored or apparently moved by the wind in the fire.

0844
+ 47

The fire has greatly diminished now. A dust devil perhaps 6 to 7 feet in diameter moved along, it was generated outside the fire line moving from south along east edge and went into the fire up near the northeast corner.

0850
+ 53

The wind seems to have slackened off and moved more into the southwest and we are getting ashes and smoke over here on the northeast corner. Talking with Phil Thomas here; we're noting that the main whirl that we were watching never really seemed to stop during the course of the fire, it would move 2 or 3 rows away, perhaps go into the burn somewhat, but tended to stay right on this outer edge and seemed to have the same identity throughout the burn. Dick Corlett feels that this was matched with the other whirl that was in the northeast corner but farther into the plots than this one. He had somewhat of a better view of them from up on the hill but he confirmed my observation that they were moving in opposite directions. I thought that the one in the northeast corner was not as intense as the one on this edge. However, from his vantage point, he thought that it was. In discussing these whirls, they appeared to be definitely triggered and influenced strongly by the winds at the edge of the fire; when the wind would pick up the whirls would too. It did not seem to be a random event, but rather there was a strong influence on rotation driven from the outside winds. At one time I could see about 3 whirls but this one on the edge was the most persistent and was stronger.

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0855
+ 58

Wind is picking up pretty good now at 8:55 from the south going across the fire but there is still enough heat to carry it aloft. I do not see any of the smoke going over towards the headquarters trailer. Estimate the wind here at the ground at perhaps 8 to 10 miles an hour.

0858
+1:01

I am talking with Phil Thomas; he was not able to distinguish whether or not the fire burned any more intensely within the pile which we had the reflector boards around the edge. Looking now to the south, there are two piles on the extreme southeast that have a lot of flame in them but do not appear to be as well burned out as those farther here to the north. This is at 8:58. A large dust devil has formed here at 8:58 right on the edge of the fire on the northeast corner. It seemed to be half in-half out of the fire. Whirling counter-clockwise swirling up a little sagebrush now moving out into the sagebrush area not connected with the fire. It is perhaps 3 feet in diameter, very persistent, it is now about 60 feet from the fire blowing right toward a man who is ducking down right on the edge. Seems to be going up the road behind this man and now it's dying out. Another large whirl forming on the northeast corner formed over the fire and moved out across the desert, now dissipating. This is at 9:00. It's picking up again, crossing the road, is perhaps 6 feet in diameter.

0900
+1:03

0902
+1:05

Another large whirl developed in the fire, in fact 2 of them going now. They seemed to have started in the fire and then moved off downwind across the desert and have dissipated. Spot fires on this side of the fire, east side, are being manned by 2 pumper trucks and 2 crews now have moved over here. Nothing at all serious, they're just putting out the fires. Whirls are still being triggered here apparently by this east, somewhat south, wind. And sometimes they form over the streets and move into a burned pile or else a fire in some places. Sometimes they start over a pile and move out across the plot and off beyond us. Down closer to the fire there are spots in the sagebrush all along the east edge here within the 50-foot cleared fire break.

Walking along the road on the east edge can see evidence of embers that have come out of the fire. Here's one stick 3 inches long and $\frac{5}{8}$ of an inch in diameter. Here's another branch--looks like some sort of brush $\frac{3}{8}$ of an inch in diameter at the butt and perhaps 18 inches long. Here are bigger pieces of wood--one 8 or 10 inches long and an inch

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in diameter at the biggest position. It is a piece of building material, appears to be acoustical tile that was in one of the British simulated roof structures.

0908 Looking at the piles, large wood still burning, smallest
+1:11 pieces of wood I can still see are now perhaps 2 inches in diameter, most of it being larger than that.

0910 Looking down the streets at 9:10 the ground is burned very
+1:13 clean between the piles, grey ash in this area. At 9:10 up at the southeast corner the wind is fresh pretty much out of the south. Right at the southeast corner is a stick one inch by one inch stuck in the ground vertically and it is perhaps 3 inches from any ash that I can see on the ground. There are logs burning within 4 to 5 feet of it, it is blackened on the side facing the fire but a piece of paper apparently a napkin that has been wrapped around it tied in a knot and put above the ground is not burned in any way. Of course now this is on the upwind side and would have received good cooling by the indraft indicating that the cooling on something like this, although it is very close to the fire, is sufficient to keep the temperature below any temperature that would cause charring to occur by radiation from the fire. Observing some of the UK blocks with the temperature indicators on them at this corner; the blocks are not charred but the temperature indicators are blackened indicating good readings will be made from them.

On the south edge now looking into the plot I can see the UK pile with the reflector boards around it. Most of the boards appear to be in place, I don't see any missing yet. Some of the corners are somewhat blackened but other than that they do not appear to be too badly damaged although they are warped concave inward. I'm on the south edge still right in the center of the fire looking at the simulating wooden pile.

0920 It is now 9:20 and just talking to Abe Broido and he called my
+1:23 attention to the milled fuel pile. It is completely burned out; don't know how long it had been burned out. There are ashes on it, a little bit of what appears to be 4 x 4 material, retaining its shape but mostly just ashes. The calorimeter above it has collapsed-apparently one of the guy cables on the north side must have failed and it is tipped to the south. There is a rupture in the water line here on one of the fittings wrapped in asbestos on the south side. The

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overhead anemometers--let's see, the one directly over the fire--still is functioning, the blades are shining, the towers on west and east and the one to the south are all intact. The one on the north side has fallen and buckled permitting the overhead anemometer to drop somewhat but it is still held by the other 3 above the plot. Looking in to the second simulated pile, I can see all 4 towers standing and I can see the vector anemometer standing directly over the pile in position, bright flashing blades. Here on the first pile again I can hear the aspirated thermocouple drawing air, functioning properly. Looking at the United Kingdoms wind indicator folded sheet metal, both of them right here at the first pile, are standing. The next two--the high velocity ones--are still standing, but the low velocities are tipped inward towards the fire. Talking with Abe; he saw no fire whirl activity at all from his vantage point which was here on the southwest corner. Our whirls seem to be strongly influenced by the wind.

0925
+1:28

I still cannot see the center instrumented pile from the south edge, this is at 9:25. One of the United Kingdoms simulated wood roof sections here on the edge not very badly damaged, little bit of charring is all, in fact not even charring, just blackening of the wood. Now looking in from the south side I can see the towers on the simulated pile that was not in line but was over on the corner and one of the towers is collapsed and fallen; this is the one on the east side. All of the material has burned off the weighing platform. The other three towers are standing. On this south edge I have seen no spot fires outside of the line indicating that they had good inflow on this side even at altitude and nothing came around over here and came out.

0931
+1:34

Reaching the southwest corner the overhead column is very white and moving off to the northeast. I had a lot of trouble with my directions today but I think you got them right. Fire burning gently throughout the area. Nothing significant. The vector anemometer over the pile in this southwest corner is still in place although one of the towers is fallen although I cannot tell if it is still oriented correctly. I can only see one vane turning, it may have been damaged.

I can now see the instrumentation above the center plot, at least one of them, I guess it's the wild fuel side. And all towers are in place and the vector anemometers overhead.

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Also the water calorimeter pipes appear to be in place. Looking now at the simulated roof section of the United Kingdoms instrumentation I see very little charring, if it could be identified as charring, looks more like rust stain from the nails. And I can see a little pitch coming out from around three knots. That's the only indication of heat on this roof section although it is on center line with the fire and only about 20 feet from the fire on the west side. This dimension must be known. Looking at the U.K. water calorimeters (open pans) I can see lots of water there whatever that means. The temperature--sensitive plates on the wooden blocks have blackened nicely, all except the top one. All the instrumentation seems to be in place here. I can see one branch which has fallen within the roof section here although it was not burning. My general impression is there was very little heat received by these wooden instruments even though they were very close to the fire. Even though the wood does not show charring, standing here right where they are at this late stage of the fire I can feel considerable heat on my face and it is uncomfortable to stand here. Looking into the fire from the west edge the bent metal anemometers are standing--they are not tipped. However, they show quite a bit of evidence of having heat on them, they're discolored and the painted numbers are discolored. Neither of the first two are tipped over. The third position--the low speed one--has tipped but not the high speed one. Here on the west edge of the fire there is a very large stump with some dirt on it burning in this pile and up against the dirt edge of the stump are some growing weeds, very porous weeds--they're green--and although they are resting right against some of the wood in the plot only the extremities that are right in close to the plot are discolored and somewhat brown. The rest of the plant is very green and still lush. This is a very porous plant and would have good convective cooling on it.

Recalling now the ignition event which went off with a loud report and then closely observing the start of the fires, it seemed to build up somewhat slower in my mind than what I had anticipated from descriptions of the fire building up quickly and recalling now what little flame there was above these piles for some seconds, I think an able-bodied man could have run from the center to the edge without being caught providing he did not trip and fall and hurt himself.

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Here on the west edge I have just run across a small cottontail rabbit outside the fire. The rabbit was frightened by me and has run in towards the burn down one of the streets--didn't go very far--tried to run underneath one of the piles but being hot he came out again and is sitting in the street between the first two piles just watching me. He's apparently smart enough not to run farther into the fire and yet does not want to come out where I am. I've walked up to within 25 feet of the rabbit. He had not moved, just sits there apparently doesn't know what to do. He's sitting well in the open and is smart enough not to try to run farther into the fire. Even though several falling objects fell close to this rabbit he was smart enough to stay in the spot of relative coolness that he has found between the piles.

0945
+1:48

Moving now to the northwest corner here are the piles that were not ignited. Here on the northwest corner there are 5 piles that are not burning, 4 along the north edge and one on the west edge. Beyond here piles are burned, I do not know personally if these piles farther to the east of me were ignited in the original ignition or whether they burned from action by the fire. Here on the north side now, the smoke is laying right along the ground. The winds from the south holding it low, not enough heat in the fire, at least on this end, to carry it up into a column. Here on the north edge again I can see the tower holding the flat-plate radiometers. It is standing intact--no physical damage. Also the water calorimeter pipe system over the pile just in from that is standing undamaged. Walking along the north edge I have seen no spot fires along here although as I get down to the northeast corner I can begin to see embers dropping out of the fire. Back on the east side again the wind is pretty much out of the west now. Considerable smoke down here on the crews that are taking care of the spots that start outside the line here. Quite uncomfortable in the smoke.

0950
+1:53

I've walked all around the fire now and back to the east side near the northeast corner and have found what appears to be--no I can't say that--I thought I found a large ember, a branch, but I think this is work of the mop up crew. Branches have been pulled away from the spot fire, and then put out.

0956
+1:59

Having circled the fire now it is 9:56. I will go back to headquarters trailer and see what is going on.

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Recalling my thoughts on previous discussions of fire whirls and mass fires I often wondered about them--well we got fire whirls, so what, what does it mean. They are so small that their only influence on the fire may be to carry embers into the air. However, having just returned from the 56,000-acre Sun Dance Fire in Idaho, with its vast destruction in heavy timber types and so much blow down, and what appeared to be fire storm centers, it looks now like I can begin to relate this in my mind to what I saw in the fire today. With the fire whirl so strong on the edge being triggered by the inflow wind from the east and southeast and burning so hard near the edge I could see fire all along to the south being pulled towards the whirl and also from the north. If this fire whirl had centered near the Pack River bridge in the Sun Dance Fire such an effect would have accelerated the indraft up the Pack River from the southeast and down the Pack River from the northwest and contributed to the blow down that occurred in this area making many of the trees lie along their path parallel with the inflow for some distance within the drainage. The indraft may have been strong enough to blow trees down anyway but it appears to have been more than that, at least on the Sun Dance Fire due to the severe burn-out and fire damage, very large trees with their tops broken off as well as tipped over. We also found one area on the Sun Dance Fire that was 75 to 80 yards in diameter very cleanly burned. We are going to check this area further as it may have been a location of intense whirl activity. From this respect, observing this Flambeau fire, and the fire whirl activity has helped the understanding of large wild fires.

I was just asked how far the whirls came out of the fire line. This would be significant information--although I said they came out I didn't give the distance. I would estimate maybe 20 to 25 feet, maybe farther, as much as 30 feet, but they didn't cross the fire line around the edge. The fire line is approximately 50 feet out and the fire whirls stayed within that boundary.

APPENDIX C

M. WOOLLISCROFT

Observations during Project Flambeau Test Fire 760-12-67, September 29, 1967. (Location - north side of fire)

7:57 + 5s Ignition time.

Pile near the roof sections to the left of the main road, that is row 9, does not seem to be alight yet.

1min 25s Lot of black smoke. One pile in row 13 - flame height probably 60 ft.

2min 30s Flame height for pile A14 about 60 ft.

3min 25s Wind from S.W.

3min 50s Flames definitely leaning towards the centre.

4min 55s Fire whirl on pile A12.

5min approx. Fire whirl somewhere about pile A14.

5min 10s Another fire whirl?

6min 50s Flame angle at the edge must be a good 50° to the vertical.

7min 40s Another whirl somewhere about pile A12 - a very fierce whirl.

8min 29s Fire noisy - large whirl on pile 11.

8min 45s Roaring whirl on pile 11.

9min 00s Really fierce. Large hunk of sage brush carried out of fire. I can see dust being blown about on pile A11. Really fierce - can hear whirl roaring. Around pile A11, whirl moved out of pile a little - dust being carried around and large quantities of debris, moving across towards 18 edge of plot.

10min 05s Died out now.

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10min 40s Wind definitely picking up now - still blowing from the S.W. Wind quite fierce - I should guess it might be up to 15 m.p.h. at least.

11min 05s Roof section between rows 7 and 8 is definitely ablaze now.

11min 20s Roof section has probably been ablaze for quite a while - must have missed it when watching the fire whirls.

11min 50s I cannot see whether the roof section on the outside of row 9 is alight yet.

13min 20s Fire seems to be dying down a bit now.

13min 20s A few minutes ago the roadway between piles 8 and 9 was obscured by flame. Now it is fairly clear. Cannot see very far in because of the smoke.

13min 55s Smoke clearing a bit - another fire whirl building up on pile A10.

14min 25s Another whirl between piles A13 and A14.

15min 05s Fire whirl on pile A12 or A13.

15min 30s I think roof section next to row 9 certainly ablaze.

16min 25s It looks as though the roof section between rows 7 and 8 is just about burnt out.

17min 30s Flame height generally down to about 30-40 ft., although pile 7 is still up to about 40-50 ft.

18min 05s I still cannot decide about the roof section next to row 9 - definitely scorching at the back but I cannot see any flames coming from it.

18min 35s Strong wind blowing - definite whirl on pile A14 or thereabouts.

19min 00s Flames seem to be higher on low number side of the plot.

19min 30s Whirl moving out of the plot from a position about pile A13.

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19min 55s Large amount of debris being carried out of the fire - whole sage brushes being carried to a distance of at least 100 ft. from the fire - I should think these bushes were carried to a height of about 100 ft.

20min 40s Standing at about 150 ft. from the fire.

21min 15s Gusts of wind blew my hat off - really quite fierce. Now blowing again from the S.W. I think this must be the prevailing wind and not caused by the fire but it is difficult to tell.

22min 10s Roof section outside pile 9 now in a state of collapse - only the uprights seem to be standing and the back has fallen off.

23min 20s Roof section between rows 7 and 8 has completely disappeared.

23min 45s Flames are generally down to the order of 20-30 ft. except on pile A7 where they are going up to about 30 ft.

24min 45s I can see the first tower down the road quite distinctly now. Smoke is definitely clearing.

25min 40s Whirl round about pile A14 - it's mostly dust now, not flame, but it is probably quite 10-20 ft. diameter.

26min 35s Fire definitely dying down. Wind picking up and veering around to the west.

26min 50s Whirl has moved down to about pile A16. Appears to be dying out now.

27min 15s Height of flames is not much higher than the height of the piles except for an occasional pile (e.g., pile A7, where flame height might be about 25 ft.).

31min 20s Nothing very much happening. Pile 7 is still blazing quite fiercely, it might average 15 ft.

32min 05s Most of the whirling seems to have finished - little bit still down in A18 corner.

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- 35min 30s I am looking down the road where our wind indicators are. The 40 m.p.h. wind indicator at the end here still seems to be standing but the 20 m.p.h. seems to have blown over.
- 37min 50s A whirl down in A18 corner again. The dust column must go to perhaps 150 ft.
- 38min 35s Still more flaming on the low number side of the plot than on the high number side.
- 40min 00s Moving away from the plot now - wind still definitely blowing from the S.W. and veering west so it must be the prevailing wind.
- 45min 30s Flames on the high number side of the plot below the height of the piles and quite a lot of the heavy stuff (large diameter tree trunks) still standing.
- 49min 30s Still a bit of a dust whirl down in the A18 corner - quite a fierce whirl about 20 ft. wide rising to about 200 ft.
- Several whirls down in that corner starting fiercely and curling up and arching over to the north.
- 47min 35s Strong whirl - seems to have whirled itself out into nothing.
- 51min 40s Seems to be getting smokier again but it is probably dust.

APPENDIX D

C. M. COUNTRYMAN

Observations during Project Flambeau Test Fire 760-12-67, September 29, 1967.

This is recorder station on the south side of the fire, Countryman reporting. Time will be from my watch, to be corrected to standard time later. Ignition at 7:58 a.m. by my watch, ignition points look good. I can see 2 ignitions on the platform at the center of the fire, 3 ignitions now.

+01 7:59 by my watch. The convection column on this end of the fire appears to be about 75 to 80 feet, moving toward the northeast. Looking down the aisle on the west side of the platform we can see to the next tower dimly. A little fire shows up beyond that. Smoke is building rather rapidly.

+02 0800. The flames are all leaning in on this side of the fire,--I can see from the southwest corner and from the southeast corner. Smoke is beginning to come out of the aspirated thermocouple system. 0800 and 30 secs. Flames are now about 30 feet high up on the crib S-9 and leaning in. There are a number of explosions inside of the fire, at least 3 or 4 that I have heard, maybe some of the cans that didn't go off. Looking down the aisle at the west side of the crib, flames now going clear across the aisle or very nearly so. Time is 0803. High speed camera touch off at approximately 0803 and 30 seconds. 0804 I see a convection cap now on the top of the columns almost directly overhead. I'm about 150 feet outside of the fire area. Looking down the aisle on the east side of the crib flames are down along the ground completely filling the aisle apparently moving from both piles, or both rows, of piles in toward the center.

0804+30

+06-1/2 I think we have lost a tower, it would be the one on the north side of the crib, or at least some of the guy wires have broken--I cannot see the tower. 0805+30. The convection cap on the top of the column now is very pronounced, almost overhead. 0806. Although the guy wire or tower collapsed over the crib area the anemometers are still above the crib and are still turning,--they appear to be about 25 or 30 feet above the crib. 0807. Flame heights now are about 25 or 30 feet above the crib, perhaps a little bit less than that. Flame heights on the wildland fuel piles

+05

+05-1/2

+06

+07-1/2

+08

+09

+10

C. M. COUNTRYMAN

are somewhat less--20 or 25 feet. 0808. There is a distinct roaring sound now--don't know whether its the fire or plane going by. I just saw the plane so that is the plane that's causing the roar. I can see into the fire a little bit further now. The tower on the north side of the crib has collapsed.

0809

+11

There is a distinct booming, roaring sound in the fire now, I am sure it is not the plane this time. The white condensation cap on top of the column is becoming very large, is still almost directly overhead. The first picture was taken

+12

at 0810,--been busy watching the fire and recording what is going on to take pictures before. Still 0810 there is a fire whirl now inside of the fire, I can barely see it. It is

+13

+13-1/2

raising enough dust to make certain that it is a whirl. 0811. Picture No. 2 0811+30. The crib is burned down now so that practically all that is left is 4 x 4's. Flames still about 20 feet high above. Wildland fuel piles, flame heights in the center are around 20 feet. Out toward the edges they are

+14-1/2

+15

+16

+18

somewhat less, perhaps 15 feet. 0812+30. The smoke is thinning out somewhat now. I can see first tower on the second crib in. Next picture at 0813. 0814. There is another fire whirl in the column. 0816 fire whirls appear to be developing consistently on this side just about the second row over to the east from the weighing platform. They seem to be small not too well defined, not very visible through the smoke anyway. Fire activity has decreased considerably. I can see down the aisles now perhaps 300 feet. There is no flame going across the aisles any longer like there was

+20

+21

earlier in the fire. At about 50 feet outside of the edge of the fire it is quite comfortable here. 0818. The crib has just begun to collapse. 0819. I can see down the aisle on the west side of the crib to the next crib quite well now. The aisles are still filled with a considerable amount of smoke. Now moved to within about 40 feet of the fire, it's

+24

+25

+28

not hot but not unbearable. 0822. The fire in the crib is burned down so that there are only a few flames coming above the top of the few 4 x 4 cribs that are still standing, about half of them appear to have collapsed at this time. 0823. I can see the pile with the masonry walls around it. At least the ones on the southside are still standing, the fire inside doesn't appear to be behaving any differently than the wildland fuels outside. 0826. Looking down the east side of the fire now, the flames are leaning outward toward the east or northeast, smoke also down along the ground for about 50 or

C. M. COUNTRYMAN

+28-1/2
+30

60 feet outside of the fire before rising into the convection column. 0826+30. There is a dust whirl out in the fire trail near the center of the fire. 0828. Looking down the aisle on the northeast corner of the fire I can see the masonry fuel crib quite plainly now through the smoke. Appears to be a little more fire inside the crib than the piles outside, that may be due to a difference of fuel loading.

+33-1/2
+41

Next picture 0831+30. 0839. All of the cribs have collapsed on the platform now. Still burning hot. The water calorimeter also collapsed--apparently about the same time the tower did. This is the end of the recording of C. M. Countryman.

APPENDIX E

ALAN WESTERN

Observations during Project Flambeau Test Fire 760-12-67, September 29, 1967. (Position: Rock ridge 50 yds. E. of Camera Station 4.)

0757 5, 4, 3, 2, 1, Fire. A magnificent sight with all firing simultaneously. Extremely fine, flames bursting out immediately. Napalm flung about the place. There are 1 or 2 spots in the lanes where napalm was flung outside the piles, but I cannot see very much of that.

(Recorder U/S)

0811 Tape recorder found to have stopped. Text till 0935 entered in notebook at the time.

0817 Smoke column over S.E. corner. Smoke thinnish and low, white on top.

0826 Smoke mostly thin. Little heat here. Has been more but never uncomfortable. Piles looking whitish. Can barely make out towers of central pile (j9) - not possible earlier. 50' roof and inert sheets round Q13 O.K. Crib S.9 has died down almost completely but S.10 is burning furiously. Flame heights average 7' - range 3' to 15'.

0838 Plume still over S.E. corner of array. Flames on S.18 sometimes lean W. and sometimes E. Pile S.13 practically out - also crib S.9.

0847 Perhaps some slight whirling near pile S.16 but not obvious. Frequent cracklings and small explosions. Low thin whitish smoke blanket covering array. Inert sheets at Q13 have been visible for 1/2 hour or so, but I cannot see clearly much further. Towers for Pile 05 visible; for J.9 tops barely visible.

0851 Flames only visible on 2/3 to 3/4 of piles. Mean height 2' range 0 to 8'.

0912 90% of piles still burning. Mean flame height 2', range 0 to 4'.

ALAN WESTERN

- 0928 Flames apparently very low, though this may be due to bright sunlight. Smoke now whitish over all array. All smoke whitish. Inert sheets at Q13 still standing. 50' roof O.K. and that between S.6 and S.7 apparently so. Some flames still up to 4' but average much less. Can barely make out top of towers by J.9.
- 0935 Tape recorder has not started again after a long period of malfunctioning. The plot is now covered with a blanket of white smoke. Some people are entering from this side near the crib (S.9) which seems to be burnt out completely. The towers there are readily visible, also for the weighed platform (0.9) half way in; the towers for the central platform J9 are only intermittently and difficultly visible through the smoke. The towers of the left hand platform (05) are also visible. The inert pile (Q13) is very well marked and none of the things seem to have fallen down. Two roof models are visible from here, the one outside of 50' which appears as far as one can tell to be undamaged, and also the one on the edge of the array in the first aisle placed sideways facing S7 and looking E. This does not seem to have ignited as far as I can tell at this long range. The smoke column is apparently coming up over the S.E. corner of the array; winds over most of the rest of the plot seem to be blowing in this direction. The S.E. corner - most of the vegetation in the aisles is not burnt up - there are patches where it has been burnt but the majority of it seems not to have been burnt.
- 0947 The plot seems to have burnt down very greatly by now - still covered by white smoke with little bits of darkish smoke here and there. Just at this instant the central towers by J.9 are not visible, but every now and then the upper parts of them appear. The other 3 cribs - the one on this side, the one half way to the centre, and the one on the left - towers are visible at each of them. The crib at S.9 seems to have burnt out completely as far as I can tell from this distance. There are still some flames visible; there would probably be a lot more if one was closer or there was not so much bright sunlight. Many of the piles look as if they are virtually out but probably are not when you get close. The wind is still quite strongly from the West and the plume seems to be going up over the S.E. corner - or it may be a bit further North, one cannot tell from this angle. Sometimes at the extreme right piles there seems to be an indraft - just at the moment I can see

ALAN WESTERN

some smoke from that; a very short indraft but it soon gets caught by the overall ambient wind and moves over towards the East.

- 1010 I am now abandoning camera station 4 and moving down towards the array. A fair amount of white smoke and a lot of white ash; I cannot see much else at the moment.
- 1012 I have now reached the fire line. There is a pall of dirty whitish smoke covering everything. One can see into the array a certain distance. In particular I can see the inert pile standing out quite nicely. Also the towers of the weighed pile that is half way in (09) and intermittently of the central pile (J.9) also of the far left one (05). I am moving left along the fire line now towards Alan Heselden.
- 1013 Still a straightforward W wind blowing smoke Eastwards. The smoke column now seems to be $\frac{2}{3}$ of the way to the Easterly side of the plot, I think at the southern end. On the westerly side the smoke is only about 30' high or so, moving along horizontally until it joins the column.
- 1014 I am nearly opposite the weighed crib S.9 now. There seems to be practically nothing left of it. I am moving closer to see. There are a lot of people standing around it looking at things. The wildland piles on the other hand are still burning slowly, flame heights I would say averaging 1 foot or slightly less. No I cannot see anything at all left of the crib; a few odd scattered charred bits of wood around the outside, but 95% or more, probably a good bit more, has burnt up. Passing the 50' roof; it is completely intact - no effect.

(Met Heselden here)

- 1015 I am coming in to have a look at the roof facing pile S.7 (in the street between S.6 and S.7). It has not ignited; there is some scorching of the wood battens, that is all. The white cardboard seems O.K.
- 1018 I have moved over to Alan Heselden's position, seeing the plot from the S.W. corner. The smoke column now seems to be further towards this end of the array, perhaps $\frac{1}{3}$ of the way along, looking as if it is at the S end but $\frac{1}{3}$ way along from the W end; in other words it looks as if the wind has reversed and now has a substantial Easterly component whereas previously it was westerly.

ALAN WESTERN

- 1035 In Heselden's car, moving back to Control. The wind seems to have swung round again, and is now pretty well southerly and the smoke is coming over the base area - we seem to have come to quite the wrong place.
- 1103 I can see a pile still burning quite fiercely about 200 yards away from base where we are. The clouds seen through the smoke pall look a sort of reddish-brown colour, rather attractive.
- 1132 We are on the southerly side of the array. It is possible to penetrate in a short distance; the main trouble is the hot air and smoke which is very unpleasant to breathe. One cannot really get very far in with safety. This S side of the plot is obviously upwind. The vegetation has not burnt to any appreciable extent beyond the piles; perhaps 1 foot or so. The great bulk of the vegetation in the aisles is still intact. Piazza blocks outside the array do not seem to be affected on this side. Still flames in most piles - about 6" to 1 foot high, but only on scattered individual logs. A small vegetation fire started just at the S.E. corner - about 12 feet out from the array.
- 1143 Wind has shifted round and southerly side is downwind. Smoke very unpleasant. We are moving round to the Westerly side.
- 1146 Now at extreme S.W. corner: out of the smoke at last. Getting reproducible results on the wood blocks.
- 1158 Standing on the W side of the array (upwind). Most of the piles are burnt out completely except for biggish logs which are very badly charred and in some cases still burning a little. Two piles along here not ignited at all. The smoke is fairly bad inside but Phil Thomas has penetrated as far as the first maximum thermometer which is about 3 rows. Piles G1 and H1 are the ones which did not ignite; the igniter system failed to work satisfactorily on these two; it is suggested the charge may have been too powerful.
- 1214 Now at pile A1; it has not ignited. None of the 4 special extra piles which were deliberately not ignited have in fact caught.
- 1218 Now walking down the North edge of the array from West to East. The ground even outside the array is covered with ash to a considerable extent; there seems to have been appreciable burning of vegetation to maybe a dozen feet or so beyond the actual

ALAN WESTERN

piles - perhaps even further in some cases. A large burnt area here which I cannot quite make out, beyond the last of the 4 unignited piles. It cannot be an actual pile; there was not one here, and there are not enough half burnt logs remaining. But all the vegetation is completely burnt off; it may be that a whirl came out at this point. I am coming now to the position of our roof section close to the original U.K. base but looking West and facing pile A.7. It is completely burnt out; the bits of asbestos are lying on the ground; all the vertical wood blocks, all four of them, are missing - oh there is one lying on the ground, an insulated block. The smoke is getting a bit much I must retire.

- 1225 A patch of vegetation has quite recently caught on the main road leading from base into the array. It is blazing quite fiercely at the moment, a bit to the right of the road more or less opposite the radiometer Tower. It is a collection of miscellaneous loose wood of one sort or another; perhaps the remains of an extra pile that has been removed. It is blazing very furiously at the moment; I'll take a photograph.
- 1235 Smoke still pretty fierce and nasty on the Northern side.
- 1400 After the last note the tape recorder packed up for a period but has not restarted. The fire is still burning gently but with a good deal of smoke. We are on the Western side, having collected a few Wood Blocks from there. One can penetrate quite easily to the 1st piazza inside and with difficulty further; but it is not at all pleasant and we are going home now. Still this white mist covering most of the area and white ash over the aisles. This is now the N.W. corner, we have been walking along the West side. The vegetation in the aisles is unaffected, at least not burnt. Passing now the N.W. corner - the 4 extra piles were not burnt, nor A.1. However, there is a curious burnt tongue sticking out on the N. side perhaps 1/4 of the way down from this corner, which it was thought might possibly be due to a whirl, but Michael reports there were not any whirls in that neighbourhood, so it is probably just some vegetation that caught - it extends out to some 50 feet or more from the array. The roof in the middle of the West side (facing J1) is completely unaffected.
- 1405 Approaching array along main road from base camp. The patch of vegetation to the right of the road that was burning seems to have passed its worst now and is just smouldering. No, there

ALAN WESTERN

is still a small amount of flaming continuing, but not very much. Now on the main road looking into the array - a desolate wilderness - but the immediate continuous flow water calorimeter on pile A.9 is surrounded by wood blocks and a good many of them are still standing - some are, some not.

1421 Walking down the North side towards the N.E. corner. The burn-out seems to be more thorough in these parts. I am looking at Wood Blocks just E of the extreme N.E. pile A.18. Of the two vertical blocks neither has scorched; on the closer one (12' away 4' high) all 5 papers have gone, but only 2 papers on the other. Small fires in the vegetation are about 30-50 feet or so downwind of the plot, now that one is getting on to the Easterly side.

1431 The smoke conditions around the N.R.D.L. observation site on the East side are pretty unpleasant and persistent; we are moving round back to camp.

Next day Saturday September 30th 1967: -

1000 Array still smoking slightly.

1105 Still smoking in S.W. corner and S. Side of plot - less elsewhere.

1200 Still slight smoke coming from most of array but none from N.E. corner.

APPENDIX F

A. BROIDO

Observations during Project Flambeau Test Fire 760-12-67, September 29, 1967.

- 0749 Ignition has been set for five minutes from now.
- 0752 I am at my observation point, south of center, on the west side of the plot, about 500 ft. due west of pile O-1. The sun has been up for almost an hour now and conditions for photography are much better than they would have been with the scheduled 7 o'clock ignition. Contrary to predictions, the surface wind is from the southwest, at what I estimate to be at least 5 mph.
- 0754 Ten seconds before ignition. The sun is in back of a cloud, and things are overcast. Zero time. Simultaneous ignition over the entire area. As far as I can see, the smoke is rising in all piles and is drifting to the north. The B52 is just overhead.
- 0756
+ 02 Black smoke on the west side of the plot except in the southernmost portion--obscuring everything except the first row of piles and the flames above them. The column seems to be rising primarily in the center of the plot, going in from both corners. The smoke from the towers on the southwest corner is blowing somewhat down and into the piles.
- 0757
+ 03 From the southwest corner, I just saw a horizontal whirl--a most peculiar thing. It looked like a barrel rolling into the fire.
- 0758
+ 04 There seems to be some spill-over from the central column dropping off to the northwest.
- 0759
+ 05 I am approaching the fire--which I would imagine is close to peak intensity now. You might hear it roaring in the background.
- 0800
+ 06 I am at the road or fire break running along the edge of the fire--50 to 75 ft. from pile N-1. It's moderately uncomfortable here, but actually with the smoke obscuring the sun, it feels cooler than it did a few feet back. I imagine if I

A. BROIDO

stayed here too long facing the fire, I would get a fair sun-burn on my face. From here, the column still seems to be going straight up. The flames are blowing in towards the center from both ends of the west side. Since I cannot see through the black smoke, I don't know what the rest of the fire is doing.

- 0803 I am looking right down the street between rows M and N. The
+ 09 street, in general, is clear, but every once in a while flames blow in from both sides and completely cover the opening. I would certainly not want to be in there at the moment.
- 0804 More smoke being released from the corner towers, blowing in
+ 10 towards the fire and in particular, the lowest pot on the near tower (100 ft. west of Q-1) is blowing definitely downwards and then in.
- 0807 I am in back (west) of that smoke tower. From here, I can see
+ 13 in diagonally at least four or five piles towards the center. It is much clearer here. The impression I had from the west side that the south end of the fire was relatively free of smoke is definitely confirmed here. The smoke being released from this tower is starting up again and it is blowing straight as an arrow down into the fire. It is quite warm here. I would hate to have to spend an hour or two facing this heat, although again, it isn't quite clear how much is coming from the fire and how much from the sun.
- 0809 I can see the towers around lumber pile O-5, or what's left of
+ 15 it. I suddenly felt my trousers becoming uncomfortably warm from the radiant energy and did have to back off ten feet or so into the shade. They cooled off within a few seconds after I turned around.
- 0810 Smoke is much lighter now through the entire area. I can see in
+ 16 probably about half-way through. There are occasional puffs of black smoke rising primarily north of where I was standing before. The column now varies from puffs of black near the bottom to gray in the middle and beautiful white fluff on top, with blue sky above that. The top of the column seems to be bending to the west and north.
- 0815 I don't know if it is the extra elevation near the tower or the
+ 21 fact that the piles there started off more slowly and were burning more vigorously while I was nearby, but I am now on the road

A. BROIDO

walking north and it's much more comfortable down here on the inside of the road than it was back there, although I must have been fifty feet further from the fire. I would guess I am now about 25 or 30 feet from the nearest flames. It's still quite warm inside the fire zone and I would certainly not wish to walk through the streets at the moment.

- 0817 I am now about ten feet from the nearest pile--which has died
+ 23 down considerably. I would not advise going any further.
- 0819 I am now next to the lone surviving tree standing about midway
+ 25 between rows L and M and about 15-20 feet out of the fire zone. The tree is cool to the touch. There is no problem around here and if my life depended on it, I think I would try running down this row. If someone caught me doing it, my life probably would depend upon it.
- 0821 There is a rabbit running back and forth between the two piles
+ 27 in this row trying to decide which side is cooler. He seems to be quite okay. He just stopped less than three feet from the southwest corner of pile L-1, then ran out of the area (into the west side, that is) and is continuing north looking for a way into the fire area. Things seem to be quite variable along this west side. The piles nearest me have very largely died down. They are still flaming, but most of the flame is obscured by the residues, whereas the piles to the south are flaming merrily.
- 0823 I am at Western's station on the west side, center. Nothing
+ 29 much seems to be happening. I am at the back edge of the station. If there is any charring on the front side, I can't see it from here. I'm not uncomfortable standing here, as long as I keep turning my face from north to south and back. If I hold the same side exposed for any length of time, I can certainly feel it.
- 0825 A couple of birds just flew by at low altitude right into the
+ 31 fire area. They did not seem to be bothered much.
- 0826 The wind seems to be picking up rather strongly from the south-
+ 32 west. Smoke and flames are being bent towards the northeast corner.
- 0827 I am right at the edge of the fire between the piles J-1 and
+ 33 K-1. I can't see any damage to Western's samples from here. Perhaps there is some slight effect. I seem to be able to see

A. BROIDO

through most of the plot. The column has cleared considerably. I don't see any trace of fire whirl activity.

0830
+ 36

Oops, somebody goofed. Piles G-1 and H-1, the edge piles two and three rows to the north of the center tower, did not ignite. They are still sitting intact. It is quite comfortable next to them. There doesn't seem to be any indication that they are going to catch from any of their neighbors. You can still hear snap, crackling, and popping throughout the fire, but it is not a very impressive sight at the moment.

0833
+ 39

There are still horizontal spurts of smoke primarily, but occasional flames, shooting across the streets--from southwest to northeast exclusively.

0836
+ 42

I just went down and looked at the face of Western's blocks. There seems to be some charring in the vicinity of the three nails on the face of the block, but nowhere else. This may be taken as evidence that heat transfer to these blocks was by radiation. (Note: See 0905, below.)

0842
+ 48

I am at the edge of the plot in front of my favorite tree, with the helicopter overhead. Especially if one crouches low, it is not at all uncomfortable here. One still feels considerable heat on the face, but by squatting, it becomes actually pleasant here. By that I mean there is more heat hitting me from the sun than from the fire.

0849
+ 55

I am inside the plot. The grass here seems to be fairly dry. I have gone one street in and am getting covered with light ash from the pile to the southwest of me. I am in two rows and it is no more uncomfortable. I would hate to have to travel any great distance in here, but if my life depended on it, I certainly would.

0850
+ 56

I am back out--brushing off the light ash which is all over me. It came exclusively from the southwest, driven by the prevailing wind. If I were going in further, I would crouch low and run or walk a little faster and I suspect I could get all the way through the plot right now.

0854
+1:00

One hour after touch-off. I still see no trace of fire whirl activity. I don't know whether we are going to see any or not, but since I am approaching the end of this tape, I think I'll change tapes and be prepared for any eventuality.

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- 0857
+1:03 I am walking south along the road and will head around the entire fire perimeter. The first thing I noticed is that the streets between piles are quite variable. In some cases, they are blackened and obviously, some vegetation had burned out. In others, at least to appearances from the outside, the vegetation is quite intact and unaffected. Oops, I suddenly realized that the bundle of cables I had spotted hanging over pile 0-5 was the remains of tower 13. Unfortunately, I no longer remember when I first spotted that mess.
- 0905
+1:11 I just took a look at Western's blocks on the southwest corner of the plot and I notice that they are black around the nails on the backside too, so perhaps this is a stain and not due to charring from the fire. Things are quite dead on the south side of the fire. There did not seem to be any scorching of the vegetation adjacent to the outside edge of the piles. I would certainly not hesitate to walk through this corner of the fire area at the moment.
- 0910
+1:16 I am right at the weight tables on the southside. The lumber is burned out completely. There is a little bit of glowing of the embers while the piles on either side are still burning moderately strongly. Certainly, the pulse shape for the lumber piles is quite different from that of the bulk of the piles. Things obviously got quite warm here--with the water calorimeter sagging badly and water flowing onto the ground on the south side.
- 0917
+1:23 Just met Dick Rothermel going around the other way. He says there was some major whirl activity on the east side of the fire during the rapidly burning phase. Of course, I was not able to see that from the west side because of the smoke obscuration.
- 0922
+1:28 I am on the east side of the fire now. Here the streets look like they were totally burned out and the ground is charred in spots some 10 to 15 feet beyond the outermost piles. The piles look like they were burned out more completely too, (Oh, it's smoky here!) with what appear to be deep piles of light ash and only the heaviest pieces remaining unburned. The wind is still driving the smoke in a northeasterly direction, which is why it is quite uncomfortable close to the piles.
- 0940
+1:46 I am at the northeast corner. A spot fire seems to have taken off here just alongside of the road, some 60 feet from the

A. BROIDO

nearest pile. Things are much more uncomfortable here--not so much from the standpoint of heat as from smoke--than they ever were on the west side of the fire.

0942 The north side of the fire is still smoking and uncomfortable.
+1:48 I was just chased back by a couple of fire whirls. Again, there seems to be no particular hazard except that breathing is not pleasant.

1007 I am on the west side again. The wind is still blowing from
+2:13 the southwest. Still much smoke in the northeast corner, but quite comfortable over here. A couple of piles on this side are still blazing fairly well, but most just have feeble flames and are emitting a lot of smoke. The piles that were not ignited at the start of the fire are still intact, as is the vegetation on the edge of the piles and in many of the streets between piles. One difference is that the vegetation in the streets is now largely white, covered with ash from the piles to the south and west of them.

1013 I walked into the fire in the same location I had earlier. As
+2:19 soon as you get past the first row, it becomes smoky and quite unpleasant, although apparently not more so than it was outside the fire on the northeast corner; that is, there appears to be little contribution to discomfort from anything burning more than a couple of feet downwind of your position and, with less certainty, not much from any but the nearest pile upwind.

These observations may provide a basic answer to one of the most burning questions (pun intended) with regard to escape action of people trapped in a large fire area. It has always been taken for granted that people in a large area simultaneously involved in fire should, if able to move, proceed to the nearest edge of the fire. The problem always has been how, when you are surrounded by fire in all directions, do you know which is the nearest edge. Since most of the hazard from fire in the immediate vicinity comes from that which is burning upwind of your position and since the more severe fire whirl problems arise on the downwind side of the fire, it would seem that a good rule to follow under almost any circumstances is to move upwind (in the direction of maximum discomfort--looking either for the upwind edge of the entire fire area or for a sufficiently large fire break between yourself and any involved area of you. Barring a major shift in wind direction during the relatively short transition period, such action would appear to be the best available. If you should wind up moving further and further in towards the center of the fire, your position relative to nearby upwind burning will not change

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significantly and thus, you should be doing yourself little harm. If you should fortunately be on the upwind side of center, you will be heading out of the fire and will most likely be doing yourself some good.

APPENDIX G

THOMAS PALMER

Observations during Project Flambeau Test Fire 760-12-67, September 29, 1967.

IGNITION: 7:57

0759
+ 02

Fire is going well. Smoke drifting, beginning to drift over the instrument trailer. Eddies are beginning to show up on the northwest corner. Clouds just obscured the sun which is in front of us, cloud of cirrus. The eddies are beginning to build up more strongly in the center now, dying down more on the edges. Fire is canted over to about an angle of 45° with eddies coming up more pronounced more eminent or obviously turbulent and convective activities increasing. Rockets just went off. Mistake, smoke just went off. Quite a bit of difference in eddy structure of the fire and the smoke from the Dikewood smoke. There's some eddies coming in and they are drifting over it (the fire) from this vantage point which is the visitor's site. They're coming in almost flat and actually with, evidently from this position, a downward component into the fire which lasts almost to the edge of the fire and then starts up again. It is difficult to see though, because the things at the edge are----there's a hole in the middle of the fire right now, there's a big hole in which there's one large, two large convective columns, one from approximately the northwest corner and one over from the northeast corner. Now the winds have shifted at the surface here now and are going inward on this side on the north side and beginning to overpower the local flow to some extent. There's one, from here, there's a series of convective activity, becoming one bubble after another rising up into the general cloud which is now heading almost straight up. Its canted over up to about the length of the plot at about 60° and then headed straight up. A very strong inflow in from the north now.

0800
+ 03

A persistent hole upward in the middle of the fire through which the sun is visible, occurs quite frequently about two thirds of the way up, from the north end and about one third from the south end, at the point which the cloud begins to bend over. Now it's beginning to drift north more at higher levels.

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0803
+ 06

It still looks like two very distinct columns one coming from more or less the south and the other coming in from the north. Although the side of the cloud is becoming more organized at the moment and the things are beginning to die out except, take that back, they are more disorganized, it looked like there was just one column forming, but there are many separate columns forming. Now there are some evidences, as you look into the fire against the sun, you can see some evidence, of what looks like cyclonic circulation right near the center of the fire. Although this may be confused with these rising bubbles but the smoke is beginning to thin out a little bit now.

0804
+ 07

Dikewood just let loose some purple smoke. It's more and more green than other colors. Still showing some eddying, eddies being relatively constant once they're formed, then they dip directly down into the smoke. Very evident from here that the smoke is going right down into the fire and sweeping down, there's very little turbulence. Eddying motions particularly at the green one (smoke plume) which is on the top, and at this point it looks as if it's actually vanishing into the smoke of the fire.

0806
+ 09

Tremendous cumulus cap cloud is formed above us here with the updraft becoming much more organized as you look up. Let me take a picture. As you look up into the dark cloud, the smoke is interlaced with the white, the white of the condensation, probably of the cloud is forming a kind of dirty white cloud. The cloud is very layered and structured in appearance here, as if there were structures, eddy structures, with a central core of it turning around the western edge of the cap cloud. I can see it from here. It's quite obvious that this thing is going into some sort of a ring vortex because you can look all the way around it now and see the upward moving velocity at the center of the cloud with the general downward motion around the outside edges. Sometimes to the south, there's a protuberance that's coming out and initiating a little circulation all of its own.

0808
+ 11

It is now beginning to have some spiralling motion; generally looking upward it's anticlockwise.

0809
+ 12

This is happening pretty fast. Again, I can still see the general downward motion around the outside edges of the cloud around all edges; it's losing some of its layer structure

THOMAS PALMER

around the parts that I can see best. The downward motion apparently has almost broken into two separate cells, with a number of cells on the lower cell, the upper cell is now very vigorously turning in and acting as though it were moving up around the central column. There is a very tornado-like fire whirl in the center of the fire, right now, is reaching up from what looks like this point of observation, and you can actually see it down in the fire. This is a very good point. I'm taking pictures right at this moment. It's a very good point because in the forward scattering of the sunlight you can get a pretty good view of the whirl. There is another one coming up. It just died out as it was coming up from the southwest corner of the fire. Dikewood smoke is still going mostly into the fire. Now the whirl has died down, no, there it still is; it's very remarkable now, you can see it, kind of orange appearing, in the sunlight and it's evidently originating someplace over in the northeast quadrant of the place. It has many spirals and eddies and so forth and it's wiggling back and forth and twisting, and its going to be very interesting, when it reaches the cloud top lifting condensation level of this cloud and it really gets an updraft on it. The cloud is broken, as far as I can ascertain above here that, looking up the cloud is, the cap cloud, is broken into two pieces, which you can see the sun through in parts of them. See if I can take a picture.

0812
+ 15

The whirl is back again very much stronger, there are eddies in the thing, it looks like it has a corkscrew appearance. It is getting difficult to take pictures now, the sun has come out from behind the smoke and its turning too much into the lens, overexposing. The whirl is roughly from this point; which is right near the billboard is, at the corner of the road, where the road turns and goes down the hill; the center of the whirl looks like it is about one-fourth of the way in from the side. There is a terrific whirl going in the northwest corner now. Extreme northwest corner is really going good. It's a really tremendous whirl. The other one a long, cylindrical, thin one; but this one is much larger at the surface. It is roughly at one of the poles that is lined up here behind a tree. Overexposed.

0814
+ 17

Looking upward at the clock now, holding the clock up against the cloud, is the way I'm looking at my watch some of the clockwise rotation is turned around and gone the other way. This is very mixed up in appearance, but the whirl has not

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reached the level of the cloud yet. There was some evidence of the whirling motion occurring in the cloud that has now only the downward, inward motion toward the center where the main smoke column is entering the base of the cloud, but there is also some evidence of anticyclonic whirl. Through some rotation of the cloud now in the central cloud as it is entering the base of this huge convective column that's overhead now.

- 0815
+ 18 Things are happening very fast. It is (the smoke plume) going around also at the outside south of the plot in which there is now condensation occurring. Although the condensation is very vividly occurring and is very violent at the top of the column here, but the thing is mainly drifting off to the north. Smoke is becoming more evident now. Further north it is perhaps due to the water vapor in the cloud evaporating.
- 0816
+ 19 Smoke has pretty well died out, it's quite thin now, sun is shining through quite well.
- 0817
+ 20 Still vigorous condensation, however, at the base of the cloud, still fire whirls evident in the fire right at the moment.
- 0818 $\frac{1}{2}$
+ 21 $\frac{1}{2}$ Fire whirls are beginning to, tend to reform in the northeast quadrant of the plot. Can see the actual motion in the flames at the base of the column. The long, sinuous spiral is again forming, the wave length is quite long, now the whirl is quite vigorous and it's becoming increasingly so. Spiralling higher and higher it's now roughly, from where I see, roughly the same distance as it is down to the Dikewood or the southeast corner of the fire and the sinuosity of the column was about three periods from the length of the column. Column is now died out.
- 0820
+ 23 New whirl tended to form but has died out; it lasted that time approximately five seconds, a new one is now forming and is dissipated about 20 seconds later. This is actually a series of two whirls. There's several of them going in there now. I count three particularly in the northwest quadrant, there is very little evidence of this type of motion in the other part and there's three of them in there; now as you can see, one has moved off to the south, the other one has moved outward to, towards the northwest corner of the plot. Correction northeast.

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0821
+ 24

The cloud on this thing (the fire) is still quite dirty and black particularly on the under side away from the sun. It's white on the other side looking at it from this point. The smoke is spread over quite widely and there is a lower level, part of the cloud is stabilized out, which is not moving upward but is actually tending to move downward towards the northern edge of the top of the cap cloud.

0821 $\frac{1}{2}$
+ 24 $\frac{1}{2}$

There is a fire whirl going in the northwest, about the north central portion of the fire now. From this point is moving back over to the north, more north-easterly part now. There is only one visible in the smoke. No evidence at all of this sort of thing in any other part of the fire. It's quite vigorous now. This was recorded and running continuously since I started describing this one, it is going quite vigorously centered along, near in a line with the pole that I see from here with the radiometers on it. Its getting increasingly strong although part of it is broken off now and the top part is decayed; now another one is formed. The first one moved to the northeast and it actually moved, it looks like it's actually moved almost out of the fire area although it's really difficult to tell from this distance. There is one just south of it, it looks like they may be rotating around each other.

0823
+ 26

There is no visual evidence yet that this cloud has glaciated at all. It may not be reaching high enough. On the top parts of it, there is still considerable smoke visible but the edges are now tending to evaporate much more rapidly.

0824
+ 27

I just took some pictures of the smoke with the sun showing on the smoke. There is considerable cumulus castilanis around _____ and some indications of building of some cumulus to the south over the mountains. Difficult to tell what distance.

0825 $\frac{1}{2}$
+ 28 $\frac{1}{2}$

Inflow still at the northern side of the fire but the fire whirls have pretty much gone.

0826 $\frac{1}{2}$
+ 29 $\frac{1}{2}$

Still quite vigorous condensation at the top of the column. Rotation of the column has somewhat changed now; it's a more outward billowing where the smoke is much more pronounced on the outside. There appears to be a central core of approximately $\frac{2}{3}$ of the diameter of the total smoke column which is its spread at the altitude at which condensation has taken

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place; which is mostly water vapor. Turbulence on the outside of the smoke column is still very much evident as it is occurring.

0827
+ 30

Still no fire whirls much in evidence, yes, there's one just starting again down in the northeast quadrant of the fire. The winds are tending to be blowing the flames at least it looks like they're blowing in from the east. Looking towards the east on the west side of the fire it's still burning fairly vigorously up in this quadrant; I can't see too much down in the other quadrant, however, there is considerably less evidence of activity at this distance. It keeps trying to make fire whirls down there, however, it just can't quite cut the mustard, they'll go and decay in a matter of just a few seconds. A whirlwind type of motion will start and then will die out very rapidly.

0828 $\frac{1}{2}$
+ 31 $\frac{1}{2}$

The wind up here appears to be about 7 knots up here at this point. Still whirlwinds.

0830
+ 33

Still whirlwinds forming in the north extreme northeast quadrant of the fire, however; they die out very rapidly, maximum height is roughly at the same height as the post on which the infrared radiometer is concerned. Now here goes a more vigorous one, it's reached up about twice the height of the pole, then it died. There's another one forming slightly to the north of where that one decayed and it didn't make it even to the top of the tower. It seems like most of the tendency towards this type of circulation is occurring, from this vantage point, in the northeastern quadrant there's very little evidence of this activity in the northwestern quadrant. The winds are, however, blowing mostly, have shifted so that they're blowing more directly across the fire in the northeast quadrant (correction) in the northwest quadrant. The fire whirls are still trying to form but they are nowhere nearly as vigorous as they were when the fire was only a few minutes old.

0831 $\frac{1}{2}$
+ 34

There's a more vigorous whirl now formed and it is extending up quite high. It however has died out. It went up to, roughly, 10 times the height of the radiometer pole. Still another whirl is being organized now and its difficult to ascertain the direction of circulation, I believe its cyclonic. It is now reaching very high and is not shrinking at all into a more organized column. The fire is pretty well died out

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- 0838
+ 41 The cloud that formed at the top of the column of smoke is beginning to spread out becoming much more flat. The convection is not nearly as vigorous as it was, particularly in the northern portion it is becoming to resemble the other naturally occurring altocumulus castilanis in the vicinity, but it has a much more dirty appearance at the bottom of it like there is considerably more light being absorbed within the cloud. This is comparing it with another cloud that's directly to the west of it in, the same in size and appearance. But it's bottom is still relatively flat. It's beginning to move out more vigorously in it's northern portion towards the west side.
- 0840
+ 43 The cloud is now broken off, there is a separate cloud forming at the top of the column. Its broken distinctly into two halves, two pieces.
- 0844
+ 47 No whirls in the fire visible from this point. A nice whirl has now formed, moved very rapidly up to roughly 10 times the height of the radiometer pole. It's reforming down at the bottom now, it's tending to, actually, it's moved out of the area of the fire, I believe. Going, tending to go up that little hill, tending to go up the side of the hill over there and it got up over, moved into some slightly rougher terrain and broke up. Now it turned around and is actually moving the other direction.
- 0853
+ 56 The cloud at the top is broken into two. Another piece is broken off, a new cloud is forming, I guess is a better description of it. No evidences of fire whirls from this point in the fire. Considerable low level tendency toward the things but they never seem to really get organized. Again, looking upward, central column of the smoke, central part of the convective column evidently occupying about $\frac{2}{3}$ of the part that's visible contains water vapor, condensed water, the outside edge, occupying roughly $\frac{1}{3}$ of it i.e., the distance out which is smoke. This may be an optical illusion because of varying wind shears aloft causing it to bend around.
- 0855 $\frac{1}{2}$
+ 58 * A whirl just formed in the northeast quadrant again and broke up very quickly.
- 0856 $\frac{1}{2}$
+ 59 * Condensation still going on in the top, in the center of the column of the thing, the smoke column. Here's a good fire whirl forming but which, again, didn't last very long in the

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northeast quadrant. Going back to the cloud and looking upward the condensation is much less evident than it was previous to this time.

- 0857 A whirlwind has formed in the northeast quadrant, has moved
+1:00 again up the hill and broken off, broken up.
- 0859 Fire whirls are forming again in the northeast quadrant very
+1:02 nearly the edge going out and breaking up. One of them is
broken up near the ground, it's still persisting at high
elevations and this may be obscured by background at the sur-
face. Quite interesting to the north of the clouds in the
vicinity this cloud is beginning to dissipate.
- 0930 Cloud is mostly evaporated to the north. Still burning, no
+1:33 whirls.
- 0949 The smoke is spread over, is hugging the ground closer in the
+1:52 vicinity of the fire now. This recording was from visitors
observation by Palmer.
- 1033 Smoke is still coming out with no active burning. End of
+2:36 recording.
- 1130 A later observation while returning to Montgomery Pass at 1130.
+3:33 The smoke from the fire showed remnants of it at the eastern
edge of a large vigorous cumulonimbus, well to the northwest of
the fire. An interesting speculation is that the smoke caused
higher absorption of sunlight within the cloud causing it to
evaporate (in accordance with Moellers theory). Later this
smoke continued to cause warming of the air resulting in a
buoyant region which developed into a thunderstorm.

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Office of Civil Defense/OSA Washington, D. C. 20310		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	
		2b. GROUP	
3. REPORT TITLE OPERATION FLAMBEAU - CIVIL DEFENSE EXPERIMENT AND SUPPORT Eyewitness Accounts of a Mass Fire			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)			
5. AUTHOR(S) (First name, middle initial, last name) Clay Preston Butler, Editor			
6. REPORT DATE May 1969		7a. TOTAL NO. OF PAGES 65	7b. NO. OF REFS NONE
8a. CONTRACT OR GRANT NO.		8b. ORIGINATOR'S REPORT NUMBER(S) NAAC-PR-69	
a. PROJECT NO.		9. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
c. OCD, Task Order DAHC20-67-C-0149 Work Unit 2561B			
10. DISTRIBUTION STATEMENT This document has been approved for public release and sale; its distribution is unlimited.			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Office of Civil Defense/OSA Washington, D.C. 20310	
13. ABSTRACT Seven men, skilled in fire research, were stationed around the periphery of FLAMBEAU FIRE 760-12 and recorded visual impressions of its magnitude. Their testimony furnishes indices of fire severity which is available to officials immediately. At each of the times when eyewitness accounts are given, instrumental data were taken both inside the fire zone and outside, so that visual magnitudes of this mass fire may be compared with its measured physical parameters. Visual magnitudes for this fire are: a. Flame heights up to 300 feet, horizontal flames 100 feet. b. Thermal radiation uncomfortable at 75 feet. c. Able bodied men might escape from center of fire. d. Cap cloud at 3000 feet. e. Streets filled with smoke. f. Fire whirled lifted bushes 100 feet. g. Downwind side of fire showed much more severe activity than the upwind. h. Firebrands were carried more than 200 feet out of the fire on the downwind side.			

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Fire Mass Fire Fire Hazards Forest Fire Urban Fire Simulation Eyewitness Fire Reports						